

Energy Use Behaviour of Manufacturing Industries in India: An Analysis Using KLEMS Framework

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Abstract

This paper analyses the input use behaviour of seven energy intensive manufacturing industries in India with special focus on the pattern of energy use based on official data published in the Annual Survey of Industries. Non-ferrous metal, Cement, Chemical, Fertilizer, Iron and Steel, Pulp and Paper, and Textile are the industries under consideration. The period of analysis is 2000-01 – 2011-12. The methodology is based on growth accounting and estimation of Translog cost function with single output and five inputs (capital (k), labour (l), energy (e), material (m) and services (s)). Growth accounting reveals if ‘service’ as an input is not included in the model the magnitude of technological progress generally tends to be overestimated. So, availability of appropriate official data on ‘service’ input is important. The parametric model suggests that the autonomous technological progress is majorly ‘energy-saving’ in nature except fertilizer and pesticide industry. However, material-using bias remains an issue of concern. Own price elasticity estimates of energy input suggest that increase in energy price may lead to decrease in physical energy demand in most of these industries but the magnitude of response may not be high.

1. Introduction

1.1 Technological progress and change in input mix are two important drivers of sustainable energy use and related emission mitigation for industries (IPCC, 2005; Bernstein, et al., 2007). In India, seven manufacturing industries with highest energy intensity faced enhanced energy efficiency targets under the first phase of the policy Perform Achieve and Trade (PAT). The present paper analyses the energy demand behaviour of similar industries as covered under PAT with a focus on the role of technological progress and response of these industries to change in energy price. This is a follow-up exercise of Dasgupta and Roy (2015) and contributes to the existing literature by adopting a more comprehensive framework through introducing ‘service’ input in the analysis which is rare, especially in the context of India. This paper covers seven energy intensive manufacturing industries in India, namely, non-ferrous metal, cement, chemical, fertilizer, iron and steel, pulp and paper and textile and the period of analysis is 2000-01 – 2011-12. The aim is to address two questions: First, what is the contribution of input growth vis-a-vis technological progress to the growth in output in these industries, especially after the ‘service’ input is introduced in the model? Second, how is energy intensity correlated with technological progress? The rest of the paper is divided in three sections: Section 2 gives a detailed description of the methodological framework, the variables constructed and the source of data. Section 3 presents the results and discusses the same. Conclusion and policy implications are presented in Section 4.

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2. Methodological Framework

The methodological framework followed in this paper is based on the neoclassical theory of producers' behaviour which analyses the response of cost minimizing industries (Berndt & Wood, 1975, 1979; Blackorby & Russell, 1976; Jorgenson, 1991). In existing literature, broadly three methods are adopted to measure total factor productivity growth (TFPG): Growth Accounting, Parametric Approach and Non-parametric Approach. While all of them have advantages and disadvantages, the selection of methodology depends largely on the purpose of the study and availability of data. In the present study as we aim to understand the industry level responses, we use the growth accounting and parametric framework. We first analyse the TFPG to understand the contribution of exogenous technological progress to output growth based on a single output and five-input (capital (k), labour (l), energy (e), material (m) and services (s)) model (*klems*, hereafter). The nature of technological progress and price induced behavioural responses are then analysed based on estimated parameters of the cost functions with similar input and output combination.

2.1 Growth Accounting

2.1.1 The neoclassical theory of growth suggests that exogenous technological progress leads to enhanced input productivity in the long-run (Stiroh, 2001). Solow (1957), followed by Denison (1974, 1985) formulated productivity measures in the context of production function and used the growth accounting framework. 'Growth accounting' decomposes growth in output in terms of growth in inputs and a residual. The residual is attributed to growth in productivity of the input mix arising due to technological progress. Indices of productivity growth, derived in this manner, differ from each other as the underlying production function or the aggregation schemes vary. Kendrick Index, Solow Index and Translog Index are commonly used in accounting productivity growth. In the present study we use the Translog Index as it has certain advantages over both Kendrick Index, as well as Solow Index. Translog Index is the discrete approximation of Divisia Index based on Translog production function. It is symmetric in data of different time periods and also closely satisfies the factor reversal test. The underlying production function is Translog in nature and hence flexible in the sense that it assumes variable elasticity of substitution and does not put forward any binding assumption of Hicks-neutrality unlike Kendrick and Solow Index (Mongia & Sathaye, 1998).

2.1.2 We assume the Translog production function with single output (Y) and five inputs: capital (K), labour (L), energy (E), material (M) and services (S). The price of output is given exogenously in the model. The production function is assumed to be continuous, twice differentiable, positive, concave and homogenous of degree one – i.e. the production function exhibits constant returns to scale. Based on this the Translog Index, TFPG is derived as:

$$\ln \left[\frac{A_{t+1}}{A_t} \right] = \ln \left[\frac{Y_{t+1}}{Y_t} \right] - \left[\sum_i \frac{(M_{it+1} + M_{it})}{2} * \ln \left(\frac{X_{it+1}}{X_{it}} \right) \right] \quad i = k, l, e, m, s \quad \dots\dots (1)$$

Where Y is the output, X_i is the i^{th} input and A is the index of the state of the technology. The rate of technological change is represented as the difference between output growth and input growth, weighted by their respective cost shares (M_i). 't' as a subscript represents the time.

2.1.3 While productivity growth has been vastly used to understand the role of technological progress in the context of Indian industries (both aggregate and sectoral), other than Banga and Goldar (2007), there is rarely any study that is based on the *klems* model. Since the growth of service sector has become phenomenal in the post-reform period, it becomes important to incorporate service input to understand the actual contribution of technological progress. If growth of service input has considerable contribution to growth in output, then omission of service input will lead to inflated values of the contribution of technological progress.

2.2 Estimation of Parametric Cost Function:

2.2.1 TFPG, however, does not provide insights of the nature of technological progress with respect to any specific input, possibility of inter-factor substitution and price induced behavioral responses. For that we estimate the Translog cost function with similar input and output combination. We assume the production function:

$$Y = Af(X_k, X_l, X_e, X_m, X_s, t) \quad \text{.....(2)}$$

f is at least quasi-concave and homothetic to satisfy all the regularity conditions. A time variable is included to estimate the autonomous technological progress and changes in input use behaviour as a result of change in the state of the technology. Under the assumption of well behavedness of the production function, a dual cost function exists and total cost function (C) can be expressed in terms of a unit cost (G) which is a function of the price of inputs and the time trend.

$$C = Y \cdot G(P_k, P_l, P_e, P_m, P_s, t) \quad \text{.....(3)}$$

Under Translog specifications, we have

$$\ln G = \ln \alpha_0 + \sum_i \alpha_i \ln P_i + \alpha_v t + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln P_i \ln P_j + \sum_i \beta_{it} \ln P_i t + \frac{1}{2} \beta_{vt} t^2, i, j = k, l, e, m, s$$

Where,

$$(i) \sum_i \alpha_i = 1$$

$$(ii) \sum_i \beta_{ij} = \sum_j \beta_{ji} = 0, i \neq j$$

$$(iii) \sum_i \beta_{it} = 0$$

$$(iv) \beta_{ij} = \beta_{ji} \forall i \neq j$$

$$(v) \beta_{it} = \beta_{ti} \forall i$$

Given linear homogeneity of price function, the parametric restrictions (i) – (iii) and given the share elasticity and productivity growth bias to be symmetric (iv) – (v) are valid.

According to Shephard's Lemma $\frac{\delta G}{\delta P_i} = X_i$ and we write

$$\frac{\partial \ln G}{\partial \ln P_i} = \frac{\delta G/G}{\delta P_i/P_i} = \frac{\delta G P_i}{\delta P_i G} = \frac{X_i P_i}{G} = \frac{X_i P_i}{\sum_j X_j P_j} = \text{cost share of input } i = M_i, ,$$

$$i,j=k,l,e,m,s \quad \dots\dots\dots(4)$$

Therefore, given Translog specification the share equation for input i is

$$M_i = \alpha_i + \sum_j \beta_{ij} \ln P_j + \beta_{it} t \quad i,j=k,l,e,m,s \quad \dots\dots\dots(5)$$

The rate of change in total factor productivity (v) is the negative of the rate of change in unit cost i.e.

$$-v = \frac{\delta \ln G}{\delta t} = \alpha_v + \sum_i \beta_{it} \ln P_i + \beta_{vt} t, i,j=k,l,e,m,s \quad \dots\dots\dots(6)$$

2.2.2 Therefore, the system consists of five cost share equations for capital, labour, energy, material and service (the general form for input i being represented by equation 5) and the productivity growth equation (equation 6). Stochastic components are incorporated to obtain econometric specifications. The underlying assumption with respect to the stochastic error term is that there might be common yet unknown factors affecting the decision of the producer and, therefore, the choice of inputs. It is thus assumed that the errors of any two share equations will be correlated at a point of time. However, this correlation is only contemporaneous and does not hold over two periods of time. The covariance between the error terms represents the link between the seemingly unrelated regression equations and hence the model is estimated with the specifications of Zellner's Seemingly Unrelated Regression Equations (SURE). Further, given the fact that the cost shares will add up to 1, 'service' inputs are dropped arbitrarily to avoid singularity. To overcome bias in the parameters arising due to the arbitrarily deleted cost share equations, Iterative Zellner's Efficient (IZEF) method has been followed using STATA 12.

2.3 Brief interpretation of parameters

2.3.1 In the productivity growth equation (Equation 6), the negative of the parameter β_{vt} represents rates of change in technological progress or input productivity holding input prices constant. The negative of α_v in the same equation represents the average of the rates of technological change.

2.3.2 To understand the energy use implications of technological progress, β_{et} in the cost share equation of energy input is the useful parameter. For $\beta_{et} < 0$, we conclude that there is decline in cost share of energy input over time and, therefore, technological change had an 'energy-saving bias'. Such a trend can be expected to contribute in achieving sustainable energy use targets. Had the value been positive it would have had 'energy-using bias'.

2.3.3 Estimated β_{ie} parameters of the cost share equations are linked to the elasticity of substitution and the own and cross price elasticity of inputs (see Dasgupta and Roy, 2015 for detailed derivation).

2.3.4 Given the productivity growth equation (Equation 6), the effect of change in energy price on technological progress is also captured through the parameter β_{et} . A negative β_{et} , given this equation, implies that an increase in energy price will induce further technological progress in industries. On the other hand if the parameter is positive it would imply that an increase in energy price will lead to retardation of overall technological progress, even if it encourages the producer to reduce energy use when the own price elasticity is negative.

2.3.5 Estimated parameters can be linked to the price elasticity parameters (see: Dasgupta and Roy 2015, Roy et al 1999). Own price elasticity (E_{ij}) reflects how industries adjust their input use behaviour when input price changes and allows us to come up with a magnitude of energy-saving in the industries associated with a rise in energy price. Early studies on price elasticity in the context of manufacturing industries in developed countries demonstrate that long term growth comes in the form of incremental changes over time and energy price plays an important role in changing the input use behaviour of industries (Berndt & Watkins, 1981; Jorgenson & Fraumeni, 1981; Hogan & Jorgenson, 1991). Cross price elasticity E_{ie} demonstrates the inter-factor relationship between energy and other inputs when there is a change in energy price. While $E_{ie} > 0$ implies that energy and i^{th} input are substitutes, $E_{ie} < 0$ implies that they are complements.

2.4 Coverage, Data and Variables

2.4.1 The study covers seven energy intensive manufacturing industries: non-ferrous metal, cement, chemical (without fertilizer and pesticide), fertilizer and pesticide, iron and steel, pulp and paper and textile over the period 2000-01 – 2011-12. The choice of the set of industries is guided by the coverage of PAT in its first phase and, therefore, is similar to Dasgupta and Roy (2015) with one exception: here ‘aluminium’ has been replaced by a broader group of industries ‘non-ferrous metal’ given the nature of available data. The industry codes used as per India’s National Industrial Classification (NIC) are presented in Table 1. Continuum is achieved using the Table of Concordance published along with the NIC.

2.4.2 Deflated values of ‘Total Output’, ‘Depreciation’ added to 10% of ‘Fixed Capital’ and ‘Total Emoluments’ in the ASI data series are used to construct the variables Output, Cost of Capital and Cost of Labour, respectively. These values are deflated using appropriate yearly wholesale price indices (WPI) published by the Office of Economic Advisor, Government of India. To arrive at an index of cost of material separately for each industry, from the input-output matrices of India (2007-08) major intermediate material inputs and their shares (in monetary terms) are identified. The ‘Material Cost’ as available in ASI is divided by the sum of prices of various components weighted by their share based on the input-output Table. Similarly the variable ‘Cost of Energy’ is constructed using the values of ‘Fuel Consumed’ in ASI and the shares of each fuel type in the input output matrix. Based on Banga and Goldar (2007), the cost towards service input is taken as difference between ‘Total input’ and the sum of ‘Fuel consumed’ and ‘Material Consumed’ as published in ASI. The prices of services for different years are arrived at based on the value added by different services sectors in current price and constant price. The input-output Table for the year 2007-08 is used to obtain the shares of different service inputs used in different industries to determine the weights of the prices.

2.4.3 At this point it is important to mention some limitations of the dataset that has been used for the analysis. First, in case of manufacturing industries the primary unit of enumeration in the ASI survey is a ‘factory’. All factories of the country are divided into two sectors – the census sector and the sample sector². Thus the exact composition of units present in the industry level aggregation is likely to vary from year to year. Besides, merger and splitting of units within an industry is one of the factors that determine the industry level output. In that case, further research may take into consideration data on unit level figures for production and other variables to come up with a more accurate time-series analysis. Second, in order to construct the variable for material cost and energy cost, the weight of different energy and material have been kept proportional to their share in production as per the Input-Output table for 2007-08. While this share is likely to vary from year to year, in absence of Input-Output tables for the rest of the years, we assume the same to be constant.

3. Results and Discussion

3.1 Contribution of Input Growth and Technological Progress in Output Growth

3.1.1 The growth accounting is carried out to understand the contribution of technological progress as represented by TFPG and the growth in input use in output growth. Dasgupta and Roy (2015) carried out a similar exercise for the period 1998-00-2011-12, but the model did not include ‘service’ as an input. Inclusion of service input in the current model renders interesting comparison between Dasgupta and Roy (2015) and the present study. Table 2 and Figure 1 represent the results obtained in the present study and Dasgupta and Roy (2015). It shows that the growths in output and inputs other than ‘service’ are comparable in these two studies; but the contribution of technological progress (as represented by TFPG) is lower in the present study. Moreover, inclusion of service input leads to negative TFPG in iron and steel sector. This is due the fact that for these industries, on an average, growth in service input contributed 16% of output growth – ranging from 34% in textile industry to 1% in cement industry. However, in case of chemical (without fertilizer and pesticide) and fertilizer and pesticide the technological progress has greater contribution even after inclusion of service input. In general, growth in material input is found to be the major source of output growth in all the industries.

3.1.2 An analysis of TFPG in relation with energy efficiency can bring out important insights on whether energy efficiency and productivity of other inputs have moved in the same direction or not (Cadot, et al., 2009). Table 3 summarized the correlation coefficients between the time series of TFPG and input intensity. While the annual TFPG for the year t represents the technological progress in the year t over $t-1$, the energy efficiency for year t represents the ratio of energy to output (both measured in monetary terms at constant prices). While a negative correlation between these two variables implies that the autonomous technological progress is accompanied by energy efficiency as represented by a declining E/Y , a positive correlation implies the opposite. In the present study, the said correlation coefficients are found to be positive, in general, but they are not very high. Iron and steel and pulp and paper are the two industries exhibiting relatively higher correlation

² According to the new sampling scheme adopted by ASI from 2012-13, ASI sample comprises two parts – Central Sample and State Sample. The Central Sample consists of two schemes: Census and Sample. Under Census scheme, all the units are surveyed.

between energy efficiency and TFPG while the magnitude is low in case of non-ferrous metal, chemical (without fertilizer and pesticide) and fertilizer and pesticide industries.

3.2 The Nature of Technological Progress and Input Use Behaviour

3.2.1 The econometric estimation of input cost share equations and the productivity growth equations lead to estimation of 189 parameters (27 parameters for each of the seven industries) (Table 4). Out of them, 131 are found to be statistically significant at 5% level. R^2 values of the estimated capital, labour, energy and material share equations and the productivity growth equation are respectively reported as $R^2(k)$, $R^2(l)$, $R^2(e)$, $R^2(m)$ and $R^2(t)$ in Table 4. This shows that out of 35 equations estimated, R^2 values are above 0.5 for 21 equations exhibiting overall goodness of fit. R^2 s are found to be low for productivity growth equations across industries. Also, negative R^2 value is observed for the fitted capital share in cement industry implying that the residual sum of squares of the model are greater than the respective total sum of squares and that the model predicts the dependent variable worse than a constant only model. Also, for monotonicity of the share equations, the positivity of the cost share is checked at each data point of each of the cost share equations and at the mean. For cement industry we also find violation of the assumption of monotonicity reflected in negative value of estimated α_s implying that the Translog specification may not be quite valid for this industry. So, for cement industry the analysis based on this model may not be quite appropriate. Concavity is tested at each data point by negative semi-definite Hessian matrices.

3.2.2 None of the estimated α_v parameters representing the average rate of technological change are found to be significant (Table 4). Significant negative estimates of β_{vt} are found for cement and chemical (excluding fertilizer and pesticide) industries suggesting acceleration in the rates of autonomous technological progress. R^2 values of the productivity growth equations are, however, not high in any of the cases. Low explanatory power of the productivity growth equation is also reported by Roy et. al, (1999). They argue that market imperfection and technology transfer might have roles to play in this.

3.2.3 The average cost shares exhibit unambiguous trends: among five inputs, the share of material remained the highest for all industries (Table 5 and Figure 2). Only for Cement industry the cost share of material input is somewhat comparable with the cost share of energy input. The cost share of energy input is higher than labour, capital and service inputs in all industries with the only exception in textile. In textile industry, the second highest input cost share is observed with respect to service input. The combined cost shares of energy and material inputs are always very high – the minimum being 68% in textile industry. However, the trends of industry-wise cost share shows that the labour as well as energy cost shares have declined over the past years. While the inclusion of service as an input reduces the cost shares for other inputs in an expected manner, the trend of high material and energy cost share as observed in Dasgupta and Roy (2015) remains unchanged.

3.2.4 Therefore, it is evident that energy intensive manufacturing industries in India are experiencing a positive trend in autonomous technological progress (as reflected in productivity growth) as well as declining trends of energy cost shares. Now, the movement of energy cost share can also be influenced by the trend of energy price. Therefore, from the perspective of physical quantity of energy use, the major question is whether this

autonomous technological advancement is energy saving in nature. This study finds that non-ferrous metal, cement, iron and steel, pulp and paper and textile industries – all of them exhibit significant energy-saving bias (negative significant estimate of β_{et}). This implies that the share of energy cost decreased as a proportion of total cost along with autonomous technological advancement, other things remaining constant. Adoption of several energy efficient technologies and measures by the industries during this period, especially after implementation of the Energy Conservation Act, 2001, could be a possible explanation for it (Dasgupta and Roy, 2015). However, fertilizer and pesticide industry is the only one exhibiting significant energy using bias. High feedstock use of energy (mostly in the form of natural gas) may act as an explanation for this. With respect to other inputs, non-ferrous metal and pulp and paper industry exhibit significant capital saving bias. There is an unambiguous labour saving bias of technological change across industries. Chemical (without fertilizer and pesticide), fertilizer and pesticide and pulp and paper industries exhibit significant material using bias of technological progress. High material cost shares along with material using bias of technological progress is something absolutely crucial as it may create a hindrance in the context of competitiveness of Indian manufacturing industries. Service-using/saving bias varied across industries: while chemical (without fertilizer and pesticide) and fertilizer and pesticide show service saving bias of technological progress, non-ferrous metal and iron and steel exhibits service using bias.

3.2.5 The estimates of own price elasticity of energy input (E_{ee}) along with the constant share elasticity are presented in Table 7. Negative own price elasticity for energy input has significant implications towards the role of energy price in managing energy use and emission in industries. We find one aberration in the own price elasticity value of energy input (textile industry), though not significant. The magnitude of own price elasticity is greater than 1 for non-ferrous metal, chemical (without fertilizer and pesticide) and pulp and paper industries and are quite low in iron and steel industry. Inelastic energy demand with respect to its own price, especially in the short run, is not uncommon in the context of industries in developing countries (Kim and Labys 1988; Mahmud, 2000; Roy, 2000; Goldar, 2010). One of the possible reasons is technology lock-in, which makes the industries unable to change the energy use behaviour rigorously in the short run. It is also noteworthy that negative own price elasticity of energy demand is present with positive values of the parameter β_{ee} for fertilizer and pesticide and iron and steel industries. This suggests while increase in energy price may lead to increased cost share of energy input in these industries, but there will be decrease in physical energy demand.

3.2.6 While own price elasticity parameters suggest that historically industries have responded by reducing their energy demand when there was an increase in energy price, it would also be important to understand what impact it had on the demand of other inputs, especially material. Based on the cross price elasticity values, the inter-factor relationship between energy and non-energy inputs are reported in Table 8. Other than pulp and paper, energy and material are always found to be substitutes. The relation between capital and energy is, however, not so obvious. Significant substitutability between energy and capital are found in case of non-ferrous metal, fertilizer and pesticide and pulp and paper industries implying that long run reduction of energy use required more capital investment. Significant complementarity between energy and service is found in non-ferrous metal, fertilizer and pesticide and pulp and paper industries.

4. Conclusion

4.1 This study analyses the input use behaviour of energy intensive manufacturing industries in India with special focus on the pattern of energy use. It is based on a growth accounting framework which decomposed the growth in output in growth in input and technological progress represented by TFPG. A *klems* Translog cost function has also been econometrically estimated to understand the nature of technological progress and the input use behaviour. Growth accounting reveals that inclusion of ‘service’ as an input in the model is important. Otherwise, the magnitude of technological progress generally tends to be overestimated during the study period 2000-01 – 2011-12. This is important because while ASI publishes aggregate level data related to other four inputs under consideration, the same for service is not available at an aggregate level. Following existing literature, which is sparse enough, we have adopted the method where cost towards service input is approximated by the difference between ‘total input’ and the sum of ‘fuel consumed’ and material consumed. This may include some expenditure that cannot be categorized as service. Availability of appropriate data on service input will enhance the quality and authenticity of any productivity growth related study in India.

4.2 Material and energy dominate the cost share of inputs in all the industries under consideration, even after introduction of service input which has gained significant importance during the past two decades. Such a high share of material input will remain a cause of concern for these industries so far the competitiveness is concerned. The autonomous technological progress is majorly energy-saving in nature except fertilizer and pesticide. However, material-using bias remains an issue of concern in industries such as chemical (without fertilizer and pesticide), fertilizer and pesticide and pulp and paper. Nature of substitution possibilities between energy and capital suggests installation of capital intensive energy efficient technologies. There is a mixed inter-factor relation between energy and service. The own price elasticity and the constant share elasticity suggest that while increase in energy price may lead to increased cost share of energy input, it will lead to decrease in physical energy demand in many of these industries. The magnitude of own price elasticity is greater than 1 only for non-ferrous metal, chemical (without fertilizer and pesticide) and pulp and paper industries implying price policies to induce behavioural change with respect to energy demand in the current set of industries may not be highly effective in the short run. However, a negative correlation between energy intensity and productivity growth of other inputs suggests that policies aimed at improving energy intensity (PAT, for example) could lead to a win-win situation as it will go hand in hand with improvements in productivity growth of other inputs as well.

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Figure 1: Decomposition of Output Growth in Input Growth and Total Factor Productivity Growth

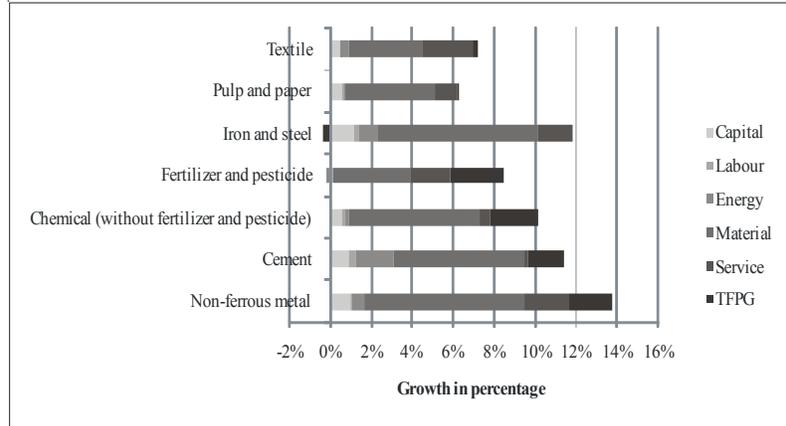
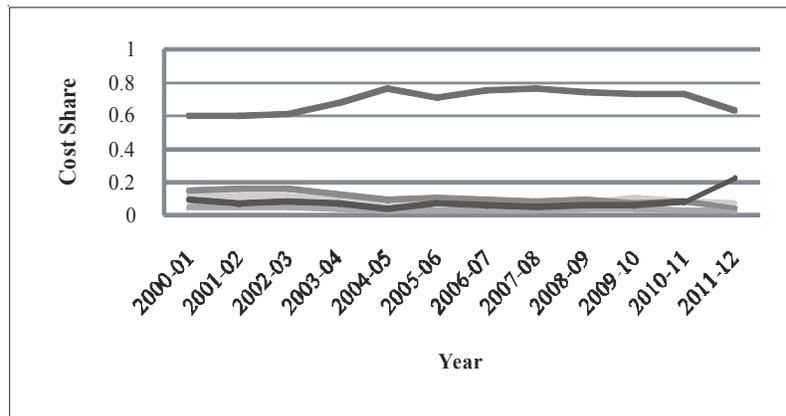
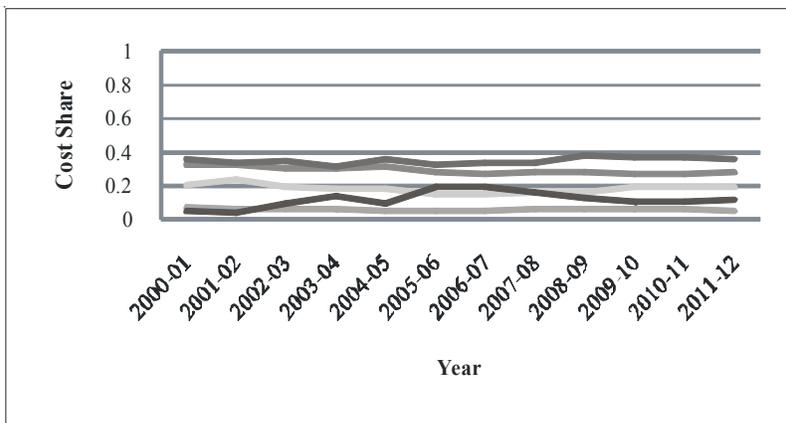


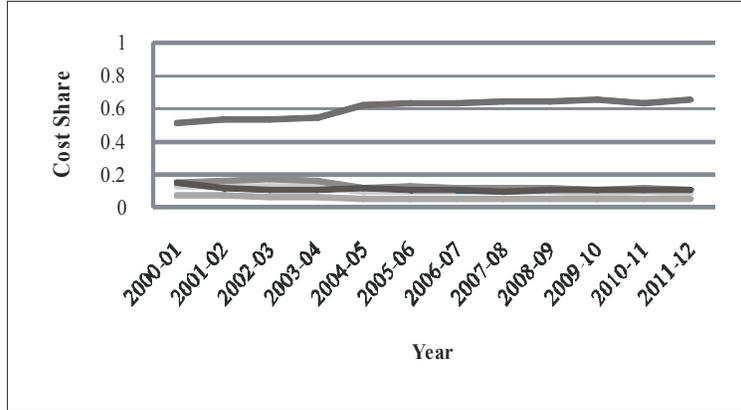
Figure 2: Trend of Average Cost Share
Non-ferrous metal



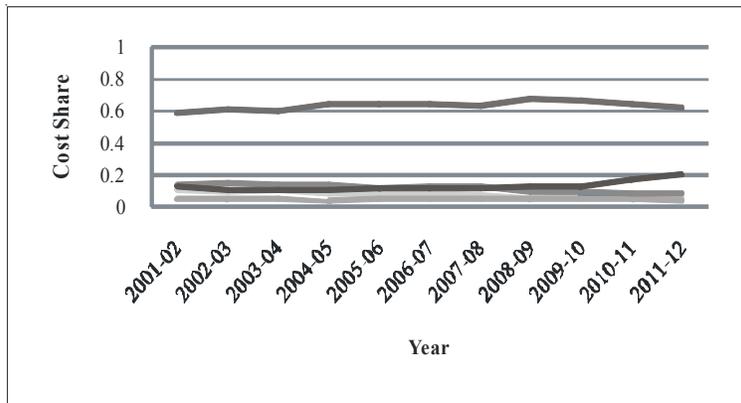
Cement



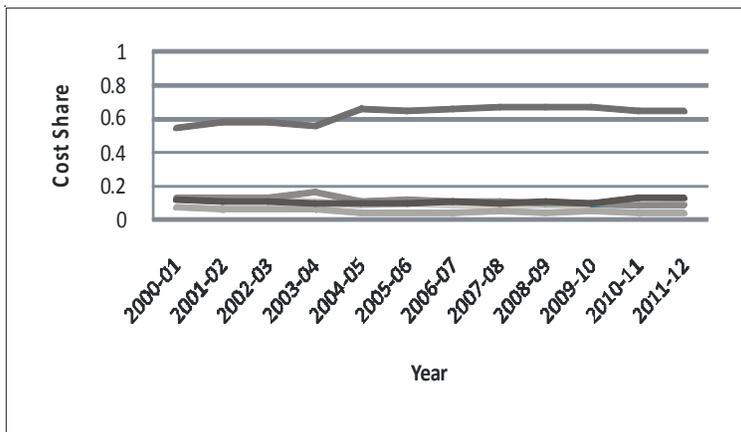
Chemical (without Fertilizer and Pesticide)



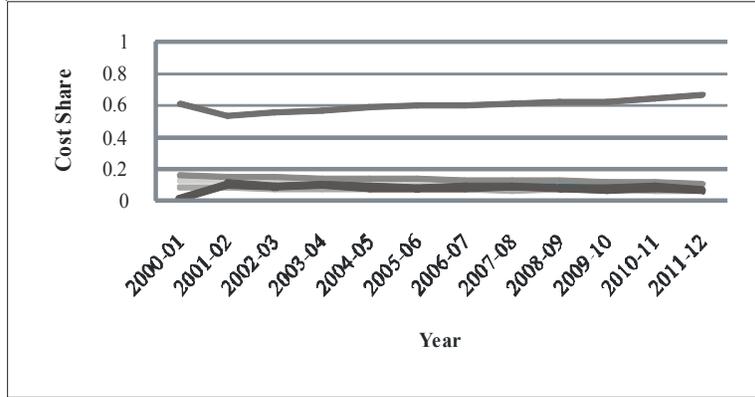
Fertilizer and pesticide



Iron and Steel



Pulp and Paper



Textile

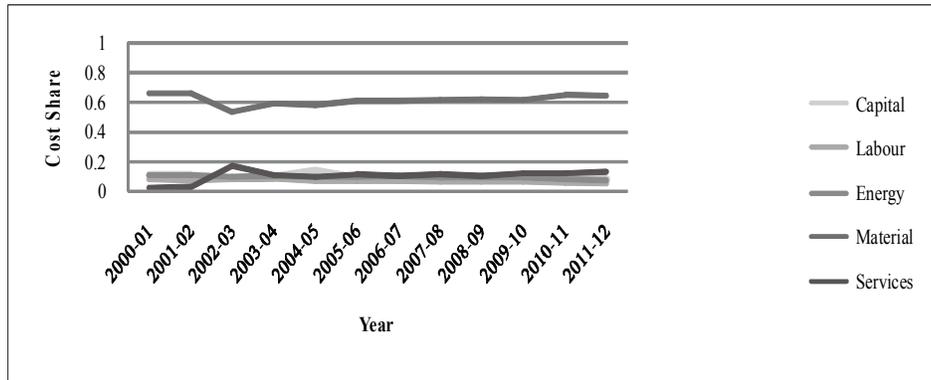


Table 1: Industry Codes under National Industrial Classifications in India

Years (NIC)	Non-ferrous metal	Cement	Chemical (Without fertilizer and pesticide)	Fertilizer and Pesticide	Iron and Steel	Pulp & Paper	Textile
2000-01- 2003-04 (NIC-1998)	272	2694	2411	2412+2421	271	2101+2102	171
2004-05 - 2007-08 (NIC-2004)	272	2694	2411	2412+2421	271	2101+2102	171
2008-09- 2011-12 (NIC-2008)	242	2394	2011	2012+2021	241	1701+1702	131

Table 2: Contribution of Input Growth and Productivity Growth (Technological Progress) in Output Growth of Energy Intensive Manufacturing Industries

		Growth in Output	Growth in Capital	Growth in Labour	Growth in Energy	Growth in Material	Growth in Service	Growth in total input	Technological progress
Non-ferrous metal	2000-01 – 2011-12	13.8%	1.0%	0.1%	0.6%	7.8%	2.1%	11.6%	2.1%
	1998-99 – 2011-12 (Aluminium)	9.10%	1.71%	0.12%	0.97%	3.34%	-	6.15%	2.96%
Cement	2000-01 – 2011-12	11.4%	0.9%	0.3%	1.8%	6.4%	0.2%	9.6%	1.7%
	1998-99 – 2011-12	9.62%	1.65%	0.26%	1.47%	2.91%	-	6.29%	3.33%
Chemical (without fertilizer and pesticide)	2000-01 – 2011-12	10.1%	0.6%	0.2%	0.1%	6.5%	0.5%	7.8%	2.3%
	1998-99 – 2011-12	9.21%	0.78%	0.15%	0.20%	7.45%	-	8.59%	0.62%
Fertilizer and pesticide	2000-01 – 2011-12	8.26%	0.05%	0.06%	-0.17%	3.83%	1.89%	5.67%	2.60%
	1998-99 – 2011-12	7.70%	0.20%	0.15%	0.05%	4.90%	-	5.30%	2.40%
Iron and steel	2000-01 – 2011-12	11.5%	1.2%	0.2%	0.9%	7.9%	1.6%	11.8%	-0.3%
	1998-99 – 2011-12	10.18%	1.17%	0.11%	0.83%	7.97%	-	10.10%	0.09%
Pulp and paper	2000-01 – 2011-12	6.25%	0.52%	0.10%	0.12%	4.38%	1.09%	6.21%	0.04%
	1998-99 – 2011-12	7.06%	0.72%	0.15%	0.24%	5.45%	-	6.56%	0.51%
Textile	2000-01 – 2011-12	7.2%	0.5%	0.0%	0.4%	3.7%	2.4%	7.0%	0.2%
	1998-99 – 2011-12	7.03%	0.68%	-0.04%	0.42%	4.66%	-	5.72%	1.31%

Table 3: Correlation between TFPG and Energy Intensity

	Non-ferrous metal	Cement	Chemical (without Fertilizer and Pesticide)	Fertilizer and pesticide	Iron and Steel	Pulp and Paper	Textile
K/Y and TFPG	-0.28	0.06	-0.19	-0.11	-0.04	-0.54	-0.20
L/Y and TFPG	-0.16	-0.45	-0.10	-0.23	-0.21	-0.46	-0.21
E/Y and TFPG	-0.10	-0.30	-0.06	-0.06	-0.43	-0.44	-0.30
M/Y and TFPG	-0.48	-0.37	-0.06	-0.20	-0.35	-0.09	0.13
S/Y and TFPG	0.06	-0.43	-0.06	-0.25	-0.44	-0.43	-0.27

Table 4: SURE Estimates of the *klem*s Model

Parameter	Non-Ferrous metal				Cement				Chemical (without fertilizer and pesticide)				Fertilizer and pesticide				Iron and Steel				Pulp and paper				Textile			
	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value	Esti mate	z- value		
α_k	0.16	14.94	0.08	2.48	0.08	8.74	0.10	7.99	0.09	17.31	0.09	12.04	0.08	18.05	0.10	26.92	0.12	23.26	0.10	11.31	0.10	11.31	0.10	11.31	0.10	11.31	0.10	11.31
α_l	0.02	1.83	0.12	11.40	0.05	13.64	0.04	10.86	0.09	12.04	0.08	18.05	0.10	26.92	0.12	23.26	0.10	11.31	0.10	11.31	0.10	11.31	0.10	11.31	0.10	11.31	0.10	11.31
α_e	0.13	16.30	0.40	21.19	0.14	14.03	0.09	8.62	0.24	8.83	0.16	42.44	0.13	25.10	0.15	5.52	0.03	3.19	0.11	1.10	0.04	0.38	0.01	0.14	0.02	-0.28	-3.56	
α_m	0.62	21.94	0.53	6.70	0.58	68.71	0.56	14.58	0.55	25.93	0.53	22.33	0.51	5.52	0.07	2.91	-0.14	-40.77	0.15	2.10	0.21	5.91	0.03	3.19	0.11	1.10	0.04	0.38
α_s	0.07	2.91	-0.14	-40.77	0.15	2.10	0.21	5.91	0.03	3.19	0.11	1.10	0.04	0.38	0.01	0.14	0.02	-0.28	-3.56	0.03	0.40	-0.12	-1.89	0.09	-0.01	-2.15	-5.84	
α_v	0.02	0.14	0.01	0.13	-0.03	-0.86	0.04	0.53	-0.07	-1.45	0.04	0.38	0.01	0.14	0.02	-0.28	-3.56	0.03	0.40	-0.12	-1.89	0.09	-0.01	-2.15	-5.84	0.06	-5.62	
β_{kk}	-0.28	-3.56	-0.35	-2.28	0.03	0.40	-0.12	-1.89	0.09	-0.01	-2.15	-5.84	0.06	-5.62	0.03	0.40	-0.12	-1.89	0.09	-0.01	-2.15	-5.84	0.06	-5.62	0.03	0.40	-0.12	-1.89
β_{kl}	0.06	2.85	-0.19	-4.52	-0.02	-0.55	0.00	0.09	-0.01	-2.15	-5.84	0.06	-5.62	0.03	0.40	-0.12	-1.89	0.09	-0.01	-2.15	-5.84	0.06	-5.62	0.03	0.40	-0.12	-1.89	
β_{ke}	0.15	4.62	-0.41	-6.04	-0.21	-5.71	0.14	3.59	-0.13	-7.13	0.11	8.75	-0.06	-3.89	0.50	2.82	-0.68	-2.68	0.49	0.53	3.48	-0.07	-4.60	0.45	9.56	0.00	-0.06	
β_{km}	0.50	2.82	-0.68	-2.68	0.49	0.53	3.48	-0.07	-4.60	0.45	9.56	0.00	-0.06	-3.89	0.50	2.82	-0.68	-2.68	0.49	0.53	3.48	-0.07	-4.60	0.45	9.56	0.00	-0.06	
β_{ks}	-0.43	-2.34	1.63	5.93	-0.30	-4.65	-0.56	-2.47	0.34	18.20	-0.35	-4.97	0.14	1.53	-0.43	-2.34	1.63	5.93	-0.30	-4.65	-0.56	-2.47	0.34	18.20	-0.35	-4.97	0.14	1.53
β_{kt}	-0.01	-8.40	0.02	3.06	0.00	1.68	0.00	-0.97	0.00	1.09	0.00	-6.04	0.00	-0.53	-0.01	-8.40	0.02	3.06	0.00	1.68	0.00	-0.97	0.00	1.09	0.00	-6.04	0.00	-0.53
β_{ll}	-0.06	2.85	0.12	6.56	0.02	1.06	0.02	2.57	0.03	2.92	0.00	-0.12	0.07	6.60	-0.08	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
β_{le}	-0.08	-5.39	0.09	4.11	-0.07	-4.58	-0.02	-1.87	0.01	0.34	0.05	4.85	-0.01	-0.56	0.40	-6.79	0.33	3.44	0.07	2.68	-0.04	-0.79	0.05	2.06	0.16	3.71	-0.10	-3.10
β_{lm}	0.40	-6.79	0.33	3.44	0.07	2.68	-0.04	-0.79	0.05	2.06	0.16	3.71	-0.10	-3.10	0.40	-6.79	0.33	3.44	0.07	2.68	-0.04	-0.79	0.05	2.06	0.16	3.71	-0.10	-3.10
β_{ls}	-0.33	7.64	-0.35	-3.45	0.00	-0.05	0.04	0.59	-0.08	-2.84	-0.13	-2.39	0.09	1.63	0.00	-0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
β_{lt}	0.00	-6.64	-0.01	-6.16	0.00	-0.69	0.00	-0.20	-0.01	-5.38	0.00	-0.08	-2.39	0.09	1.63	0.00	-0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
β_{ee}	-0.09	-3.17	0.11	2.39	-0.18	-4.62	0.02	0.40	0.06	5.25	-0.08	-6.63	0.10	4.58	0.00	-0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
β_{em}	1.06	7.39	0.47	2.94	0.41	13.02	0.58	4.74	0.02	0.22	-0.16	-4.75	-0.03	-0.67	1.06	7.39	0.47	2.94	0.41	13.02	0.58	4.74	0.02	0.22	-0.16	-4.75	-0.03	-0.67
β_{es}	-1.04	-8.42	-0.26	-1.51	0.05	0.94	-0.72	-4.27	-0.53	-6.58	0.08	1.63	0.00	-0.01	-1.04	-8.42	-0.26	-1.51	0.05	0.94	-0.72	-4.27	-0.53	-6.58	0.08	1.63	0.00	-0.01
β_{et}	-0.01	-4.56	-0.02	-5.67	0.00	-1.48	0.01	3.25	-0.02	-3.62	0.00	-6.46	0.00	-7.43	-0.01	-4.56	-0.02	-5.67	0.00	-1.48	0.01	3.25	-0.02	-3.62	0.00	-6.46	0.00	-7.43
β_{mm}	-0.56	-0.63	0.52	0.74	-1.82	-15.33	0.86	1.53	0.20	2.34	-0.40	-1.86	-0.70	-7.77	-0.56	-0.63	0.52	0.74	-1.82	-15.33	0.86	1.53	0.20	2.34	-0.40	-1.86	-0.70	-7.77
β_{ms}	-1.40	-1.80	-0.64	-0.88	0.85	8.22	-1.94	-2.56	-0.20	-3.22	-0.05	-0.19	0.84	0.95	-1.40	-1.80	-0.64	-0.88	0.85	8.22	-1.94	-2.56	-0.20	-3.22	-0.05	-0.19	0.84	0.95
β_{mt}	-0.02	-4.74	-0.04	-2.35	0.01	5.46	0.02	2.11	0.00	-1.05	0.01	5.42	0.01	0.79	-0.02	-4.74	-0.04	-2.35	0.01	5.46	0.02	2.11	0.00	-1.05	0.01	5.42	0.01	0.79
β_{ss}	3.19	4.92	-0.38	-0.09	-0.60	-4.46	3.18	8.71	0.47	-5.56	0.45	5.92	-1.06	-4.10	3.19	4.92	-0.38	-0.09	-0.60	-4.46	3.18	8.71	0.47	-5.56	0.45	5.92	-1.06	-4.10
β_{st}	0.04	9.08	-0.04	-2.35	-0.01	-3.75	-0.02	-2.09	0.03	7.44	-0.01	-1.83	0.00	-0.01	0.04	9.08	-0.04	-2.35	-0.01	-3.75	-0.02	-2.09	0.03	7.44	-0.01	-1.83	0.00	-0.01
β_{vt}	-0.03	-1.56	-0.02	-2.05	-0.01	-2.55	-0.02	-1.68	-0.01	-0.75	-0.01	-0.91	-0.01	-1.10	-0.03	-1.56	-0.02	-2.05	-0.01	-2.55	-0.02	-1.68	-0.01	-0.75	-0.01	-0.91	-0.01	-1.10
$R^2(k)$	0.72		-0.29		0.84		0.54		0.97		0.80		0.15		0.72		-0.29		0.84		0.54		0.97		0.80		0.15	
$R^2(l)$	0.93		0.48		0.91		0.27		0.63		0.67		0.82		0.93		0.48		0.91		0.27		0.63		0.67		0.82	
$R^2(e)$	0.93		0.80		0.80		0.78		0.29		0.96		0.65		0.93		0.80		0.80		0.78		0.29		0.96		0.65	
$R^2(m)$	0.57		0.29		0.99		0.72		0.76		0.54		0.00		0.57		0.29		0.99		0.72		0.76		0.54		0.00	
$R^2(y)$	0.17		0.29		0.35		0.19		0.05		0.07		0.10		0.17		0.29		0.35		0.19		0.05		0.07		0.10	

Table 5: Average Cost Share

Input	Non-ferrous metal	Cement	Chemical (without Fertilizer and Pesticide)	Fertilizer and pesticide	Iron and Steel	Pulp and Paper	Textile
Capital (M_k)	9%	18%	10%	8%	10%	11%	10%
Labour (M_l)	3%	6%	6%	5%	5%	7%	7%
Energy (M_e)	11%	29%	13%	12%	11%	13%	10%
Material (M_m)	70%	35%	61%	63%	63%	61%	58%
Services (M_s)	8%	12%	10%	12%	11%	8%	15%

Table 6: Factor Price Bias of Technological Change

Input	Non-ferrous metal	Cement	Chemical (without Fertilizer and Pesticide)	Fertilizer and pesticide	Iron and Steel	Pulp and Paper	Textile
Capital	Saving*	Using*	Using	Saving	Using	Saving*	Saving
Labour	Using	Saving*	Saving	Saving	Saving*	Saving*	Saving*
Energy	Saving*	Saving*	Saving	Using*	Saving*	Saving*	Saving*
Material	Saving*	Saving*	Using*	Using*	Saving	Using*	Using
Service	Using*	Saving*	Saving*	Saving*	Using*	Saving	Saving

Table 7: Own Price and Constant Share Elasticity Estimates of Energy Demand (E_{ee} and β_{ee})

Own price and constant share elasticity	Non-ferrous metal	Cement	Chemical (without Fertilizer and Pesticide)	Fertilizer and pesticide	Iron and Steel	Pulp and Paper	Textile
E_{ee}	-1.7*	-0.3*	-2.3*	-0.8*	-0.3*	-1.4*	0.1
β_{ee}	-0.09*	0.11*	-0.18*	0.02	0.06*	-0.08*	0.10*

Table 8: Inter-factor Substitution Possibility^a

Inter-factor relation	Non-ferrous metal	Cement	Chemical (without Fertilizer and Pesticide)	Fertilizer and pesticide	Iron and Steel	Pulp and Paper	Textile
K-E	S*	C*	C*	S*	C*	S*	C*
L-E	C*	S*	C*	C	S	S*	C
M-E	S*	S*	S*	S*	S	C*	S
S-E	C*	C	S	C*	C*	S	S

^a 'C' and 'S' respectively denote complements and substitutes

*significant at 5% level of significance