UGC Major Research Project

Final Report

Impact of Environmental Emission on Total Factor Productivity Growth for Energy Intensive Industries in India

By,

Professor Mihir Kumar Pal,

Principal Investigator of MRP,

Dept. of Economics, Vidyasagar University,

Midnapore-721102, West Bengal, India.

PREFACE

This study tries to assess the impact of environmental pollution proxied by CO_2 emissions on the Total Factor Productivity Growth of the energy intensive industries in India.

Main findings of the present work are not in line with the prevailing opinion. To be more specific, we have found that total factor productivity growth (TFPG) in the energy intensive industries in India registered significant unsustainable growth in it during the study period. In our study, we found that the reform process has its adverse impact on the industry's energy intensity as well as in their capacity utilization.

Along with the conventional approach, we have formulated a model in the estimation of the relationship between CO_2 emission and TFPG of the concerned industries. It is only hoped that our results will stand scrutiny by experts.

Prof. Mihir Kumar Pal

-:CONTENTS:-

Chapter I

Introduction

1.1. Overview of the Study:

Environment refers to the biosphere, the atmosphere, the geosphere and all flora and fona. But due to exploitation of resources the beauty of the earth is disappearing as well as causing pollution. Pollution means undesirable damage in the physical, chemical or biological characteristics of water & air due to insensible human activities that make the environment unhealthy to live in. In this project we want to examine whether the use of the CO_2 emission contributes respectively to the output and productivity growth by the energy intensive industries in India. Cement industry, Aluminium industry, Fertilizer industry, Paper & Paper Products industry, Iron & Steel industry and Chemical & Chemical product industry environmental pollution should be accounted for in total factor productivity growth (TFPG) measurement and deducted from residual. A theoretical frame work of growth accounting methodology with environment as a factor of production which is unpaid in the absence of environmental policy has been tried to be developed. Using data from panel of above mentioned major energy intensive industries in India we may show that emission growth have statistically significant contribution to the growth of output, that emission augmenting technical change is present along with labour augmenting technical change, and that part of the output growth which is traditionally attributed to technical change should be attributed to the use of the environment as a not fully compensated factor of production.

Growth Accounting is the empirical methodology that allows for the break-down of output growth into its sources which are the factors of production and technological progress, and provides estimates of the contribution of each source in output growth. The concept of total factor productivity growth (TFPG) which is central in growth accounting, measures the part of output growth which is attributed to technological progress, and which corresponds to the part of output growth not “accounted for” by factors of production such as capital or labour. Growth accounting still remains a central concept in growth theory, although there are still conceptual disputes about the subject, and Easterly and Levine (2001) state that "economists need to provide much more shape and substance to the amorphous term TFP".

It was Solow in the late 1950’s, (Solow, 1957) who provided an explicit integration of economic theory into the growth accounting calculations, which imply decomposing total output growth and measuring the contribution to growth of specific factors, including that of technological progress. During the last decades many different approaches have been used to measure TFPG, which include dual approaches using mainly factor prices insteadof factor quantities, and approaches which basically involve disaggregationsand refinement of inputs in the production function.

In the early 1970's, a new dimension was given to the theory of economic growth with the introduction into growth models of environmental damages created by emissions. This new dimension which has generated a large volume of literature on "Growth and the Environment", implies a new way of looking at TFPG measurement. Brock (1973) stated that "received growth theory is biased because it neglects to take into account the pollution costs of economic growth". This is because in an unregulated market the cost of pollution is not internalized. Pollution in this case is an unpaid factor of production, with production becoming more costly if less pollution is allowed. In this context environment is used as a factor of production which is not fully compensated, and its use in the production process can be captured by introducing emissions as an input in an aggregate production function.

1.2. Interdisciplinary relevance:

So far as industrial production and productivity is concerned, it is quite logical to state that, increase in output, keeping the amount of inputs constant, will increase productivity of that industry. Again, in our case, the energy intensive industries creates both air and water pollution to a large extent. This is the negative aspects of increasing production of energy intensive industries. So, in a sense we can't go on increasing the output of energy intensive industries in an unlimited manner. In other words, factor productivity or total factor productivity are affected negatively by the extent of pollution (industrial waste) generated by energy intensive industries. Hence it would not be illogical to say that economic theory along with environmental studies are to be taken into account for the present study. Here in lies the interdisciplinary relevance of our research work.

1.3. Review of Literature:

A number of studies have investigated the relationship between environmental quality and economic growth. Most of the literature has focused on examining the relationship between indicators of environmental degradation (a variety pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide etc) and per capital income. This is the well-known Environmental Kuznets Curve (EKC) literature. There are numerous reviews concerning the Kuznets curve literature. The pioneering empirical work in this literature is the work of Grossman and Krueger (1993, 1995). Most of the empirical studies following the study of

Grossman and Krueger confirm the inverted-U relationship between pollution and income (Selden and Song (1994), Ansuategi et al. (1998), List and Gallet (1999), Stern and Common 2001), etc.). However, some of the empirical evidence goes counter to the validity of the EKC hypothesis, mostly depending on the choice of the pollution indicators as well as the method used (see Harbaugh, Levinson and Wilson (2002), List, Millimet and Stengos (2003), Azomahou, Lasney and Van (2006)). Chimeli & Braden (2005) try to link total factor productivity with the Environmental Kuznets curve by developing a theoretical model. They find a U-shaped response of environmental quality to variations in TFP.

This study departs from this literature in that the relationship between the environment and industrial growth is examined from another perspective; the effect of emissions on growth and not the other way around is investigated. Furthermore, as a measure of industrial growth, the TFP growth index is used.

There are three main studies in the empirical "green growth accounting": Tzouvelekas,

Vouvaki and Xepapadeas (2007), Vouvaki and Xepapadeas (2008) and Kalaitzidakis, Mamuneas and Stengos (2008).

Tzouvelekas et al (2007) estimate the contribution of CO_2 emissions, to the growth of real per capita output. They find that the growth of emissions contributes to the growth of output. By ignoring the growth of emissions, the traditional TFP growth estimates are overestimated.

Vouvaki et al (2008) reach to the same conclusions by using energy as an input in the production function. The authors argue that energy, a paid input of production generates the unpaid environmental externality, pollution. They use a given marginal damage factor of CO_2 emissions to measure the unpaid part of energy created during the production process. However, the results from both papers are based on this arbitrary marginal damage cost of CO_2 emissions.

Kalaitzidakis et al (2008) estimate the contribution of CO_2 emissions on TFP growth for a set of OECD countries for the years1981-1998. Their work is conceptually similar to the task undertaken by Tzouvelekas et al (2007). The difference is that they estimate a general production function and their estimatesare based on nonparametric methods. They find that the emission stock contributes onaverage about 1% to productivity growth for the period under investigation.

In this regards, some another study are also made. Chen et al (1998) examines the impact of economic and demographic variables on generation and treatment of four classes of polluting residuals from industrial production in China.

Afash et al (1996) have argued for a broader model which includes the community and the market as major players in the determination of factories enviro0nmental performance.

The effects of pollution on industrial performance have been elaborately discussed in World Bank Green Rating Project of CSE (1999.2004).

Jeon& Sickles (2004) analysed productivity growth using directional distance function method and treating CO2 emissions as an undesirable output.

Stern Report (2006) strictly speaking CO2 emission is not a pollutant and we treat them as such because of their relation to climate change and implied environmental damages. Chimeli& Braden (2005), explore the relationship between total factor productivity (TFP) and the Environmental Kuznets curve. Tolet all (2006), postulates a long term relationship between energy intensive industries and CO2 emissions in USA.

Pragal et al (1997) uses survey data from industrial plants to examine regulatory inspections and water pollution emissions in India, and to check whether the monitoring and enforcement efforts of provincial pollution control authorities are affected by local community characteristics. This paper explains the level of pollution emitting from the industries and pollution elicit a formal regulatory response in the form of inspections on emissions under living the institutional failures.

Pritam (1983), Fare, et all, (1989,1993) postulates that this is not the same as TFPG measurement at the micro level where TFPG is usually measured with the use of distance function and linear programming approaches. Not much work has been done at national level.

The manufacturing sector is the largest consumer of commercial energy in India; this sector consumes about half of the commercial energy available in the country. 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.

Goldar (2010): in his paper he has examined the factors that influence energy intensity in Indian industries. He has taken up ten, four digit industries from 2003-04, the energy intensity is more than 10%, it is found that these industries have accounted for 57% of total energy consumption in organised manufacturing and about 25% in value added and 22% in value of output during 2003-04.

Again, there is a similar analysis for three digit industries for 2005-06, in which the energy intensity exceeds 10%, along with which the energy intensity is between 9% and 10% has accounted for about 67% of the total energy consumption in organized manufacturing (in value) and one-third in value added in 2005-06. In this paper Goldar has said that energy intensity varies across industries.

Jena (2009): in his paper he has observed that energy intensity in Indian manufacturing sector has declined during the post-reform period. Estimates revealed that aggregate energy intensity of the Indian manufacturing sector has increased during 1992-93 to 1995-96 but declined during 1996-97 to 1997-98 and then shown a fluctuating trend. Rise in energy intensity in 1995-96 was the outcome of both the increase in output and increase in energy consumption required to produce that stipulated amount of output. He has observed that both the structural effect and sectoral energy intensity effect are the determinants of the aggregate energy intensity of the manufacturing sectors in India. He has made a conclusion that the aggregate energy intensity of the Indian manufacturing sector is mainly driven by energy intensity effect of individual industry rather than structural effect.

During 1980-96, the structural effect (positive) has contributed greater share rather than the intensity effect (negative) in the changes in total energy intensity of Indian industry. Reduction in energy intensity (due to negative intensity effect) has significant role to improve energy efficiency in industrial sector in India.

Sahu and Narayan (2009): the demand for commercial energy has been growing rapidly, with the growth of the economy. The Indian manufacturing sector is the largest consumer of commercial energy compared to other industries in India. In their study they found that energy consumption of the aggregate Indian manufacturing industry was rising in absolute term, energy intensity of the Indian manufacturing was declining from 1990-2000. They found through their study that there is a positive relationship between technology import, firm size and energy intensity. On the other hand, energy intensity is negatively related with labour intensity, research intensity, export intensity, profit margin and size of the firm. It is seen that foreign ownership is important determinant of energy intensity of the Indian manufacturing industries. The change in energy intensity in Indian manufacturing is mainly due to the change in the structural change and has a negative relation between them. The sectoral energy intensity has a positive relation with the energy intensity of the Indian manufacturing sector

G Byod, J.F. McDonald et. al (1987): in this paper the focus was on two major components of trend in manufacturing energy demand: (1) change in real energy intensity is due to improved efficiency as is measured by the amount of energy used per unit of manufacturing output and (2) structural shift, that shows changes in industrial output from energy intensive to non-energy intensive sectors. In this paper they examine the sectoral shift for the United States and other nations to see the emerging consensus regarding key facts, for the year 1967-1981. The analysis was done using Divisia index method, where the weights in the index numbers changed overtime instead of remaining fixed. It is found that sectoral shift is quite sensitive to the way manufacturing output is measured and a short period of time is examined..

Marlay (1983): in his work particularly used time series data on energy consumption for aggregated manufacturing and mining sector. During the period 1972-1980, he found that the energy consumed by combined manufacturing and mining industry per value added declined by 16.5%.

Samuels et. al (1984): in this paper he studied the changes in energy intensity as determinants of energy consumption in manufacturing. The study covered the period from 1975 to 1980. They decomposed the manufacturing sector to 448 four digit SIC industries. The total reduction in energy used per dollar of shipments from 1975-80 was decomposed into (1)the reduction brought about by shifts away from energy intensive sectors and (2)reduction due to improvements in energy efficiency. Most changes in energy intensity was from 1975-80 due to improvement in energy efficiency.

Werbos (1984): has presented a summary of studies of energy consumption in manufacturing conducted by EIA. The manufacturing sector was disaggregated into 18 sectors for the years 1974-81. His results showed that there was a 17.2% decline in energy intensity in manufacturing. Werbos found that sectoral shift accounts for nearly 50% of the change in energy expenditures.

R. B. Howarth and L. Schipper (1991): in this paper the evolution of manufacturing energy use of eight industrialised nations are seen: West Germany, Denmark, France, Japan, Norway, Sweden, the United Kingdom and the United States. During the period 1973-88, the manufacturing energy use fell in these nations by 16% and the manufacturing value added increased by 41%. The intensity reduction would have driven down sectoral energy use by 32% if the level and composition of output had remained constant. Energy intensity is determined by the relative price of energy, and long term technological improvements should lead to continued intensity reduction even in periods of low energy prices.

Sahu and Narayanan (2010): in their paper they have concentrated on the decomposition of industrial energy consumption in order to examine the factors affecting the changes in energy intensity of Indian manufacturing industry during 1990-2008. They found that energy intensity was lowest in 1992. After 1992, it started to increase till 1994 and then declined. The changing pattern of output share of sub-sectors and sectoral energy intensity are the crucial components of changing pattern of aggregate energy intensity in the manufacturing sectors in India. Their estimates revealed that the structural change and the change in aggregate energy intensity are inversely related in Indian manufacturing sectors. But changes in sectoral energy intensity and changes in total energy intensity are unidirectional.

S. Ray (2001): the paper estimates productivity performance of India's energy intensive industries in terms of total factor productivity growth for the period 1979-80 to 2003-04. The productivity performance has been seen by the translog indices in three framework- material, labour and capital for assessing energy intensity in those industries. The result gives an overall productivity and shows the declining total factor productivity growth during post- reform period as compared to pre- reform period. The liberalization process is found to have an adverse impact on total factor productivity growth.

Sterner (1985): a study covering Mexico from 1970 to 1975 reveals that the increase in energy intensity in manufacturing that took place over this period was a result of increase in energy intensity in individual sectors. Mexican policy during this period was to subsidize energy consumption to stimulate industrialization, through which the energy-intensive sectors was expected to grow more rapidly than the other sectors.

Nurul Islam (1970): in his paper he said that the choice of technology in the developing countries is a matter of theoretical and empirical investigation. He said that economy like Pakistan should choose for labour intensive technology to maximize income and employment. Through the theory of comparative advantage it is known that labour abundant country will specialize in labour intensive commodities production and use labour intensive technology for getting the highest output from a given input of scarce factors. Through this work he gave an analysis of the existing factor intensities of Pakistan's large scale manufacturing industry.

Ostblom (1982): a study for the year 1973 to 1978 revealed that the decline in the energy-output ratio was caused due to sectoral shift. Ostblom's study disaggregated total gross output to 24 sectors and he included non-manufacturing sectors in the

1.4. Significance of the study:

Recent studies reveal that India ranks sixth in the total energy consumption and needs to accelerate the development of this sector to meet its growth aspiration. As theory postulates that more energy intensity leads to more polluting environment, thus there is a scope to find the scenario of productivity performance of energy intensive industries by considering the environmental pollution as a factor of production.

1.5. Its potential contribution to knowledge in the field of social relevance or national importance:

To meet up the basic requirement of the fast growing population, India needed an industrial revolution. As the consequence of uncontrolled growth of industrialization led urbanization, expansion and massive intensification of industry and the destruction of forest, industrial pollution occurred. The pressure on the natural resources of India has greatly increased due to having 18% of world's population with 2.4% of world's area. At the present moment India is experiencing huge pollution problem due to its rapid economic development based on highly polluting industries. India has become one of world's largest carbon dioxide (CO_2) emitters responsible for climate change.

Earlier in the measurement of total factor productivity, environmental issues were not incorporated. In this study we have tried to attach high importance to environmental issues and incorporated it in the analysis of the measurement of total factor productivity growth. Here in lies the potential contribution to knowledge.

1.6. Objectives:

Considering the review of literature and the research gap therein, the major objectives of our study may be underlined as follows:

1) To develop a sound methodology to measure energy intensity of the manufacturing industries in India.
2) To frame a proper method of estimating capacity utilization of the concerned energy intensive industries.
3) To develop a full proof methodology for estimating the amount of CO_2 emission from the concerned energy intensive industries.
4) To examine whether the use of the environment, proxied by Co_2 emission, as a factor of production contributes in the factor productivity growth in energy intensive industry in India.
5) To estimate the adjusted or corrected total factor productivity growth of the concerned energy intensive industries.

Chapter 2

Methodology:

2.1. Method for measuring energy intensity:

Energy intensity of any industry is defined as the ratio of total energy consumption (in value) to total output production (in value) of that industry. In this paper, energy intensity 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. Declining energy intensity in any industry indicates efficient use of energy.

In this paper we have formulated the methodologies which involve the decomposition of total energy consumption (E) and aggregate energy intensity (I).

Let,

Yit : Total output production in an economy, say India, of i^{th} industry at t,

t= 1, 2 , …….. , n.

Yt = ∑Yit: Total output Production in an economy, say India, at t,

t= 1, 2, ……., n.

Eit : Total energy consumption of i^{th} industry in an economy, say India at t,

$t = 1, 2, \ldots\ldots, n.$

$E_t = \sum E_{it}$: total industrial energy consumption in any economy, say India at t,

$t=1, 2, \ldots\ldots, n.$

Then,

The output share of the ith industry:

$\alpha_{it} = Y_{it}/Y_t$

Energy intensity of ithindustry :

$I_{it} = E_{it}/Y_{it}$

We define Aggregate Energy Intensity as :

$$I_t = E_t/Y_t = \sum E_{it}/Y_t$$

$$= \sum I_{it} Y_{it}/Y_t$$

$$= \sum \alpha_{it}.I_{it} \text{ ----------- } (1)$$

There may be two situations,

$I_t > 0$, when $\alpha_{it} > 0$, $I_{it} > 0$.

$I_t > 1$, when $\alpha_{it} > 0$, $I_{it} > 0$. In this case an increase in the aggregate energy intensity is associated with either increase in output share of the industry or increase in industry's energy intensity or both.

Aggregate energy intensity (I_t) is the weighted summation of the i^{th} industry's intensity where weights being the output share of the respective industry. In other words, it is the weighted average of i^{th} industry's intensity where weights being the output share of the respective industry.

Following Liu and Ang (2003) the aggregate energy intensity ratio (R_I) is defined as,

$$R_I = I_1 / I_0 = \sum \alpha_1 . I_1$$

Where, I^0 be the aggregate energy intensity at the base year "0" and I^1be the aggregate energy intensity at the current year "1" in any economy.

$R_I = F_\alpha . F_I$ .... (2)

The Aggregate Energy Intensity Index (**R_I**) is decomposed multiplicatively into Fisher structural index **(F_α)** and Fisher intensity index **(F_I)**. Thus aggregate energy intensity index is an indicator of energy efficiency.

In our study, we have used the Fisher Ideal index to decompose the aggregate energy intensity.

The Fisher Ideal Indices are defined as:

$$F\alpha = \sqrt{\frac{\sum \alpha_1 I_0}{\sum \alpha_0 I_0} \frac{\sum \alpha_1 I_1}{\sum \alpha_0 I_1}}$$

$$F_I = \sqrt{\frac{\sum \alpha_0 I_1}{\sum \alpha_0 I_0} \frac{\sum \alpha_1 I_1}{\sum \alpha_1 I_0}}$$

$\mathbf{F_\alpha}$ denotes the *structural effect*, is defined as the change in the total energy consumption due to change in the composition of the output production.

$\mathbf{F_I}$ denotes the *intensity effect or efficiency effect*, defined as the change in the total energy consumption due to changes in energy intensity of each individual industry.

2.2. Measurement of Capacity Utilization:

As a part and parcel of self-appraisal, each and every industry is constantly engaged in search of tools for assessing its own current performance. The performance can be judged suitably by comparing it with the various targets, past achievements and operative capacity. Manufacturing capacity utilization is such a key indicator of economic performance which explains changes in investment, inflation, long-run output growth etc. Capacity utilization is a crucial factor that not only affects growth but also indicates the level of resource utilization in an economy. Higher unutilized capacity implies slower growth rates. Therefore, the estimation of capacity output and its utilization will be very useful to evaluate the variations in the performance of an industry over a period of time.

Economic capacity is defined as the level of output at which costs are minimized, given fixed capital equipments, the technique of production, the factor prices and the available quota of inputs in the cases when they are rationed (Phan-Thuy et. Al. 1981). In this study, we apply Choice Theoretic approach to estimate capacity output.

We prefer Choice Theoretic approach because it is firmly based in the behavioural concept of economic theory. The Choice Theoretic approach defines capacity output as the long run desired level of output given capital stock and input prices.

Simply, capacity output is defined as the maximum feasible level of output of the firm. An economically more meaningful definition of capacity output originated by Cassel (1937) is the level of production where the firms long run average cost curve reaches a minimum. As we consider the long run average cost, no input is held fixed. For a firm with the typical 'U' shaped average cost curve, at this capacity level of output, economies of scale have been exhausted but diseconomies have not set in. The physical limit defines the capacity of one or more quasi-fixed input. Klein (1960) defined capacity as the maximum sustainable level of output an industry can attain within a very short time, when not constrained by the demand for product and the industry is operating its existing stock of capital at its customary level of intensity. Klein (1960) argued that long run average cost curve may not have a minimum and proposed the output level where the short run average cost curve is tangent to the long run average cost curve as an alternative measure of capacity output. This is also the approach adopted by Berndt and Morrison (1981).

In view of variations in CU as a short-run phenomenon caused by the quasi-fixed nature of capital, an econometrically tractable short-run variable cost function that assumes capital as a quasi-fixed input has been used to estimate CU.

Considering a single output and three input framework (K, L, E) in estimating CU, we assume that firms produce output within the technological constraint of a well-behaved production function.

$Y = f(K, L, E)$ where K, L and E are capital, labor and energy respectively.

Since capacity output is a short run notion, the fundamental concept behind it is that firm faces short run constraint like stock of capital. Firms operate at full capacity where their existing capital stock is at the long run optimal level. Capacity output is that level of output, which would make existing short run capital stock optimal.

Rate of CU is given as

$$CU = Y/Y^* \quad \ldots\ldots\ldots (1)$$

Y is actual output and Y^* is capacity output.

In association with variable profit function, there exists a variable cost function, which can be expressed as

$VC = f(P_L, P_E, K, Y)$… (2)

Short run total cost function is expressed as

$STC = f(P_L, P_E, K, Y) + P_K.K$…………..(3)

P_L& P_E is the price of labour and energy respectively & P_K is the rental price of Capital.

Variable cost equation which is variant of general quadratic form for (2) that provide a closed form expression for Y* is specified as

$$VC = \alpha_0 + K_{-1}(\alpha_K + ½ \beta_{KK} (\frac{K_0}{Y}) + \beta_{KL}.P_L + \beta_{KE}.P_E)$$

$$+ P_L (\alpha_L + ½\beta_{LL}.P_L + \beta_{LE}.P_E + \beta_{LY}.Y)$$

$$+ P_E(\alpha_E + ½\beta_{EE}.P_E + \beta_{EY}.Y) + Y(\alpha_Y + ½\beta_{YY}.Y) \text{ ………. (4)}$$

K_0 is the capital stock at the beginning of the year, which implies that a firm makes output decisions constrained by the capital stock at the beginning of the year.

Capacity output (Y*) for a given level of quasi-fixed factor is defined as that level of output, which minimizes STC. So, the optimal capacity output level, for a given level of quasi-fixed factors, is defined as that level of output, which minimizes

STC. So, at the optimal capacity output level, the envelop theorem implies that the following relation must exist.

$$\frac{\partial STC}{\partial K} = \frac{\partial VC}{\partial K} + P_K = 0 \ldots\ldots\ldots\ldots (5)$$

In estimating Y*, we differentiate VC equation (4) w.r.t K_{-1} and substitute expression in equation (5)

$$Y^* = \frac{-\beta_{KK.} K_{-1}}{(\alpha_K + \beta_{KL}P_L + \beta_{KE}P_E + P_K)} \ldots\ldots\ldots\ldots (6)$$

The estimates of CU can be obtained by combining equation (6) and (1).

Now in capacity utilization (CU) estimate, output is measured as real value added produced by manufacturers ($Y = P_L L + P_K K_{-1} + P_E. E$) suitably deflated by WIP index for manufactured product (base 1991-92 = 100) to offset the influence of price changes. Variable Cost is sum of the expenditure on variable inputs ($VC = PL*L + P_E*E$). Total number of persons engaged in those industries is used as a measure of labor inputs. Price of labor (P_L) is the total emolument divided by number of laborers which includes both production and non-production workers (Goldar& others 2004).

Deflated cost of fuel has been taken as measure of energy inputs. Due to unavailability of data regarding periodic price series of energy in India, some approximation becomes necessary. We have taken weighted aggregative average price index of fuel (considering coal, petroleum and electricity price index, suitably weighted, from statistical abstract) as proxy price of energy. Deflated gross fixed capital stock at 1991-'1992 prices is taken as the measure of capital input. The estimates are based on perpetual inventory method. 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. Rental price of capital is assumed to be the price of capital (P_K) which can be estimated following Jorgenson and Griliches (1967): P_K= (Interest paid/Capital investment).

2.3. Model Building by incorporating CO_2 as an input of Production Process:

Pollution, is modelled either as an input (see, e.g. Baumol and Oates (1988)) or as an (another) output of the production process (see e.g. Fare, Grosskopf and Pasurka (2001)). Modelling pollution as an output captures the idea that "good" output cannot be produced unless pollution ("bad output") is also produced (see e.g., Fare, Grosskopf, Lovell, and Yaisawarng (1993), Ball, Lovell, Nehring, and Somwaru (1994), and Fernandez, Koop & Steel (2005)). That is pollution is a by-product of the production of goods. Those who model pollution as an input argue that trying to reduce pollution involves diverting some of the traditional inputs into the abatement effort, something that results in fewer inputs available in the production of goods. In other words it is argued that by reducing pollution, output is reduced and in this sense pollution can be treated as an input into production (see, e.g., Laffont (1988), Cropper and Oates (1992), Koop (1998) and Reinhard, Lovell, and Thijssen (1999)).

Another argument in favour of the use of pollution as an input is that pollution represents the extractive use of natural environment. That is pollution is treated as a proxy for the use of environmental resources (see Bovenberg and Smulders (1995), Brock and Taylor (2005)). A number of authors argue that some of these approaches are inconsistent with the materials balance condition a "…fundamental imperative of physical science-as well as common sense" (Murty& Russell (2002), p. 16). The materials balance approach was first introduced by Ayres &Kneese (1969), and it was only recently that has gained attention in the modeling of emissions or production residuals in the production process (Murty& Russell (2002), Pethig (2003, 2006), Førsund (2009), Lauwers (2009)). The materials balance condition implies that the generation of residuals inevitably arises in the process of consumption and production. Murty and Russell (2002) account for this condition by defining a residual generating mechanism that relates the generation of production residuals with the use of polluting inputs. These polluting inputs (or material inputs as defined by others like Pethig (2003, 2006)) are used in the production of the output but are also responsible for the generation of a by-product; pollution. Therefore the link between output and pollution comes through the use of the polluting generating inputs.

This study uses the pollution generating mechanism as the main tool used in order for a production function to be defined. A firm or industry or state produces output y, using a vector of non-residual generating inputs x, and an input vector x_e which represents one or more residual generating inputs.

The production of output as well as the generation of the production residual are summarized in the following two equations:

$$y = F(x, x_e, t) \qquad (1)$$

where, t is a technology index measured by time trend. The residual-generation mechanism is described by

$$e = g(x_e, t) \qquad (2)$$

Solving (2) for x_e, $x_e = h(e, t)$ and replacing it in (1) the following production function is defined in 3:

$$y = F(x,h(e,t),t) = f(x,e,t) \qquad (3)$$

That is output, y, depends on x, a vector of traditional inputs like physical capital, K, and labour L, emissions, E (or production residual) and the time trend t. Having defined the role of emissions in the production process, the next step would be to define a functional form for the production function. Unlike most previous studies the analysis here is based on a general framework; now a parametric functional form is assumed for modelling the relationship between emissions and growth.

Total differentiation of (3) with respect to time and division by y yields the following for a particular industry in year t:

$$\dot{Y} = \varepsilon_K \dot{K} + \varepsilon_L \dot{L} + \varepsilon_E \dot{E} + \dot{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, ($\cdot$) => Growth rate

$\dot{A}$ => $\frac{(\frac{\delta Y}{\delta t})}{Y}$ means the exogenous rate of technical change

ε_i => Elasticity of output with respect to i-th input

Now, subtracting from both sides of equation (4) the contribution of traditional inputs to the output growth results to

$$\dot{Y} - \varepsilon_K \dot{K} - \varepsilon_L \dot{L} = \varepsilon_E \dot{E} + \dot{A} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Assuming a perfectly competitive environment, the output elasticities of labour and physical capital are equal to the observed income shares of labour, s_l , and physical capital, s_k. Therefore a TFP index can be define based on the observable data which discretely approximates the left hand side of equation (5). This index allows for the contribution of each input to differ across state and time and to be dictated by the data. The Tornqvist index of TFP growth for a particular industry in year t is defined as:

$$T\dot{F}P_t = \dot{Y}_t - (w_{Kt}\dot{K}_t + w_{Lt}\dot{L}_t) \quad \text{...}(6)$$

Where, (.) represents growth rates, w_{Kt} = 0.5(s_{kt} + $s_{k(t-1)}$) &w_{Lt}= 0.5((s_{Lt} + $s_{L(t-1)}$) are the weighted average income shares of physical capital and labour. This measure of TFP growth contains the components of output growth that cannot be explained by the growth of the traditional inputs (K and L). Using equation (6), equation (5) can be written as:

$$T\dot{F}P = \varepsilon_E\dot{E} + \dot{A} \quad \text{..}(7)$$

The measured TFP growth is decomposed into the two unknowns to be estimated: the exogenous rate of technological change,$\dot{A}$,and the output elasticity of emissions. This last term in equation (7) is of central importance for this study since it captures the unobserved contribution of emissions to aggregate productivity.

2.4. Measurement of CO_2 :

One of the objectives of this work is to estimate the CO_2 emission at firm level. Further, we econometrically model the factors explaining determinants of inter-firm differences in the CO_2 emission. We begin explaining the construction of the firm level CO_2 emission for the sampleof firms in Indian manufacturing industries.

Data at the aggregate level is available but firm level emission information is not reported. One of the ways to capture the firm level emission is to compute the emission from the input use that is from thefossil fuel used by the firms. Which is an indirect measure based on ascientific approach however, is closely related to the emission generatedfrom firm according to the**Intergovernmental Panel on Climate Change**(IPCC).

The estimation of emission from the fossil fuel consumption is based onthe IPCC reference approach that refers as a top down approach using aggregate information of fossil fuel consumed, to calculate the emissionsof CO_2 from combustion of mainly fossil fuel. However, the study has fewdata limitations such as quality of coal used. This is not consideredmainly because the calculation is carried out for the first time at firm level in Indian manufacturing firms using PROWESS data base. Data iscollected from the Centre for Monitoring Indian

Economy (CMIE) data-basePROWESS 4.0. This data is a combination of the annual audited balancesheet (that gives information of the firm characteristics) and energy consumption at firm level. Therefore, firms that don't report energyconsumption are dropped from the active data sheet. Also, since we areadopting the IPCC reference approach, we have considered only fossilfuels consumed by the firms.

The IPCC reference approach of estimating emissions from fossil fuels is as follows:

$$CO2 = \sum_{i=1}[\ ((ac_f \ X\ cf_f \ X\ cc_f)\ X\ 10^{-3} - ec_f)\ X\ cof_f \ X\ (44/12)] \ldots\ldots (1)$$

Where, ac_f = apparent consumption fuel (Consumption that includes internal consumption, refinery fuel and loss, and bunkering. For countries in the Organization for Economic Cooperation and Development (OECD), apparent consumption is derived from refined product output plus refined product imports minus refined product exports plus refined product stock changes plus other oil consumption (such as direct use of crude oil). For countries outside the OECD, apparent consumption is either a reported figure or is derived from refined product output plus refined product imports minus refined product exports, with stock levels assumed to remain the same. Apparent consumption also includes, where available, liquefied petroleum gases sold directly from natural gas processing plants for fuel or chemical uses.

cf_f = conversion factor for the fuel to energy units (TJ) on net caloric value basis,

ccf = carbon content (tonne C/TJ i.e. to kg C/GJ),

ec_f = excluded carbon defined as carbon infeed-stocks and non-energy use excluded from fuel burning emissions (Gg C),

cof_f = carbon oxidation factor defined as fraction of carbon oxidized (usually the value is 1, reflecting complete oxidation).Lower values used only to account for carbon retained indefinitely in soot, and

(44/12) is the molecular weight ratio of CO_2 to Carbon (C).

Further, following Chen et al. (2010) we construct the firm level emission from equation (1) as:

$$C_t = \sum_{i=1}^{n} C_{i,t} = \sum_{i=1}^{n} E_{i,t} \, X \, NCV_i \, X \, CEF_i \, X \, COF_i \, X \, (44/12) \quad \ldots\ldots\ldots\ldots (2)$$

Where, C_t = flow of carbon dioxide with unit of 10,000 tons,

NCV_i = net calorific value provided by IEA energy statistics for India, 2011, (**net calorific value** is determined by subtracting the heat of vaporization of water vapour [generated during combustion of fuel] from the higher **heating value**).

CEF_i = carbon oxidization factor provided by 2006 National Greenhouse Gas Inventories in IPCC,

COF_i is the carbon oxidization factor (The **oxidation factor** is used to calculate the amount of the fuel that is contributing to **carbon** dioxide emissions. **Oxidation factors** vary by type of fuel and by technology) set to be one in this study.

Therefore, based on equation (2) in manufacturing industries the calculated CO_2 emission coefficient for coal is 2.0483 (kg CO_2/ kg coal), for oil 3.272 (kg CO_2/ kg oil) and for natural gas 2.819 (kg CO_2/m^3 natural gas).

2.5. Database & Variables:

2.5.1. Study Period:

This study covers a period of 31 years from 1980-81 to 2010-11. The entire period is divided into two phases as pre-reform period (1980-81 to 1990-91) and post reform period (1991-92 to 2010-11). The sub periods are taken logically to examine the impact of liberalization on the growth, employment and real wages for the Industries.

2.5.2. Data Sources:

The present study is based on industry level time series data taken from several issues of Annual Survey of Industries (ASI) published by Central Statistical Organization (CSO), RBI Handbook of Statistics on Indian Economy published by Reserve bank of India (RBI), CMIE PROWESS Database, I-O tables, World Bank's Development Indicator, Economic and Political weekly database, National Accounts Statistics (NAS) and various issues of Economic Survey published by Government of India.

2.5.3. Measurement of Output:

Output is measured as real value added produced by manufactures. In this case, it is obtained by the use of a simple value added deflator straightaway instead of the wholesale price index. NAS provides estimates of real value added in the manufacturing sector as a whole, but this is arrived at by using a single wholesale price index deflator. Thus, we could not use the ratio between the current and constant price value added in manufacturing (as in NAS) as the price index of value added in the sector. So we used GDP deflator obtained from NAS as the ratio between current and constant price GDP.

In our view this index, though not satisfactory, may not be worse than the whole sale price index for our purpose. The use of the GDP deflator is apparently too simplistic a solution. But it is not clear that we are more correct when we deflate by the wholesale price index for even the particular industrial product. Because the inputs and output are different products. The ideal, of course, is to take separate and specific price indices to deflate inputs and output. But that is too large a task for the present study.

In fact the GDP deflator shows a trend somewhat steeper than that for the wholesale price of manufacturing. So the value added growth rate obtained by us is lower than what would be obtained by us is lower than what would be obtained by using a wholesale price index for manufacturing. Therefore, it seemed to us interesting and worthwhile to work with this deflator.

2.5.4. Measurement of Labour Input:

As for the measurement of labour input, Kendrick (1973) considers all workers within each industry to be homogeneous. He totally neglects the influence of labour quality on the measurement of industry's labour input. Denison (1974) is of the view that disaggregation by characteristics is essential in measuring labour input. He also points out that earnings can be used in weighting the component of labour input only if the average earnings for different categories of labour input cross classified by education or by age and sex are proportional to the corresponding marginal products.

‘Total employees’ as a measure of labour input includes both workers and persons other than workers. The latter category of employees includes supervisors, technicians, managers, clerks and other similar types of employees. If we take ‘total employees’ as the measure of labour input then we would be guided by the assumption that ‘workers’ and ‘persons other than workers’ are perfectly substitutable. The above assumption is unrealistic as is pointed out by Griliches (1967). Further, he adds that efficiency differences in different classes of labourers are reflected in their rates of remuneration.

In the context of Indian economy, all the major works on productivity of the manufacturing sector, such as Goldar (1986), Ahluwalia (1991), Balakrishnan&Pushpangadan (1994), considers ‘total employees’ as the measure of labour input. In majority of the earlier studies of Sastry (1966) and Sankar (1970) attempts have been made to take into account quality changes of different components of labour by weighting them by their wage share. Goldar (1986), talks off imperfection of the labour market and their inappropriateness of the assumption of efficiency of different categories of labour being reflected in their rates of remuneration in the Indian context.

In our present study we have made the uncomfortable assumption that efficiency differences in different classes of labour are largely reflected in their remunerations. Although we are convinced that the assumption is not particularly valid for a country like India, the alternative of treating labour as homogeneous also involves serious error. Thus, admittedly, our labour index is not very satisfactory but, probably, it is better than an unweighted sum of different categories of labour. 'Workers' and 'other employees' (includes supervisors, technicians, managers etc.) are the two groups of labour, data are consistently available for the period under study. Labour index is formed by a weighted sum of the number of heads in these two groups, weights being the relative group remunerations. i.e.,

L = $w_1 * L_1 + w_2 * L_2$

Where, L = Labour input, L_1= workers, L_2= other employees except workers,

w_1=remuneration per worker, w_2=remuneration per other employees except workers.

Relevant data is obtained from Annual survey of Industries and Indian labour Statistics.

2.5.5. Measurement of Capital Input:

The estimation of capital stock, apart from the theoretical problems regarding the very concept (Robinson, J. 1970, Garegnani, 1970) is a tricky job. The treatment of capital as a factor of production became the central issue in an extended debate among Denison (1957, 1966, 1972), Griliches and Jorgenson

(1966), Jorgenson (1980, 1989) and Kendrick (1961, 1973). The state of the debate is well summarised in Diewart (1980). For the Indian economy two important studies are by Banerji (1975) and the other by Hashim&Dadi (1973).

We have not taken into account, working capital so far as the measurement of capital is concerned. In this regard Sinha and Sawhney (1970) argues, as quoted in Goldar (1986), "While the importance of working capital to industrial productivity cannot be denied, the inventory and cash holdings are more often determined by supply and market expectations than technological pipeline requirements and have, therefore; far less bearing on productivity than fixed investment. The available data on inventories and cash are as on the last day of the year and not the average holding of working capital though the year which alone may be appropriately related to the annual follow of output. In this respect Banerji (1975) talks off the difficulty of arriving at a suitable price index required for deflation purpose.

Many intricate issues come out with regard to the choice between gross and net stock of capital. Most of the studies favoured gross stock on the ground that the net value declines much rapidly then the ability of a capital good to contributes to production. Denison(1967) is of the view that the correct index of capital services would lie somewhere between the gross and net stocks and advocates a weighted average of the two. In this regard Goldar (1986) points out that the available data is too crude to make a proper estimate of capital consumption and hence of net capital stock for Indian industries. This has also been pointed out by Sinha and Sawhney(1970), banerji (1975) and others who argue that the figures on depreciation presented in census of Manufacturing Industries and Annual survey of Industries are calculated at the rates allowed by income tax authorities and rarely represents the actual capital consumption.

Kendrick (1973) and Denison (1974) have strongly argued against any correction of capital stock figures for underutilization of capacity in productivity analysis. They are of the view that the degree of capacity utilization reflects the degree of efficiency of enterprises and hence would be incorporated in the change in productivity indices. In addition to the conceptual intricacies, Goldar(1986) have pointed out the poor quality data on capacity utilization.

Since the study by Goldsmith in 1951, most of the studies have used the perpetual inventory method (PIM) for estimating capital input. For the Indian case, important studies such as Goldar (1986) and Ahluwalia (1991), have used some variant of the PIM. In this method the capital stock of a given year is traced to the stream of past investment at constant prices. PIM requires an estimate of the capital stock for a benchmark year and estimates of investment in the subsequent periods. Let, K_0 denote the benchmark year real capital stock and I_t the real gross value investment in fixed capital in the year 't' and let 'r' be the annual rate of discarding of assets. Then K_t, real gross fixed capital stock for the year 't' is obtained as follows:

$K_t = K_0 + \sum_{t=1}^{t} I(t)$,

Where, $I(t) = I_t - rK_{t-1}$

Goldar (1986) talks of various possibilities with regard to the rate of discarding of assets. This may be zero, a constant or a fraction of previous year's fixed capital stock.

In our study, we have taken the real value of capital stock at constant (1991-92) prices as the measure of capital input. Fixed capital represents the depreciated value of fixed assets owned by factory as on the closing day of the accounting year.

Fixed capital covers all types of assets, new or used or own constructed, deployed for production, transportation, living or recreational facilities, hospitals, schools etc., for factory personnel. It includes the fixed assets of the head office allocable to the factory and also the full value of assets taken on hire purchase basis (whether fully paid or not) excluding interest element. It excludes intangible assets and assets solely used for post manufacturing activities. The case for inclusion of investment in labour welfare (like living and recreational facilities, hospitals etc.) in capital stock may not be particularly convincing.

Probably, these expenses should be treated as investment in durable consumer goods. But we did not have sufficiently disaggregated data to adjust for them.

Deflator for fixed capital stock is obtained from data on Gross Fixed Capital Formation (GFCF) at current and constant prices, for different years. Data for the above purpose are obtained from the various issues of Annual Survey of Industries and National Accounts Statistics published by the Central Statistical Organization.

Chapter 3

Results & Discussion:

According to C.P.R Environmental Education Centre, India, Paper and Paper Product industry, Chemical & Chemical product industry, Iron & Steel industry, Cement industry, Aluminium industry, Fertilizer industry are heavily polluting industries in India. These polluting industries are energy intensive in nature. We have taken up these industries for our analysis as they are the major energy intensive industries.

3.1. Estimation of Energy intensity:

Table 3.1: Estimates of energy intensity of selected energy intensive manufacturing industries in India:

INDUSTRY / YEAR	Paper & Paper Product industry	Chemical & Chemical Product Industry	Iron & Steel Industry	Cement Industry	Aluminium Industry	Fertilizer Industry
1980/81	13.36	8.612	12.574	9.97	9.39	11.09
1981/82	14.84	9.761	11.471	10.85	10.17	11.67
1982/83	16.96	9.832	11.613	12.15	10.59	12.16
1983/84	17.03	10.96	14.119	14.60	10.82	13.59
1984/85	16.02	11.03	13.935	13.91	11.17	13.34
1985/86	16.58	10.5	13.48	16.91	11.46	13.06
1986/87	17.07	12.04	13.302	15.26	11.31	13.84
1987/88	17.44	11.9	13.252	15.01	10.59	13.83
1988/89	16.77	10.11	11.653	14.92	9.93	12.27
1989/90	14.94	9.883	11.59	13.19	9.77	11.79
1990/91	14.06	9.809	11.222	15.33	9.79	11.44
1991/92	15.79	9.619	12.299	17.81	9.63	12.06
1992/93	16.39	9.885	11.975	16.19	9.59	12.21
1993/94	15.32	9.396	12.166	15.18	9.17	11.82
1994/95	15.19	9.496	12.182	17.11	9.27	11.85
1995/96	14.25	8.638	13.024	16.20	8.87	11.42
1996/97	16.96	9.715	12.074	14.15	8.08	12.26
1997/98	16.42	8.328	11.435	14.97	7.39	11.18
1998/99	16.13	6.514	12.484	15.71	7.33	10.15
1999/2000	17.07	7.452	11.606	15.99	8.02	10.76
2000/01	13.72	8.126	13.315	16.23	8.39	11.07
2001/02	14.46	8.504	13.648	15.98	8.22	11.56
2002/03	14.01	8.393	13.228	15.99	8.05	11.27
2003/04	13.35	7.792	11.948	14.33	7.84	10.46
2004/05	13.29	7.991	12.001	16.00	7.89	10.57
2005/06	12.99	7.759	11.810	15.85	7.66	10.33
2006/07	13.01	7.710	11.913	15.91	7.48	10.39
2007/08	12.93	7.519	11.975	15.07	7.28	10.21
2008/09	12.78	7.221	11.770	16.11	7.24	9.94
2009/10	12.52	7.110	11.509	17.06	7.79	9.75
2010/11	12.71	7.399	11.897	16.78	8.85	10.07
Overall period	**14.97935**	**9.000129**	**12.33774**	**15.35833**	**9.167**	**11.586**
Pre-reform	**15.91545**	**10.40336**	**12.56464**	**14.213**	**9.252**	**12.576**
Post-reform	**14.4645**	**8.22835**	**12.21295**	**15.931**	**8.228**	**11.007**

Source: Authors own estimation

From Table 3.1, for paper and paper product industry the annual average energy intensity in the pre-reform period is 14.98 and in the post-reform period it is 14.46. When we look into the chemical and chemical products industry, the annual average energy intensity in the pre-reform period is 10.4 and in the post-reform period it is 8.23, again in, Iron & Steel Industry the annual average energy intensity in the pre-reform period is 12.565 and in the post-reform period it is 12.213.So far as cement industry is concerned, the energy intensity in the pre-reform period is 14.213 and in the post-reform period it is 15.931. When we consider the aluminium industry the annual average energy intensity in the pre-reform period is 9.252 and in the post-reform period it is 8.228. For the fertilizer industry the annual average energy intensity in the pre and post reform period is 12.576 and 11.007 respectively.

From these above industries, we may note that the energy intensity for these industries have declined in the post-reform period implying may be the use of modern technology in the production process.

Now, the trend growth rate of energy intensity in paper and paper products industry in the pre reform period is 4.7% and it sharply declined in the post-reform period to -1.6%. Now, for both the sub-periods the overall model significance is high as the F-values are high. The R^2 and Adjusted R^2 and the t-values are also very high for both the regression models. The observed results are represented in the following table 3.1.1.

3.1.1. Trend growth rate of energy intensity for Paper & Paper Products industry

Trend Growth Rate	Pre-Reform Period	Post-Reform Period
Intercept	15.63 (16.63)***	16.45 (24.59)***
Coefficient	0.047 (2.9901)***	-0.016 (-2.7103)***
Regression Results	R^2 = 0.96612 Adj. R^2 = 0.95110 F = 121.9006	R^2 = 0.9701 Adj. R^2 = 0.9669 F = 119.3110

(**Source: own estimation, the figures in the parenthesis are the 't" values)**

The trend growth rate of energy intensity in case of Chemical & Chemical Products industry in the pre reform period is 9% and it sharply declined in the post-reform period (-17.4%). Now, for both the sub-periods the overall model significance is high as the F-values are high. The R^2 and Adjusted R^2 and the t-values are also very high for both the regression models. The observed results are represented in the following table 3,1.2.

Table-3.1.2. Trend growth rate of energy intensity for Chemical & Chemical Products industry

Trend Growth Rate	Pre-Reform Period	Post-Reform Period
Intercept	9.85 (14.95)***	9.82 (21.66)***
Coefficient	0.09 (2.96)***	-0.174 (-2.7701)***
Regression Results	R^2 = 0.9121 Adj. R^2 = 0.8990 F = 114.111	R^2 = 0.9099 Adj. R^2 = 0.8701 F = 117.229

(**Source: own estimation. the figures in the parenthesis are the 't" values)**

The trend growth rate of energy intensity in the Iron & Steel Industry in the pre reform period is -7.7% and it sharply increased in the post-reform period to 6.1%. Now, for both the sub-period, the overall model significance is high as the F-values are high. The R^2 and Adjusted R^2 and the t-values are also very high for both the regression models. The observed results are represented in the following table 3.1.3.

Table-3.1.3. Trend growth rate of energy intensity for Iron & Steel industry

Trend Growth Rate	Pre-Reform Period	Post-Reform Period
Intercept	**13.3 (18.08)*** **	**11.98 (30.32)*** **
Coefficient	**-0.077 (-3.99)*** **	**0.061 (3.78)*** **
Regression Results	**R^2 = 0.97111 Adj. R^2 = 0.96001 F = 108.991**	**R^2 = 0.9701 Adj. R^2 = 0.9669 F = 110.009**

(**Source: own estimation)(the figures in the parenthesis are the 't" values)**

The trend growth rate of energy intensity in Indian cement industry in the pre reform period is 4.24% and it also declined in the post-reform period to 3.56%. Now, for both the sub-periods the overall model significance is high as the F-values are high. The R^2 and Adjusted R^2 and the t-values are also very high for both the regression models. The observed results are represented in the following table 3.1.4.

Table-3.1.4. Trend growth rate of energy intensity for Cement industry

Trend Growth Rate	Pre-Reform Period	Post-Reform Period
Intercept	**11.28 (10.64)**	**15.97 (37.41)**
Coefficient	**0.0424 (2.71)**	**0.0356 (10.92)**
Regression Results	**R^2 = 0.67061 Adj. R^2 = 0.66976 F = 107.355**	**R^2 = 0.66111 Adj. R^2 = 0.65001 F = 119.991**

(**Source: own estimation. the figures in the parenthesis are the 't" values)**

The trend growth rate of energy intensity in the Indian aluminium industry in the pre reform period is -1.7% and it sharply increased in the post-reform period to 8.5%. Now, for both the sub-period, the overall model significance is high as the F-values are high. The R^2 and Adjusted R^2 and the t-values are also very high for both the regression models. The observed results are represented in the following table 3.1.5.

Table-3.1.5. Trend growth rate of energy intensity for Aluminium industry

Trend Growth Rate	Pre-Reform Period	Post-Reform Period
Intercept	**10.557 (22.374)*** **	**9.096 (32.351)*** **
Coefficient	**-0.017 (-2.982)*** **	**0.085 (3.632)*** **
Regression Results	**R^2 = 0.82477 Adj. R^2 = 0.81802 F = 98.611**	**R^2 = 0.92159 Adj. R^2 = 0.8963 F = 99.180**

(**Source: own estimation. the figures in the parenthesis are the 't" values)**

The trend growth rate of energy intensity in Indian fertilizer industry in the pre reform period is 3.2% where as it is sharply declined in the post-reform period to -1.6%. Now, for both the sub-periods the overall model significance is high as the F-values are high. The R^2 and Adjusted R^2 and the t-values are also very high for both the regression models. The observed results are represented in the following table 3.1.6.

Table-3.1.6. Trend growth rate of energy intensity for Fertilizer industry

Trend Growth Rate	Pre-Reform Period	Post-Reform Period
Intercept	**12.359 (18.042)*** **	**12.218 (64.968)*** **
Coefficient	**0.032 (3.186)*** **	**-0.016 (-7.593)*** **
Regression Results	**R^2 = 0.85609 Adj. R^2 = 0.84170 F = 93.937**	**R^2 = 0.76209 Adj. R^2 = 0.74887 F = 97.658**

(**Source: own estimation. the figures in the parenthesis are the 't" values)**

3.2: Estimation of Capacity Utilization (CU):

In this section, we have analysed the results obtained from the trend in capacity utilization of the selected energy intensive industries under our study. The period covered by our study is from 1980-81 to 2010-11. In order to facilitate comparison of the estimates we have also subdivided the entire period into 1980-81 to 1990-91 as the pre reform period and 1991-92 to 2010-11 as the post reform period.

The rate of capacity utilization (CU), measuring the extent to which actual output differs from capacity output, is one of the central variables in economic analysis. As a yardstick for evaluating economic performance in a capital-scare economy like India, manufacturing capacity utilization is a key indicator which not only determines how much more output can be obtained by fuller utilization of existing capacity but also defines the required expansion of capacity for a targeted output and also explains changes in investment, inflation, level of resource utilization, assesses possible future demand for investment goods, a demand that tends to vary directly with increase in CU, permits economic analysts to adjust current productivity growth calculations for departure from full equilibrium. etc. Therefore, the estimation of capacity output and its utilization will be very useful to evaluate the variations in the performance of an industry over a period of time.

The result of the rate of capacity utilization is obtained through the ratio of actual output to capacity output. Now, to derive capacity output, first, we have to estimate the variable cost (VC) equation shown as equation (4) in methodology (Chapter 2) through ordinary least square methods (OLS), and then we have to minimize the short-run total cost with respect to capital. Our model assumes that capacity utilization (CU) is a function of input prices, output and quasi-fixed factor input, capital. We found that capacity utilization and input prices have a negative relationship and that of with output is positive. The derivative of VC (equation 4) with respect to K is negative since capital will substitute labour and energy. In order to test the concavity of the variable cost function with respect to variable input prices, its Hessian matrix for negative semi-definiteness is evaluated and it is found that concavity condition is fulfilled at all observation points. Therefore, the partial derivative with respect to each of input prices is negative. The partial derivatives of VC with respect to output is positive because in our empirical results $\beta_{KK} > 0$ and $(\alpha_K + \beta_{KL} P_L + \beta_{KE} P_E) < 0$ for all data points. Therefore, positive relation between output and capacity utilization is an indication that an increase in demand will lead to higher levels of capacity utilization.

The following table (Table-3.2.1) display vivid portrait regarding variation in CU.

Table 3.2.1: Yearly estimates of Economic CU for the pre-reform period

YEAR	Paper and Paper Product	Chemical and Chemical Product	Iron & Steel Industry	Cement industry	Aluminium industry	Fertilizer Industry
1980-81	0.84	0.88	0.91	0.92	0.89	0.90
1981-82	0.77	0.79	0.96	0.86	0.86	0.85
1982-83	0.95	0.87	0.86	0.92	0.87	0.90
1983-84	0.95	0.93	0.85	0.94	0.90	0.91
1984-85	0.96	0.91	0.72	0.88	0.82	0.85
1985-86	0.94	0.99	0.86	0.96	0.92	0.94
1986-87	0.92	0.96	0.90	0.95	0.93	0.94
1987-88	0.98	0.86	0.950	0.96	0.91	0.93
1988-89	0.99	0.95	0.98	1.00	0.97	0.98
1989-90	0.93	1.01	0.97	1.00	0.98	0.98
1990-91	0.95	0.99	0.93	0.99	0.96	0.97

(**Source: own estimation)**

Table 3.2.2: Yearly estimates of Economic CU for the post-reform period

YEAR	Paper and Paper Product	Chemical and Chemical Product	Iron & Steel Industry	Cement industry	Aluminium industry	Fertilizer Industry
1991-92	0.78	0.73	0.83	0.80	0.82	0.78
1992-93	0.81	0.72	0.65	0.73	0.75	0.72
1993-94	0.82	0.89	0.77	0.85	0.87	0.83
1994-95	0.71	0.84	0.76	0.80	0.82	0.78
1995-96	0.82	0.93	0.79	0.87	0.90	0.85
1996-97	0.69	0.88	0.82	0.83	0.86	0.81
1997-98	0.75	0.87	0.73	0.81	0.83	0.79
1998-99	0.73	0.81	0.70	0.77	0.79	0.75
1999-2000	0.76	0.79	0.81	0.81	0.84	0.80
2000-01	0.81	0.85	0.77	0.83	0.85	0.81
2001-02	0.75	0.73	0.83	0.79	0.82	0.78
2002-03	0.78	0.81	0.79	0.82	0.84	0.80
2003-04	0.86	0.91	0.88	0.91	0.94	0.89
2005-06	0.97	0.87	0.81	0.89	0.91	0.87
2006-07	0.91	0.94	0.90	0.94	0.97	0.92
2007-08	0.93	0.95	0.97	0.98	1.01	0.96
2008-09	0.98	0.92	0.89	0.95	0.97	0.93
2009-10	0.95	0.87	0.95	0.95	0.97	0.92
2010-11	1.01	0.98	0.92	0.99	1.02	0.97

(**Source: own estimation)**

In some cases the Economic Capacity Utilization maybe greater than unity. This is due to the fact that at times, due to drastic increase in demand for the product and to maintain the goodwill, the industry or a firm may continue production at the right side of the minimum point of short-run average cost curve (SAC).

Table 3.2.3: Industry wise Annual Average Growth Rates of Capacity Utilization

Periods	Paper and Paper Product	Chemical and Chemical Product	Iron & Steel Industry	Cement industry	Aluminium industry	Fertilizer Industry
Annual average CU for the Pre-reform Period	0.93	0.92	0.90	0.94	0.91	0.92
Annual average CU for the Post-reform Period	0.83	0.86	0.82	0.86	0.88	0.84
Annual average CU for the Overall Period	0.87	0.88	0.85	0.89	0.89	0.87

The aggregate estimate in Table- 3.2.3, shows that, Paper & Paper product industry's average capacity utilization (CU) declined from 0.93 to 0.83, when comparing the pre-reform period with that of the post reform period. This indicates that a net fall of 10% over the pre- reform period.

In Indian Chemical and Chemical Products industry, a comparison of the average utilization of capacity in the two periods showed lower capacity utilization in the post reform period as compared with the pre reform period.

Analysis of capacity utilization for Indian Iron & Steel industries depicts that there is a falling trend in capacity utilization over the years as shown in the decline in CU from 0.90 in pre reform period to 0.82 in the post reform period i.e., there is 8% decline in the rate of CU.

So far as the capacity utilization of Indian Cement industry is concerned, we observe a falling tendency in the rate of capacity utilization from 0.94 to 0.86 from pre to post reform period.

In Indian Aluminium industries & Fertilizer industries, a comparison of the average utilization of capacity in the two periods shows lower capacity utilization in the post reform period as compared with the pre reform period for both the industries.

Now, so far as the annual average CU for the entire period of the concerned industries, it is very much significant to note that the industries are operating at under utilization of the existing capacity.

3.3. Estimates of Emission Elasticity of Output Growth, Conventional TFPG and TFPG by considering CO_2 as an input of Production ($TFPG^c$) for Paper & Paper Product Industry:

PAPER AND PAPER PRODUCT INDUSTRY	Emission Elasticity of Output	TFPG	$TFPG^c$
1980/81	0.00413	0.0159	0.015074
1981/82	0.00413	0.0142	0.013374
1982/83	0.00414	0.0131	0.012272
1983/84	0.00414	0.0129	0.012072
1984/85	0.00414	0.0115	0.010672
1985/86	0.00451	0.0148	0.013898
1986/87	0.00458	0.0128	0.011884
1987/88	0.00412	0.0141	0.013276
1988/89	0.00413	0.0113	0.010474
1989/90	0.00415	0.0119	0.01107
1990/91	0.00457	0.0111	0.010186
1991/92	0.00662	0.0114	0.010076
1992/93	0.00413	0.0101	0.009274
1993/94	0.00414	0.0159	0.015072
1994/95	0.00433	0.0149	0.014034
1995/96	0.00412	0.0138	0.012976
1996/97	0.00414	0.0201	0.019272
1997/98	0.00442	0.0209	0.020016
1998/99	0.00475	0.0211	0.02015
1999/2000	0.00413	0.0195	0.018674
2000/01	0.00414	0.0181	0.017272
2001/02	0.00413	0.0188	0.017974
2002/03	0.00413	0.0199	0.019074
2003/04	0.00414	0.0222	0.021372
2004/05	0.04085	0.0291	0.02093
2005/06	0.04199	0.0299	0.021502
2006/07	0.04182	0.0197	0.011336
2007/08	0.04109	0.0193	0.011082
2008/09	0.04198	0.0119	0.003504
2009/10	0.03008	0.0200	0.013984
2010/11	0.03627	0.0218	0.014546
Overall period	**0.012198**	**0.016839**	**0.014399**
Pre-reform	**0.004249**	**0.012917**	**0.012067**
Post-reform	**0.01657**	**0.019316**	**0.016002**

Table 3.3 shows the effect of pollution, as measured by CO_2 emissions, on TFPG for the Paper & Paper Products Industry. We construct a TFP growth index by subtracting the weighted growth of physical capital and labour inputs, from the output growth, using the observed income shares of physical capital and labour

as the weights. The TFP index based on the observable data allows us to estimate the contribution of each input. We then examine the relationship between TFP growth and pollution using our model that allows us to directly estimate the elasticity of pollution.

Our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that pollution affects TFP growth positively. Average pollution elasticity of 0.012198. This implies that in the case of CO_2, 1% increase in emissions increases the average output by 1.22%. In addition pollution contributes on average about 0.4% to the total factor productivity growth. This implies that the use of the environment approximated by CO_2 emissions, which is an unpaid factor, contributes to the growth of output along with physical capital and labour and its contribution should be accounted for in TFPG measurements.

3.4. Estimates of Emission Elasticity of Output Growth, Conventional TFPG and TFPG by considering CO_2 as an input of Production ($TFPG^c$) for Chemical & Chemical Product Industry:

CHEMICAL & CHEMICAL PRODUCT INDUSTRY	Emission Elasticity of Output	TFPG	$TFPG^c$
1980/81	0.0034	0.0273	0.0180
1981/82	0.00358	0.0281	0.0190
1982/83	0.00344	0.0241	0.0220
1983/84	0.00401	0.0208	0.0220
1984/85	0.004	0.0221	0.0280
1985/86	0.00619	0.0242	0.0230
1986/87	0.00475	0.0220	0.0250
1987/88	0.00363	0.0158	0.0220
1988/89	0.02802	0.0114	0.0190
1989/90	0.00354	0.0136	0.0170
1990/91	0.00335	0.0127	0.0160
1991/92	0.01226	0.0180	0.0170
1992/93	0.00328	0.0154	0.0180
1993/94	0.00384	0.0142	0.0220
1994/95	0.00333	0.0199	0.0310
1995/96	0.00696	0.0178	0.0320
1996/97	0.00768	0.0189	0.0330
1997/98	0.00355	0.0194	0.0360
1998/99	0.00326	0.0169	0.0290
1999/2000	0.00417	0.0230	0.0310
2000/01	0.00366	0.0227	0.0330
2001/02	0.00727	0.0180	0.0380
2002/03	0.00483	0.0217	0.0330
2003/04	0.00359	0.0278	0.0401
2004/05	0.03546	0.0183	0.0360
2005/06	0.0355	0.0254	0.0270
2006/07	0.04022	0.0193	0.0440
2007/08	0.03605	0.0121	0.0410
2008/09	0.03545	0.0094	0.0490
2009/10	0.03764	0.0075	0.0310
2010/11	0.034	0.0086	0.0390
Overall period	**0.013**	**0.0186**	**0.0287**
Pre-reform	**0.007**	**0.0200**	**0.0207**
Post-reform	**0.016**	**0.0177**	**0.0338**

Table 3.4 shows the impact of pollution, as measured by CO_2 emissions, on TFPG for the Chemical & Chemical Product Industry. We construct a TFP growth index by subtracting the weighted growth of physical capital and labour inputs, from the output growth, using the observed income shares of physical capital and

labour as the weights. The TFP index based on the observable data allows us to estimate the contribution of each input. We then examine the relationship between TFP growth and pollution using our model that allows us to directly estimate the elasticity of pollution.

Our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that pollution affects TFP growth negatively. Average pollution elasticity of 0.013. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 1.3%.Inaddition pollution contributes on average about 1.0 % to the total factor productivitygrowth. This implies that the use of the environment approximated by CO_2 emissions, which is an unpaid factor, contributes to the growth of output along with physical capital and labour and its contribution should be accounted for in TFPG measurements. This result can be interpreted as an indication that total use of resources, including the "unpaid"environment properly valued, exceeds the total factor productivity growth generated by conventional inputs. In this case development that uses "unpaid" factors may be considered as unsustainable.

3.5. Estimates of Emission Elasticity of Output Growth, Conventional TFPG and TFPG by considering CO_2 as an input of Production ($TFPG^c$) for Iron & Steel Industry:

IRON & STEEL INDUSTRY	Emission Elasticity of Output	TFPG	$TFPG^c$
1980/81	0.04202	0.0174	0.018277
1981/82	0.0421	0.0170	0.017841
1982/83	0.04146	0.0197	0.020548
1983/84	0.01575	0.0191	0.01941
1984/85	0.04202	0.0166	0.017522
1985/86	0.03945	0.0176	0.018462
1986/87	0.04074	0.0181	0.01897
1987/88	0.04203	0.0192	0.020072
1988/89	0.03254	0.0183	0.01899
1989/90	0.04161	0.0200	0.020889
1990/91	0.04204	0.0210	0.021835
1991/92	0.03513	0.0161	0.016804
1992/93	0.03384	0.0161	0.01686
1993/94	0.04109	0.0163	0.017193
1994/95	0.04211	0.0161	0.017
1995/96	0.0396	0.0163	0.017106
1996/97	0.0411	0.0161	0.016915
1997/98	0.04203	0.0161	0.017014
1998/99	0.04196	0.0159	0.016789
1999/2000	0.04066	0.0161	0.016926
2000/01	0.04184	0.0170	0.017889
2001/02	0.0375	0.0158	0.016561
2002/03	0.04155	0.0159	0.016815
2003/04	0.042	0.0158	0.016722
2004/05	0.04082	0.0163	0.017131
2005/06	0.0421	0.0162	0.017079
2006/07	0.03793	0.0170	0.01781
2007/08	0.03463	0.0171	0.01781
2008/09	0.04173	0.0164	0.017253
2009/10	0.04178	0.0173	0.018166
2010/11	0.04481	0.0170	0.017947
Overall period	**0.039547**	**0.017124**	**0.017955**
Pre-reform	**0.038074**	**0.018335**	**0.019135**
Post-reform	**0.040478**	**0.01636**	**0.01721**

Table 3.5 shows the impact of pollution, as measured by CO_2 emissions, on TFPG for the Iron & Steel Industry. We construct a TFP growth index by subtracting the weighted growth of physical capital and labour inputs, from the output growth, using the observed income shares of physical capital and labour as the weights.

The TFP index based on the observable data allows us to estimate the contribution of each input. We then examine the relationship between TFP growth and pollution using our model that allows us to directly estimate the elasticity of pollution.

Our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that the pollution affects TFP growth negatively. Average pollution elasticity of 0.03945. This implies that in the case of CO_2, 1% increase in emissions increases the average output by 3.95%. In addition pollution contributes on average about 0.08% to the total factor productivity growth. As seen in table 3.5, the adjustment for the externality adjusted TFPG exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative. This result suggests that, if the externality associated with energy use is incorporated in our model, then the part of output growth attributed to technological change may reduce to some extent the increase in TFPG due to output growth.

3.6. Estimates of Emission Elasticity of Output Growth, Conventional TFPG and TFPG by considering CO_2 as an input of Production ($TFPG^c$) for Cement Industry:

CEMENT INDUSTRY	Emission Elasticity of Output	TFPG	$TFPG^c$
1980/81	0.005357	0.019109	0.016987
1981/82	0.005502	0.018200	0.016353
1982/83	0.005392	0.017795	0.017084
1983/84	0.005411	0.016858	0.016684
1984/85	0.005821	0.015589	0.016087
1985/86	0.007342	0.018104	0.017689
1986/87	0.006616	0.016776	0.016962
1987/88	0.005535	0.016103	0.017585
1988/89	0.009723	0.012995	0.014943
1989/90	0.00548	0.014453	0.015226
1990/91	0.005544	0.01386	0.01453
1991/92	0.01149	0.014607	0.013788
1992/93	0.005203	0.013271	0.013471
1993/94	0.0057	0.015411	0.017651
1994/95	0.005405	0.016715	0.01848
1995/96	0.007288	0.01579	0.017988
1996/97	0.007574	0.018207	0.02123
1997/98	0.005642	0.018575	0.021976
1998/99	0.005544	0.017703	0.020881
1999/2000	0.005923	0.019124	0.020705
2000/01	0.005569	0.018972	0.020819
2001/02	0.007383	0.017438	0.021077
2002/03	0.006339	0.018841	0.021097
2003/04	0.005516	0.020789	0.022809
2004/05	0.038871	0.019952	0.0224
2005/06	0.039611	0.022298	0.021113
2006/07	0.039926	0.018588	0.017954
2007/08	0.037059	0.015549	0.017567
2008/09	0.039477	0.011934	0.008247
2009/10	0.035822	0.012441	0.01889
2010/11	0.037831	0.013576	0.019986
Overall period	**0.013577**	**0.016762**	**0.018008**
Pre-reform	**0.006157**	**0.016349**	**0.016375**
Post-reform	**0.017659**	**0.016989**	**0.018906**

Table 3.6 shows the impact of pollution, as measured by CO_2 emissions, on TFPG for the Cement Industry. We construct a TFP growth index by subtracting the weighted growth of physical capital and labour inputs, from the output growth, using the observed income shares of physical capital and labour as the weights.

The TFP index based on the observable data allows us to estimate the contribution of each input. We then examine the relationship between TFP growth and pollution using our model that allows us to directly estimate the elasticity of pollution.

Our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that the pollution affects TFP growth negatively. Average pollution elasticity of 0.013577. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 1.36%.Inaddition pollution contributes on average about 0.13% to the total factor productivity growth. This implies that the use of the environment approximated by CO_2 emissions, which is an unpaid factor, contributes to the growth of output along with physical capital and labour and its contribution should be accounted for in TFPG measurements. As seen in table 3.6, the adjustment for the externality exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative. This result suggests that, if the externality associated with energy use is internalized then the part of output growth attributed to technological change put it differently the positive contributions of technological change to output growth has been counter balanced by the negative externality generated in the process of output growth during the period.

3.7. Estimates of Emission Elasticity of Output Growth, Conventional TFPG and TFPG by considering CO_2 as an input of Production ($TFPG^c$) for Aluminium Industry:

ALUMINIUM INDUSTRY	Emission Elasticity of Output	TFPG	$TFPG^c$
1980/81	0.017169	0.01747	0.019296
1981/82	0.017244	0.016467	0.018234
1982/83	0.016997	0.016865	0.01913
1983/84	0.008434	0.016286	0.018464
1984/85	0.017327	0.014563	0.016974
1985/86	0.017101	0.016835	0.019185
1986/87	0.017312	0.015892	0.01833
1987/88	0.017228	0.016468	0.019524
1988/89	0.015464	0.014198	0.017023
1989/90	0.01708	0.015451	0.018088
1990/91	0.017385	0.01532	0.017844
1991/92	0.017747	0.014036	0.015589
1992/93	0.014391	0.013157	0.015182
1993/94	0.016977	0.01587	0.019134
1994/95	0.017282	0.015905	0.01898
1995/96	0.017003	0.015297	0.018427
1996/97	0.017605	0.018136	0.02201
1997/98	0.017364	0.018525	0.022619
1998/99	0.017418	0.018234	0.022164
1999/2000	0.016904	0.018241	0.021584
2000/01	0.017183	0.018024	0.021459
2001/02	0.016338	0.017346	0.021318
2002/03	0.01734	0.018214	0.021845
2003/04	0.017219	0.019596	0.023346
2004/05	0.04018	0.021784	0.023177
2005/06	0.041234	0.022799	0.022883
2006/07	0.039892	0.018429	0.018055
2007/08	0.037593	0.017316	0.017809
2008/09	0.041062	0.013411	0.011118
2009/10	0.035894	0.01658	0.019565
2010/11	0.039637	0.017459	0.020117
Overall period	**0.021774**	**0.016909**	**0.019306**
Pre-reform	**0.016249**	**0.015983**	**0.018372**
Post-reform	**0.024813**	**0.017418**	**0.019819**

Table 3.6 shows the impact of pollution, as measured by CO_2 emissions, on TFPG for the Aluminium Industry. We construct a TFP growth index by subtracting the weighted growth of physical capital and labour inputs, from the output growth, using the observed income shares of physical capital and labour as the weights.

The TFP index based on the observable data allows us to estimate the contribution of each input. We then examine the relationship between TFP growth and pollution using our model that allows us to directly estimate the elasticity of pollution.

Our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that the pollution affects TFP growth negatively. Average pollution elasticity of 0.021774. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 2.18%. In addition pollution contributes on average about 0.26% to the total factor productivity growth. As seen in table 3.7, the adjustment for the externality exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative. This result suggests that, if the externality associated with energy use is internalized then the part of output growth attributed to technological change, put it differently, the positive contributions of technological change to output growth has been counterbalanced by the negative externality generated in the process of output growth during the study period.

3.8. Estimates of Emission Elasticity of Output Growth, Conventional TFPG and TFPG by considering CO_2 as an input of Production ($TFPG^c$) for fertilizer Industry:

FERTILIZER INDUSTRY	Emission Elasticity of Output	TFPG	$TFPG^c$
1980/81	0.003765	0.0216	0.019844
1981/82	0.003855	0.02115	0.019424
1982/83	0.00379	0.0186	0.020563
1983/84	0.004075	0.01685	0.020443
1984/85	0.00407	0.0168	0.023203
1985/86	0.00535	0.0195	0.022139
1986/87	0.004665	0.0174	0.02213
1987/88	0.003875	0.01495	0.021166
1988/89	0.016075	0.01135	0.017684
1989/90	0.003845	0.01275	0.016842
1990/91	0.00396	0.0119	0.015712
1991/92	0.00944	0.0147	0.016246
1992/93	0.003705	0.01275	0.016364
1993/94	0.00399	0.01505	0.022243
1994/95	0.00383	0.0174	0.02702
1995/96	0.00554	0.0158	0.026986
1996/97	0.00591	0.0195	0.031363
1997/98	0.003985	0.02015	0.03361
1998/99	0.004005	0.019	0.02949
1999/2000	0.00415	0.02125	0.029804
2000/01	0.0039	0.0204	0.030163
2001/02	0.0057	0.0184	0.033584
2002/03	0.00448	0.0208	0.031244
2003/04	0.003865	0.025	0.036883
2004/05	0.038155	0.0237	0.034158
2005/06	0.038745	0.02765	0.029101
2006/07	0.04102	0.0195	0.033202
2007/08	0.03857	0.0157	0.031249
2008/09	0.038715	0.01065	0.031502
2009/10	0.03386	0.01375	0.02699
2010/11	0.035135	0.0152	0.032128
Overall period	**0.012388**	**0.017716**	**0.025887**
Pre-reform	**0.005211**	**0.016623**	**0.019923**
Post-reform	**0.016335**	**0.018318**	**0.029167**

Table 3.8 shows the impact of pollution, as measured by CO_2 emissions, on TFPG for the Fertilizer Industry. We construct a TFP growth index by subtracting the weighted growth of physical capital and labour inputs, from the output growth, using the observed income shares of physical capital and labour as the weights.

The TFP index based on the observable data allows us to estimate the contribution of each input. We then examine the relationship between TFP growth and pollution using our model that allows us to directly estimate the elasticity of pollution.

Our results indicate that there exists a robust linear relationship between pollution and TFP growth. Wefind that the pollution affect TFP growth negatively. Average pollution elasticity of 0.012388. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 1.34%.Inaddition pollution contributes on average about 0.8171% to the total factor productivitygrowth. As seen in table 3.8, the adjustment for the externality exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative. This result suggests that, if the externality associated with energy use is internalized then the part of output growth attributed to technological changeput it differently the positive contributions of technological change to output growth has been counterbalanced by the negative externalitygenerated in the process of output growth during the period.

Chapter 4

Major findings, Conclusions and Policy Recommendations of our Study

In this study, we have tried to estimate energy intensity, capacity utilization, CO_2 emission and its impact on total factor productivity growth of the six major energy intensive industries in India over the period from 1980-81 to 2010-11. The six major energy intensive industries taken up for our study are: Paper and Paper product industry, Chemical and Chemical Product industry, Iron and Steel industry, Cement industry, Aluminium industry and Fertilizer industry.

From the above analysis, the major findings and conclusions thereof may be summarized as follows:

i) For paper and paper product industry the energy intensity in the pre-reform period is 14.98 and in the post-reform period it is 14.46. When we look at the Chemical and Chemical Product industry the energy intensity in the pre-reform period is 10.4 and in the post-reform period it is 8.23. In case of Indian Iron & Steel Industry the energy intensity in the pre-reform period is 12.565 and in the post-reform period it is 12.213.So far as, the Indian Cement Industry is concerned, we observe an increase in the energy intensity from pre to post reform period, as,in the pre-reform period, the energy intensity of the Indian Cement industry was 14.213 whereas in the post-reform periods it is 15.931. Now, for both the Indian Aluminum Industry and Fertilizer industry we find a fall in energy intensity from pre to post-reform period.Thus, it may be said that the energy intensity for these industries except Indian Cement industry, have declined in the post-reform period and thus, we can say that it may be due to the use of modern technology in the production process.

ii) Secondly, the trend growth rate of energy intensity for paper and paper product industry in the pre reform period is 4.7% and it has sharply declined in the post-reform period to -1.6%.

iii) The trend growth rate of energy intensity in chemical & Chemicals product industry in the pre reform period is 9% where as it has sharply declined in the post-reform period to -17.4

iv) The trend growth rate of energy intensity in the Iron & Steel Industry in the pre reform period is -7.7% and we notice a sharp increasing trend in the post-reform period (6.1%).

v) The trend growth rate of energy intensity in the Cement Industry in the pre reform period is 4.24% and we notice a sharp falling trend in the post-reform period (3.56%).

vi) The trend growth rate of energy intensity in the Aluminum Industry in the pre-reform period is -1.7% and we notice a sharp increasing trend in the post-reform period and it is 8.5%.

vii) The trend growth rate of energy intensity in the Fertilizer Industry in the pre reform period is 3.2% and we notice a sharpdecreasing trend in the post-reform period as the growth rate becomes -1.6%.

viii) The discussion on the trend growth rate of energy intensity suggests that the use of new energy efficient technologies in the production process in the post reform period may cause the above scenario as discussed earlier.

ix) For two years, the Economic Capacity Utilization turns out to be greater than unity. This is due to the fact that at times, due to drastic increase in demand for the product and to maintain the goodwill, the industry or a firm may continue production at the right side of the minimum point of short-run average cost curve (SAC).

x) From our analysis, we find that all the industries have experienced a slowdown in their level of capacity utilization when we move from pre to post-reform period.

xi) Our study, also tries to assess the impact of pollution, as measured by CO_2 emissions, on TFPG of the Paper & Paper Product Industry. Our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that the pollution affect positively the TFP growth. Average pollution elasticity of 0.012198. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 1.22%. In addition pollution contributes on average about 0.4% to the total factor productivity growth. This implies that the use of the environment approximated by CO_2 emissions, which is an unpaid factor, contributes to the growth of output along with physical capital and labour and its contribution should be accounted for in TFPG measurements. Therefore, we may say that the usage of energy efficient machineries in this industry is sustainable for further growth in output.

xii) For the Indian Chemical and Chemical Products industry, our results indicate that there exists a robust linear relationship between pollution and TFP growth. We find that pollution affects TFP growth negatively. Average pollution elasticity of 0.013. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 1.3%.Inaddition pollution contributes on average about 1.0 % to the total factor productivity growth.

xiii) For the Indian Iron & Steel industry, we also find that the pollution affects TFP growth negatively. Average pollution elasticity of 0.03945. This implies that in the case of CO_2, 1% increase in emissions increases the average output by 3.95%. In addition pollution contributes on average about 0.08% to the total factor productivity growth. As seen in table 3.5, the adjustment for the externality exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative.

xiv) From our study, we find that the pollution affect negatively the TFP growth of the Indian Cement Industry. Average pollution elasticity of 0.013577. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 1.36%.Inaddition pollution contributes on average about 0.13% to the total factor productivitygrowth. This implies that the use of the environment approximated by CO_2 emissions, which is an unpaid factor, contributes to the growth of output along with physical capital and labour and its contribution should be accounted for in TFPG measurements.

xv) For the Indian Aluminum industry, we find that the pollution effect negatively on TFP growth. Average pollution elasticity of 0.021774. This implies that in the case of CO_2, 1% increase in emissions increases on average output by 2.18%.Inaddition pollution contributes on average about 0.26% to the total factor productivitygrowth. As seen in table 3.7, the adjustment for the externality exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative.

xvi) In case of Indian Fertilizer industry, the pollution effect negatively on TFP growth. Average pollution elasticity of 0.012388. This implies that in the case of C_{O2}, 1% increase in emissions increases on average output by 1.34%. In addition pollution contributes on average about 0.8171% to the total factor productivity growth.

xvii) For the negative impact of CO_2 emission on TFP may be referred as the situation where the adjustment for the externality exceeds the traditional TFPG estimate and therefore the overall externality adjusted TFPG is negative. These result suggests that, if the externality associated with energy use is internalized then the part of output growth attributed to technological change put it differently the positive contributions of technological change to output growth has been counterbalanced by the negative externality generated in the process of output growth during the period.

xviii) Thus, we can say that, the industries that are taken up in our study, except Paper and Paper Products industry, may use energy efficient technologies in their production process but they are still lagging in the imposing of technologies which are both energy efficient as well as environmental friendly.

In 1990, industrial activities accounted for 45% of CO_2 emission from fossil fuel combustion, having the largest share in energy consumption. The major energy-intensive industries in India are Paper and Paper Product industry, Chemical & Chemical Product industry, Iron and Steel industry, Aluminium industry, Cement industry and Fertilizer industry.

The various methods for reducing energy consumption and CO_2 emissions for particular major energy intensive industries in India are summarized in Table 4.1.

Table 4.1: Measures for the reduction of energy consumption as well as CO_2 emissions in the most energy-intensive industries in India

Paper and paper Product Industry	Recycling Improved energy and emission efficiency
Chemical & Chemical Product industry	Innovative production technologies for the reduction of energy requirements for chemical transformations Product innovations: products that reduce the use of or replace the currently used raw materials—natural gas and petroleum; material substitution Innovations in recycling technologies (especially for plastics) Standardization (especially for plastics)
Iron and Steel industry	Use of more efficient production technologies (e.g. electric arc furnaces) Innovative production technologies (e.g. changing the source of carbon from coal to chemical organic wastes or tires) Improved energy efficiency (heat recovery and use for processes with lower heat demand) Recycling intermediate and end products; material substitution
Aluminum industry	Recycling—may lead to 8 to 10 times less energy consumption
Cement industry	Use of more efficient production technologies already available (e.g. dry-process kilns for cement production) Innovations in production technologies (especially needed for cement and cement-brick production) Product innovations (lighter materials to reduce transport related energy consumption; material substitution; new materials) Inter-industry recycling and material substitution
Fertilizer industry	Technological innovations in the fields of food production via non-chemical intensive fertilizers Energy management systems and improved energy-efficiency

In general, the major policy prescription for reducing energy consumption and hence CO_2 emissions for the Indian energy intensive industries may be given as:

- Replacement of production technologies by more efficient ones already technically available
- Product innovations and production technology innovations
- Energy management systems for minimization of energy losses and energy efficiency improvements through heat recovery and re-use
- Recycling of intermediate or end-use products, and material substitution
- Reduction of carbon intensity of energy fuels and production
- Reduction of energy intensity of industrial and transport activities, as well as of end-use technologies and appliances in the residential/commercial sector
- Reduction of demand for energy and transport services
- Control of population growth
- Limit to economic growth

References:

Antweiler, W., Copeland, B. R., and Taylor, M. S. (2001). Is Free Trade Good for the Environment? American Economic Review 91(4): 877-908.

Arellano, M., and Bond, S. (1991). Some test of specification for panel data: Monte Carlo evidence and an application to employment equations. Review of economic Studies 58: 277-297. .

Bandyopadhyay, S., and Shafik, N. (1992). Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence. Background Paper for the World Development Report 1992, World Bank, Washington, DC.

Castañeda, B. E. (1999). An index of sustainable economic welfare (ISEW) for Chile. Ecological Economics, 28: 231-244.

Cavlovic, T. A., Baker, K.H., Berrens, R.P., and Gawande, K. (2000).A Meta-Analysis of Environmental Kuznets Curve Studies. Agricultural and Resource Economics Review, 29(1): 32-42.

Chichilnisky, G. (1994). North-South Trade and the Global Environment. American Economic Review, 84(3): 851-74.

Cole, M. A. (2004). Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. Ecological Economics, 48: 71- 81.

Cole, M. A. (2003). Development, trade, and the environment: how robust is the Environmental Kuznets Curve? Environment and Development Economics, 8: 557-580, Cambridge, MA.

Copeland, B. R., and Taylor, M. S. (2004). Trade, Growth, and the Environment. Journal of Economic Literature, 42(1): 7-71.

Copeland, B. R., and Taylor, M. S. (1995). Trade and Transboundary Pollution. American Economic Review, 85(4): 716-37.

Costantini, V., and Martin, C. (2007).A Modified Environmental Kuznets Curve for Sustainable Development Assessment Using Panel Data.FEEMFondazioneEni Enrico Mattei Working Paper Series, No. 107, Milan.

Dasgupta, P., Laplantem B., Wang H., and Wheeler D. (2002).Confronting the environmental Kuznets curve. Journal of Economic Perspectives, 16(1): 147-168.

Driscoll, J. C., and Kraay, A. C. (1998).Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data. Review of Economics and Statistics, 80: 549-560.

Gale, L. R., and Mendez, J. A. (1998).The Empirical Relationship between Trade, Growth and the Environment. International Review of Economics and Finance, 7(1): 53-61.

Grossman, G. M., and Krueger, A. B. (1993).Environmental Impacts of the North American Free Trade Agreement. In: The U.S.-Mexico Free Trade Agreement, P. Garber. Massachusetts Institute of Technology, The MIT Press, Cambridge, MA., pp. 13-56.

Grossman, G. M., and Krueger, A. B. (1995).Economic Growth and the Environment. Quarterly Journal of Economics, 110(2): 353-77.

Hamilton, K. (2000). Genuine Saving as a Sustainability Indicator. World Bank Environment Department Papers, No. 77, Environmental Economics Series, World Bank, Washington, DC.

Hartwick, J. M. (1977). Intergenerational Equity and the Investing of Rents from Exhaustible Resources. American Economic Review 67: 972-974.

Mani, M., and Wheeler, D. (1998).In Search of Pollution Havens? Dirty Industry in the World Economy, 1960-1995. Journal of Environment and Development, 7(3): 215-247.

Organisation for Economic Co-operation and Development (OECD) (1995).Foreign direct Investment, Trade and Employment. OECD, Paris.

Pearce, D. W., and Atkinson, G. (1993). Capital Theory and the Measurement of Sustainable Development: An Indicator of Weak Sustainability. Ecological Economics, 8: 103-108.

Pethig, R. (1976). Pollution, Welfare and Environmental Policy in the Theory of Comparative Advantage. Journal of Environmental Economics and Management, 2: 160-69.

Rauscher, M. (1991).National Environmental Policies and the Effects of Economic Integration. European Journal of Political Economy, 7: 313-29.

Selden, T. M., and Song, D. (1994). Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions? Journal of Environmental Economics and management, 27: 147-62.

Shafik, N. (1994). Economic Development and Environmental Quality: an econometric analysis. Oxford Economic Papers, No. 46: 757-773.

Stern, D. I., and Common, M. S. (2001). Is There an Environmental Kuznets Curve for Sulfur? Journal of Environmental Economics and Management, 41(2):162-78.

Suri, V., and Chapman, D. (1998). Economic growth, trade and the energy: Implications for the environmental Kuznets curve. Ecological Economics, 25: 195-208.

United Nations Environment Programme (UNEP) (2008). UNEP Geodata Portal, http://geodata.grid.unep.ch/, access 07.01.08, 18:07.

United Nations Environment Programme (UNEP) (2007). Global Environment Outlook-4: Environment and Development. GEO Yearbook, United Nations Environment Programme, Nairobi.

United Nations Environment Programme (UNEP) (2001). Economic Reforms, Trade Liberalization and the Environment: A Synthesis of UNEP Country

Projects. Synthesis Report, United Nations Environment Programme, Division of Technology, Industry and Economics Economics and Trade Unit, Geneva.

United Nations Environment Programme (UNEP) (1999). Trade Liberalisation and the Environment: Lessons learned from Bangladesh, Chile, India, Philippines, Romania and Uganda - A Synthesis Report. United Nations Environment Programme, New York and Geneva.

Vincent, J. R. (1997). Testing for environmental Kuznets curves within a developing country. Environment and Development Economics, 2: 417-431, Cambridge, MA.

Wagner, G. (2007). Energy Content of World Trade.Mimeo, Harvard University.

World Bank (2008a).Country Groups.http://go.worldbank.org/D7SN0B8YU0; access 10/02/2008, 10:47.

World Bank (2008b).Regional and Income Group Results for ANS. http://go.worldbank.org/U4645U1WI0 and http://go.worldbank.org/OQ35BMJ5A1, access 13/01/2008, 09:12.

World Bank (2007).World Development Indicators 2007. On DVD, Development Data Group, World Bank, Washington, DC.

World Bank (2001). Is Globalization Causing A 'Race To The Bottom' In Environmental Standards? World Bank Briefing Paper, Part four: Assessing Globalization, Economic Policy Group and Development Economics Group, World Bank, Washington, DC.