India's Energy Consumption Changes during 1973-74 to 1989-90: An Input-Output Approach[1]

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Abstract

The oil crisis of 1973-74 was followed by similar shocks up until 1981, each having an adverse impact on the Indian economy. This paper analyzes the effects of energy consumption changes that have taken place in the Indian economy during the periods 1973-74 and 1989-90, and factors responsible for these changes, based on an Input-Output model. Here, we develop a Structural Decomposition Analysis. These energy consumption changes have been due to two different factors: i) production technology change and ii) final demand shifts. The application of our model to the Indian experience suggests that changes in the final demand shift contributed more to increase energy consumption. On the other hand production technology change resulted in a marginal saving of energy. On the whole, energy consumption has increased.

1. Introduction

Since the first oil crisis shook the world's economy, an atmosphere of uncertainty in the international oil market has led many Asian oil importing country to strive to find various means of coping with this new reality. The first oil crisis of 1973-74 was followed by similar shocks till 1981, beyond which, prior to the Gulf crisis, a sense of optimism more or less prevailed in the oil market. This had adverse effects on the Indian economy, pushing economic programmes into the doldrums.

Various measures have been adopted in India to influence the pattern of energy consumption, which has changed in a big way since the years 1950-51. The share of commercial fuels has increased from 26% in 1950-51 to nearly 60% in 1993-94. The share of non-commercial sources of energy has declined from 74% in 1950-51 to 41% in 1990-91.

Quite a large number of energy related studies have been carried out in India. The first and most elaborate venture in this field in India was taken up by the NCAER in 1950s. Remarkable individual efforts to scrutinize the Indian energy scene are observed

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by Chitale and Roy (1975), Parikh (1976), Saha (1980), Kar and Chakraborty (1985), Sengupta (1990).

All these studies are useful, but very few of them have analyzed the energy consumption changes and factors responsible for changes after the energy crisis especially in a multisectoral framework. The present study is directed towards this end. The objective of the paper is to attempt to analyze energy consumption changes that have taken place in the Indian economy during the periods 193-74 and 1989-90, and the factors responsible for these changes. The scheme of the study is as follows: The theoretical model adopted for the present study is outlined in Section 2. Data and empirical results are presented in Section 3. The summary and the conclusions are drawn in Section 4.

2. The Model

We start our model formulation from a static input-output model. Mathematically, the structure of the I-O model can be expressed as:

$$X = AX + Y \ . \tag{1}$$

Equation (1) yields n general equilibrium relationships between the total outputs $X_1 ... X_n$ of all producing sectors and the final bill of goods $Y_1 ... Y_n$ absorbed by household, government and other final users. Equation (1) can be written as:

$$X = (I - A)^{-1} Y \ , \tag{2}$$

where	$A = n \times n$	matrix of technical coefficients,
	$X = n \times 1$	vector of gross output,
	$Y = n \times 1$	vector of final demand,
	$I = n \times n$	vector of identity matrix.

and $(I - A)^{-1}$ considers all direct and indirect requirements for producing one unit of final goods or services. The matrix of technical input-output coefficient is needed to calculate this inverse, and through that equilibrium the level of output in each sector of the economy.

For an energy input-output model, the monetary flows in the energy rows in equation (2) are replaced with the physical flows of energy, in order to construct the energy flows.

We apply a hybrid method adopted from the studies of Bullard and Herenden (1975), and Bullard et al. (1978), and replace all the energy rows in the monetary Input-Output Table with energy flows in physical unit. This formulation, as demonstrated by Miller and Blair (1985), is generally superior to other formulations because it always conforms with conservation condition[2]. We have used a contemporary framework of energy input-output, where we construct a transactions table in so called "hybrid units" — that is, we trace energy flows in the economy in (MTCR), and non energy flows in (MRS).

Therefore, in equation (2) X is a hybrid unit total output vector $(n \times 1)$, in which the outputs of energy sectors are measured in million tonnes coal replacement (MTCR), while the outputs of other sectors are measured in millions of rupees (MRS). Y is a hybrid unit final demand vector $(n \times 1)$, in which the final demand for different types of energy are measured in MTCR, while the final demand for the outputs of other sectors are measured in millions of rupees. A is a hybrid unit technical coefficient matrix $(n \times n)$, in which the unit of the input coefficients of an energy sectors from energy sectors is MTCR/MTCR; the unit of the input coefficients of an energy sector from non energy sectors is MRS/MTCR; the unit of the input coefficients of a non energy sector from energy sector is MTCR/MRS; and the unit of the input coefficients of a non energy sector from non energy sector is MRS/MRS. I is an identity matrix $(n \times n)$.

We use the Structural Decomposition Analysis[3] in our model, which involves an analysis of economic changes by means of a set of comparative static adjustments of key parameters of Input-Output Tables.

We generate a system of mutually exclusive, and completely exhaustive, estimation equations. We have considered three energy sectors —coal, crude petroleum and natural gas, and electricity; and others as the non energy sector. The energy sectors in our static model can be presented as:

$$E_i + E_f = E . \tag{3}$$

E_i is the vector of intermediate energy consumption, E_f is the vector of final energy consumption, E is the vector of total energy consumption.

The intermediate energy consumption is the energy used by production sectors as an input (i.e. energy used in production activities). The direct energy consumption is the energy used, or sold directly to final users, such as household consumption, government expenditure etc.

By using equation (1) we can be write the energy balance condition of equation (3) as:

$$uAX + uY = uX , \tag{4}$$

[2] The justification of the use of hybrid method is discussed by Blair and Miller in detail: pp.217-229. Furthermore, most of the recent works related to this method have also attempted by Lin and Polenske (1995), Han and Lakshmanan (1994).

[3] Similar attempt have been made by Lin (1991, 1994) and Polenske and Lin (1993) for China, Schipper and Meyers (1992), Strount (1966), Reardon (1976), Park (1982) for U.S., Rose and Chen (1991) for Taiwan, Han and Lakshmanan (1994) for Japan.

where u is a diagonal matrix containing ones and zeros, with ones appearing in the diagonal locations that correspond to energy sectors, and all the other elements of the matrix being zeros. We can obtain the amount of intermediate energy required in the economy by combining and resetting equations (2) and (4) which gives;

$$E_i = uAX = uX - uY = u(I - A)^{-1} Y - uY .$$

$$E_i = u[(I - A)^{-1} - I]Y . \qquad (5)$$

To calculate direct energy consumption E_f we have to adjust final energy consumption (i.e. private consumption, government consumption, gross final investment, change in stock, exports and imports).

$$E_f = E_y + E_m - E_n - E_e = uy , \qquad (6)$$

where E_y is the vector of final energy consumption which includes public, as well as private, energy and gross final capital formulation, E_m is the vector of imported energy, E_e is the vector of exported energy, E_n denotes energy net inventory changes.

Total energy consumption E in the economy is the sum of intermediate and direct energy consumption. Therefore;

$$E = E_i + E_f = u[(I - A)^{-1} - I]Y + uy = PY + uy , \qquad (7)$$

where $P = u[(I - A)^{-1} - I]$.

Equation (7) shows that total energy consumption in the economy is determined by the total intermediate energy consumption, and direct energy requirement from final demand (y). P is a function of production technology measured in terms of technical coefficient matrix A, which includes both energy and non energy inputs.

Actual energy consumption changes between two years can be formed by equation (7) as;

$$\Delta E = E_t - E_0 = P_t Y_t + uy_t - P_0 Y_0 - uy_0 = (P_t Y_t - P_0 Y_0) + u(y_t - y_0), \qquad (8)$$

where E_0 and E_t denotes the base period and current period respectively. The first portion of (8) represents changes in intermediate energy use, which depends both on P (i.e. production technology change) and changes in final demand: Y. The second part measures direct energy consumption which is only a function of final demand shift. Equation (8) can be split into two parts: one resulting from changes in production methods (production technology changes), and others from changes in consumption habits (i.e. final demand shifts). To determine this we have used a hypothetical economy model, with base period production technology (P_0) and current period final demand (Y_t). The energy consumption in this hypothetical economy can be produced as;

$$Ep_0y_t = P_0Y_t + ey_t \ , \tag{9}$$

where Ep_0y_t measures the amount of energy consumed by that particular economy, assuming base period production technology was used to deliver current period final demand. Using (9) as a reference point, we can rewrite the energy consumption changes from 0 to t as;

$$\begin{aligned}
\Delta E &= E_t + Ep_0y_t - Ep_0y_t - E_0 , \\
&= P_tY_t + ey_t + P_0Y_t + ey_t - P_0y_t - ey_t - P_0Y_0 - ey_0 . \\
\Delta E &= P_0(Y_t - Y_0) + u(y_t - y_0) \quad ; \text{ final demand shift} \\
&\quad + (P_t - P_0)Y_t \quad ; \text{ production technology change.}
\end{aligned} \tag{10}$$

This represents the effect of the final demand shift, which indicates the energy impact of final demand changes; while holding production technology is constant. Also, the production technology change quantifies the energy effect of changes in production technology with a given final demand.

In equation (10), we try to find out "how much more (or less) energy would have been required in t year's if the 0 years production technology had still been used in order to satisfy t years final demands."

We can break down the final demand shift component along three dimensions. Here, energy use changes are associated with changes in level, distribution and pattern of final demand. The level of demand refers to the overall level of total demand (i.e. the GDP), which equals the sum of all final outputs and expenditures. The distribution of demand refers to the distribution of total demand along individual final demand sectors, such as domestic consumption, government consumption, etc. The pattern of demand refers to the mix of goods and services within each individual final demand category. In matrix form the effect of final demand shift is the product of level, distribution and pattern component.

$$Y = SBV . \tag{11}$$

Here, S denotes the matrix of the spending mix of individual final demand categories, which explains the pattern effect of the final demand shifts. Next, is matrix B, which is a diagonal matrix, with the categorical composition; of total demand on the diagonal, by which the distributional effect of final demand shift can be distinguished. Another component of the final demand shift is V, which is a diagonal matrix with the overall total demand level on the diagonal. It expresses the level effect of the final demand shift.

We put equation (11) into equation (10) to show the different dimensional change. Then equation (11) can be formed as;

$$\begin{aligned}\Delta E_y &= P_0(Y_t - Y_0) + u(y_t - y_0),\\ &= P_0(S_t B_t V_t - S_0 B_0 V_0) + u(s_t b_t v_t - s_0 b_0 v_0),\\ &= P_0 S_0 B_0 (V_t - V_0) + u s_0 b_0 (v_t - v_0) \quad \text{; level effect}\\ &\quad + P_0 S_0 (B_t - B_0) V_t + u s_0 (b_t - b_0) v_t \quad \text{; distribution effect}\\ &\quad + P_0 (S_t - S_0) B_t V_t + u(s_t - s_0) b_t v_t \quad \text{; pattern effect}\end{aligned} \tag{12}$$

Next, we calculate the contribution of individual final demand sectors, such as public consumption, private consumption etc. due to final demand shifts. Mathematically, this can be written as;

$$\Delta E_y = \sum_h \Delta E_y^h = \left[P_0\left(Y_t^h - Y_0^h\right) + u\left(y_t^h - y_0^h\right)\right], \tag{13}$$

where h denotes the final demand sectors.

Finally, we calculate how changes in the purchase of an individual product or product groups affect energy consumption.

$$\Delta E_{y,k} = P_0 k\left(\hat{Y}_t - \hat{Y}_0\right) + uk\left(\hat{y}_t - \hat{y}_0\right), \tag{14}$$

where $\hat{Y}_t$ and $\hat{Y}_0$ denote the diagonal matrices of the final demand vectors in t and 0 period, k is a matrix consisting of ones and zeros, with ones in the row locations that correspond, to products k (fuel types), and zeros in all other elements of the matrix. Equation (14) also estimates how much energy use changes resulting from final demand shifts comes directly from purchases of energy products; and how much comes indirectly from non energy products.

The production technology component in equation (10) measures the energy use changes resulting from changes in the total intermediate energy requirements of final goods and services. This can be written as;

$$\begin{aligned}\Delta E_T &= (P_t - P_0)Y_t = [u(G_t - I) - u(G_0 - I)]Y_t,\\ &= u(G_t - G_0)Y_t,\end{aligned} \tag{15}$$

where
$$G_t = (I - A_t)^{-1},$$

$$G_0 = (I - A_0)^{-1}. \tag{16}$$

From (16) it follows that

$$G_t(I - A_t) = G_0(I - A_0) = I, \tag{16a}$$

$$G_t - G_0 = G_t(A_t - A_0) + (G_t - G_0)A_0, \tag{16b}$$

or
$$G_t - G_0 = G_t(A_t - A_0)G_0. \tag{17}$$

Inserting equation (17) into equation (15) we get

$$\begin{aligned}\Delta E_t &= (P_t - P_0)Y_t \\ &= u(G_t - G_0)Y_t \\ &= uG_t(A_t - A_0)G_0Y_t.\end{aligned} \tag{18}$$

We can separate the effect of production technology changes in direct energy requirements and direct non energy requirements of energy use by splitting equation (18) as;

$$\begin{aligned}\Delta E_t = {} & uG_t(A_{te} - A_{0e})G_0Y_t \quad ; \text{ changes in energy inputs} \\ & + uG_t(A_{tn} - A_{0n})G_0Y_t \; ; \text{ changes in non energy inputs}\end{aligned} \tag{19}$$

The total inputs requirement matrix can be identified as G. (the changes in the technical coefficient $(A_t - A_0)$ can be written as:

$$A_t - A_0 = (A_{te} - A_{0e}) + (A_{tn} - A_{0n}),$$

where A_{te} represents the energy rows of the technical coefficients matrix and A_{tn} represents non energy rows).

Equation (19) demonstrates that the changes in intermediate energy demand can be caused not only by changes indirect energy inputs (A_{te}), but also by changes indirect non energy inputs (A_{tn}).

Next, we examine the relative contributions of individual sectors (j), such as agriculture, mining etc, due to production technology changes. This, therefore, can be expressed as:

$$\Delta E_t = \sum_j \Delta E_t^j = \left[uG_t\left(A_t^j - A_0^j\right)G_0Y_t\right]. \tag{20}$$

Here, Y_t vector is arranged diagonally, so as to reveal the relative contributions of all sectors to intermediate energy demand changes.

We summarized the whole structure of the estimation equations, which we have used in our analysis as below:

—Structural Decomposition Analysis of Energy Use Changes Factor—

1. Actual Energy Use Changes	$E_t - E_0 = P_t Y_t - P_0 Y_0 + u(y_t - y_0)$
2. Final Demand Shift	$P_0(Y_t - Y_0) + u(y_t - y_0)$
Level Effect	$P_0 S_0 B_0 (V_t - V_0) + u s_0 b_0 (v_t - v_0)$
Distribution Effect	$P_0 S_0 (B_t - B_0) V_t + u s_0 (b_t - b_0) v_t$
Pattern Effect	$P_0 (S_t - S_0) B_t V_t + u(s_t - s_0) b_t v_t$
For Demand Source h	$P_0 (Y_t^h - Y_0^h) + u(y_t^h - y_0^h)$
For Product Group k	$P_0 k(Y_t - Y_0) + uk(y_t - y_0)$
3. Production Technology Changes	$(P_t - P_0) Y_t$
For Energy Inputs	$u G_t (A_{te} - A_{0e}) G_0 Y_t$
For Non Energy Inputs	$u G_t (A_{tn} - A_{0n}) G_0 Y_t$
For Individual Sector j	$u G_t (A_t^j - A_0^j) G_0 Y_t$

3. Results

3.1. Data Source

To implement the model and conduct the SDA of energy structural changes we require three key data components for both 1973-74 and 1989-90: Input-Output Tables, price indices and energy flow data.

(1) Input-Output Table

The Input-Output Tables used in our SDA MODELLING are commodity-by-commodity tables for India in 1973-74 and 1989-90, prepared by CSO and Planning Commission. Both Input-Output Tables consist of 60 × 60 sectors which have been aggregated into 21 sectors on the basis of the nature of commodities and energy intensiveness. Out of 21 sectors we have taken three energy sectors (i.e. coal, crude petroleum and natural gas and electricity) and 18 non energy sectors.

(2) Price Indices

The analysis of change in the structure of energy patterns over time requires that each yearly Input-Output Table be based on the same set of prices, using price indices. We use 1989-90 as a base year, and adjust 1973-74 table to 1989-90 prices using price indices.

(3) Energy Flow Data

We convert the monetary units of energy sectors into physical units from the energy data published by C.M.I.E (1995) report. Three energy sectors, such as coal (measured in millions of tonnes), crude petroleum in million tonnes, natural gas in million cubic meters, and electricity in T.W.H have been converted into one common unit, which is millions of tonnes coal replacement or mtcr. The conversion method is given below:

Coal 1mt - 1mtcr.
Natural Gas 1m.c.m - 0.0036mtcr.
Crude Petroleum 1mt - 6.5mtcr.
Electricity 1twh - 1mtcr.

3.2. Empirical Results

The results of our analysis are presented in Tables 1 and 2. These tables deal with the various energy use changes in India from 1973-74 to 1989-90. Table 1 shows the energy use changes in India from 1973-74 to 1989-90 in terms of absolute amount. Also, Table 2 shows the percentage change in energy use in the intermediate, as well as final demand, sectors of the Indian economy for each of three fuel types and energy as a whole, attributable to each source of change for 1973-74 to 1989-90.

—Actual Energy Consumption Changes—

Energy consumption in India during our study period has increased by 519.28mtcr or 117.86%, which was nearly 7% annually. This high rate of change was due to coal and lignite as 157.75mtcr or 213.47%, crude petroleum and natural gas as 236.22mtcr or 78.75%, and electricity as 125.31mtcr or 187.89%. The annual contributions were 13%, 5% and 11.9%, respectively.

The various factors contributing to these changes are:

(1) Final Demand Shift

Changes in the final demand shift were the dominant force behind the increase in the energy consumption in Indian economy. The increase in the level of economic activity, and shifts in expenditure, towards more energy intensive products were the main factors that pushed energy use up by 540.88mtcr or 122.76% (i.e. 7%, annually).

(2) Production Technology Change

This upward pressure on energy demand, however, was driven down by changes in production technology, which reduced energy consumption by 21.6mtcr or 4.90%, assuming all other factors were constant.

3.2.1. Final Demand Shifts

Due to final demand shifts, the coal and lignite and electricity sectors have shown some reasonable increments (such as 96.85mtcr and 76.06mtcr), but there were abnormal movements in the crude petroleum sector such as 367.97mtcr, or 7.6% annually.

The overall energy consumption pattern in India shows a high GDP elasticity of commercial energy, caused partly by a steady subscription of non commercial fuels, in terms of crude petroleum and natural gas. The bulk of crude petroleum consumption in the industry and transport was mainly responsible. The energy impact of final demand shift can be viewed from three different dimensions:

(1) Level, Distribution and Pattern of Final Demand

The final demand level (i.e. overall level of total demand distribution), of distribution of total demand along individual final demand sectors and the pattern (i.e. spending mix) of individual final demand categories.

The energy use increase resulting from final demand shifts was a consequence of the increase in the overall level of spending (i.e. due to level effect), which happened to increase the total energy consumption by 408.11mtcr, or 92.63% (i.e. 5.9% annually). The contribution of crude petroleum in this respect was 257.54mtcr, or 85.85% (i.e. 5% annually).

The distribution of demand refers to the distribution of total demand along individual final demand sectors, such as public consumption, private consumption, gross final investment, exports, imports, etc. Changes in final demand distribution also increased energy consumption growth by 88.81mtcr, or 20.15% (i.e. 1.3% annually).

The pattern of demand refers to the mix of goods and services within each individual final demand category. Changes in the spending mix of the individual demand sectors increased energy consumption by 44.25mtcr, or 10.04%. But coal and lignite sector, in this respect, reduced energy consumption to 28.94mtcr, or 39.16% (i.e. 2.5% annually); although the other two sectors reacted positively.

It automatically follows that the individual spending pattern is towards more electrical goods (and is also machinery oriented), which contributes to the increase in the pattern effect by 35.47% (i.e. 2.2% annually) of the power sector.

(2) Sources of Final Demand

As for the sources related to private consumption, the increases were almost six times higher than that of public consumption. This is because the household sector is the largest consumer of energy, accounting for about 50% of total energy consumption. The other sources, such as capital investment (and the rise in exports) were the main force behind the energy use increase associated with final demand shifts. Private consumption increased by 362.18mtcr, or 82.20% (i.e. 5.1% annually); on the other hand, public consumption reached 62.78mtcr, or 14.24% (i.e. below 1% annually). The share of capital investment, in this respect, was 155.94mtcr, or 35.39% (i.e. 2.2 % annually). The contribution of exports, in this respect, was 83.91mtcr, or 19.04% (i.e. 1.2% annually). But this strong upward pressure on energy use was dampened by the rapid growth in imports, which saved India 125.98mtcr of energy, or 28.59%. Crude petroleum imports are rather high, at 84.19mtcr; more than the other two sectors: coal and electricity. The significant deviation between 1973-74 and 1989-90 is largely due to the rapid expansion of domestic demand, changes in input coefficient, and an increase in imports. These three effects have more than offset the increased dependence on imports.

(3) Different Product Groups

The total energy content of final demand consists two components. One is the direct delivery of primary and secondary energy sources to final demand, and the other is the energy content which is hidden in all goods and services of final demand. The contribution of the demand related energy use increases to purchases of energy by final consumer was 2% out of 122%; and the contribution of the demand related energy use increases to the purchases of non energy products was 120% out of 122%. Electricity contributes a major portion out of all energy products (i.e. 7.72mtcr or 1.75%); but

Table 1: Structural Decomposition Analysis of Energy Use Changes in India from 1973-74 to 1989-90

mtcr	Coal & Ing	Cr.Petro	Electricity	Total
Actual. Changes	157.75	236.22	125.31	519.28
Final.Dd.Shift	96.85	367.97	76.06	540.88
Level.Effect	104.94	257.54	45.63	408.11
Distribution. Effect	20.85	60.59	7.37	88.81
Pattern Effect	-28.94	49.53	23.66	44.25
Demand Source				
Pvt.Cons	56.92	257.30	47.96	362.18
Pub.Cons	14.63	40.50	7.65	62.78
Gr.Final.C.F.	29.25	103.84	22.85	155.94
Ch.In.Stk	2.21	-5.30	5.07	1.98
Export	15.99	55.82	12.10	83.91
Import	-22.24	-84.19	-19.55	-125.98
Product Group				
Coal & Lig	-0.18	-0.13	-0.27	-0.58
Cr.Petro&N.Gas	-0.005	-0.08	-0.004	-0.089
Electricity	3.63	0.66	3.43	7.72
Agriculture	3.87	31.79	6.97	42.63
Mining & Qua	-1.21	-6.45	-2.53	-10.19
Sugar	0.70	3.21	1.64	5.55
Food & Beve	4.78	16.12	3.99	24.89
Textile	19.47	42.75	22.02	84.24
Wood	0.03	0.12	0.04	0.20
Paper	2.28	2.53	2.24	7.05
Leather	0.42	1.63	0.41	2.46
Rubber & Plas	2.97	7.94	2.97	13.88
Petroleum. Pro	2.13	85.88	0.28	88.29
Fertilizer	-0.40	-1.59	-0.39	-2.38
Chemical. Pro	4.23	15.57	5.79	25.59
Cement	0.68	-0.15	-0.10	0.43
Oth.Non.Min.Pro	6.49	8.00	1.68	16.17
Basic.Metal & Pro&Ma	11.93	42.13	11.63	65.69
Construction	9.62	35.28	3.44	48.34
Transportser	6.11	40.81	2.56	49.48
Trade & Oth. Ser	19.19	41.94	9.26	70.39
Technology.Change	60.90	-131.75	49.25	-21.60
Energy.Inputs	62.52	-114.57	42.91	-9.14
Non.Energy.Inputs	-1.62	-17.18	6.34	-12.46
Sector				
Coal &Lig	-0.30	-0.39	-0.31	-1.00
Cr. Petro &N.Gas	-0.51	-1.23	-0.35	-2.09
Electricity	6.38	1.86	2.53	10.77
Agricultural	17.62	5.56	9.83	33.01
Mining & Qua	-0.60	0.89	-0.15	0.14
Sugar	0.85	-0.32	0.34	0.87
Food & Beve	5.14	-2.52	1.98	4.60
Textile	12.89	-7.69	13.52	18.72
Wood	0.05	0.049	0.03	0.12
Paper	0.02	-0.97	0.10	-0.85
Leather	0.59	-0.19	0.42	0.82
Rubber & Plas	-0.48	-5.39	-0.53	-6.40
Petroleum. Pro	5.71	-12.52	0.88	-5.93
Fertilizer	-1.30	-3.27	-0.77	-5.34
Chemical. Pro	0.29	-5.48	-0.72	-5.91
Cement	0.004	0.003	0.00	0.007
Oth.Non.Min.Pro	8.42	9.19	2.29	19.90
Basic.Metal & Metal Pro	8.07	-31.89	0.51	-23.31
Construction	5.15	-20.42	14.59	-0.68
Transportser	0.12	-25.38	1.35	-23.91
Trade & Oth. Ser	-7.22	-31.61	3.68	-35.15

coal has the largest downward effect on energy use (i.e. 0.58mtcr). The expenditure on textile, petroleum, and basic metal & metal products, and machinery, construction, transport services, trade and other services augmented India's energy consumption from 1973-74 to 1989-90; the contributions being 84.24mtcr or 19.12%, 88.29mtcr or 20.03%, 65.69mtcr or 14.19%, 48.34mtcr or 10.97%, 49.48mtcr or 11.23% and 70.39mtcr or 15.97% respectively. The remaining contributions were made by agriculture at 42.63mtcr (i.e. 9.67% annually), chemical products at 25.29mtcr (i.e. 5.80% annually), rubber and plastic at 13.88mtcr, and other non metallic mineral products at 16.17mtcr. From the interrelationship between energy and non energy sectors of the economy it has been found that energy sectors depend more or less on transport, chemical industries and the engineering sectors, and all the non energy sectors are interdependent on themselves, in addition to their dependency on energy sectors. A higher spending on textile leads to a 26.34% increase in coal and lignite, 14.25% increase in crude petroleum and 33.01% increase in electricity. Besides, petroleum products, chemical products, construction, transport services trade and other services increased the consumption of crude petroleum only. A major exception, in this respect, was mining and quarrying, which caused a decrease in the consumption of three (fuel types) sectors.

It is quite remarkable that, despite the oil price hike of 1973, the petroleum industries picked up a very high growth rate in India. This growth can be attributed, to a great extent, to the heavy pressure on the domestic economy to combat the continuous deterioration in the balance of payments, which was largely due to petroleum imports. Similarly, the consumption of petroleum products also grew sharply, such as 5.3% in the 6th plan, 6.4% in the 7th plan and 53mt in 1989-90. The introduction of the diesel irrigated pumpset (6th plan) is largely responsible in this respect. To combat the situation, a number of bottleneck reducing measures, and refinery expansion projects have been taken up during 6th, as well as in the 7th plan, period which improve refining capacity but indirectly hurts the electricity sector. The intensity of energy use in the power sector has been rising sharply, mainly on account of higher electricity consumption. The relatively high proportion in the industry mix of power intensive primary metal industries (during the initial stages of industrialization, and substitution of other energy forms by electricity) appears to have contributed to the high electricity intensity. These caused an increase in energy consumption in the power sector.

3.2.2. Production Technology Changes

Production technology changes reduced energy consumption (or increased efficiency improvement) from 1973-74 to 1989-90 by 21.6mtcr or 4.90%, on the whole. Compared with the energy requirements of using 1973-74 production technology to satisfy 1989-90 final demand, the adoption of 1989-90 production technology saved about 21.6mtcr, which was 4.9% of the 1973-74 total energy consumption; out of which energy inputs cover 9.14mtcr or 2.07%, and non energy inputs cover 12.45mtcr or 2.82%. The only contribution was made by crude petroleum sector, in this respect, which was 131.75mtcr, or 43.91% or 2.7% annually. The other two sectors increased

Table 2: S.D.A on the Growth Rate of Energy Consumption in the Indian Economy from 1973-74 to 1989-90 (% of 1973-74 Total Energy Consumption)

% Contribution	Coal	Cr. Petro	Electricity	Total
Actual. Change	213.46	78.74	187.89	117.86
Final .Dd.Shift	131.05	122.66	114.05	122.76
Level. Effect	142.00	85.85	68.42	92.63
Distribution. Effect	28.21	20.19	11.05	20.15
Pattern Effect	-39.16	16.51	35.47	10.04
Demand Source				
Pvt.Cons	77.02	85.77	71.91	82.20
Pub.Cons	19.79	13.50	11.47	14.24
Gr.In.Stk	39.58	34.61	34.26	35.39
Ch.In.Stk	2.99	-1.76	7.60	0.44
Export	21.63	18.60	18.14	19.04
Import	-30.09	-28.06	-29.31	-28.59
Product Group				
Coal & Lig	-0.24	-0.04	-0.40	-0.13
Cr.Petro & N.Gas	-0.00	-0.02	-0.00	-0.02
Electricity	4.91	0.22	5.14	1.75
Agriculture	5.23	10.59	10.45	9.67
Mining & Qus	-1.63	-2.15	-3.79	-2.31
Sugar	0.94	1.07	2.45	1.25
Food & Beve	6.46	5.37	5.98	5.64
Textile	26.34	14.25	33.01	19.12
Wood	0.04	0.04	0.06	0.04
Paper	3.08	0.84	3.35	1.60
Leather	0.56	0.54	0.61	0.55
Rubber & Plas	4.01	2.64	4.45	3.15
Petroleum.Pro	2.88	28.62	0.41	20.03
Fertilizer	-0.54	-0.53	-0.58	-0.54
Chemical.Pro	5.72	5.19	8.68	5.80
Cement	0.92	-0.05	-0.14	0.09
Oth.Non.Min.Pro	8.78	2.66	2.51	3.67
Basic.Metal & Pro & Ma	16.14	14.04	17.43	14.91
Construction	13.01	11.76	5.15	10.97
Transportser	8.26	13.60	3.83	11.23
Trade & Oth.Ser	25.96	13.98	13.88	15.97
Technology.Change	82.40	-43.91	73.84	-4.90
Energy.Inputs	84.60	-38.19	64.34	-2.07
Non.Energy.Inputs	-2.19	-5.72	9.50	-2.82
Sector				
Coal & Lig	-0.40	-0.13	-0.46	-0.22
Cr.Petro & N.Gas	-0.69	-0.41	-0.52	-0.47
Electricity	8.63	0.62	3.79	2.44
Agriculture	23.84	1.85	14.73	7.49
Mining & Qua	-0.81	0.29	-0.22	0.03
Sugar	1.15	-0.10	0.50	0.19
Food & Beve	6.95	-0.84	2.96	1.04
Textile	17.44	-2.56	20.27	4.24
Wood	0.06	0.01	0.04	0.02
Paper	0.02	-0.32	0.15	-0.19
Leather	0.79	-0.06	0.62	0.18
Rubber & Plas	-0.64	-1.79	-0.79	-1.45
Petroleum & Plas	7.72	-4.17	1.31	-1.34
Fertilizer	-1.75	-1.09	-1.15	-1.21
Chemical.Pro	0.39	-1.82	-1.07	-1.34
Cement				
Oth.Non.Min.Pro	11.39	3.06	3.43	4.51
Basic.Metal & Metal Pro	10.92	10.63	0.76	-5.29
Construction	6.96	-6.80	21.87	-0.15
Transportser	0.16	-8.46	2.024	-5.42
Trade & Oth.Ser	-9.76	-10.53	5.51	-7.97

energy consumption through production technology change by 60.90 mtcr or 82.40% and 49.25mtcr or 73.86%. The energy sector usually depends directly on a limited number of sectors but —indirectly— on almost all the sectors. In terms of sectoral contribution, the production technology changes in petroleum products, fertilizer, rubber, plastic, trade, transport, textile and construction services were the most important sources of energy savings in the crude petroleum sector, which saves energy directly, as well as indirectly. The energy efficiency improvements of any one sector will be multiplied across the entire economy by reducing their direct energy requirements in those sectors, which use an industry's product as an input. For example, a higher efficiency rate in the crude petroleum sector not only reduces its own energy intensity, but also that of the petroleum products sector and other energy intensive sectors. The percentage contribution of energy savings in crude petroleum sector (in terms of non energy inputs such as basic metal, metal products and machinery, construction, transport services, trade and other services, petroleum products, textiles) were 31.89mtcr (i.e. 10.63% annually), 20.42mtcr (i.e. 6.80% annually), 25.38mtcr (i.e. 8.46%), 31.61mtcr (i.e. 19.53%), 12.52mtcr (i.e. 4.17%), 7.69mtcr (i.e. 2.56%), respectively during our study period.

The slower response was seen from the production side, through technical changes, because it involves not only new investments but also alterations in production. Still, these partial technological improvements in few sectors have been possible due to technological advancements in various industries and the infrastructure. Important improvements were made in petroleum refineries and petrochemical plants, to reduce energy consumption and improve yields. But the impact of technological achievements on productivity was seen mainly in new projects and in a few existing establishments. The effects of these changes suggest that one major characteristic of India's technological changes in this period was the substitution of material inputs for energy inputs in a few sectors. Smaller energy input requirement per unit of output worked directly, and indirectly, to reduce the total energy use. During 1973-74 to 1989-90 periods, changes in energy input coefficient and non energy input coefficients both worked to drive down the energy consumption of the Indian economy. This suggests that energy intensive goods lose their share directly, as well as indirectly. These changes were due to several factors. Firstly, the government's decision to cushion energy prices by means of a gradual increase is a major factor here. Secondly, there was some conservation measures, such as a shift towards energy saving equipment.

4. Summary and Conclusion

The present work concerns the changes that took place during 1973-74 to 1989-90 in India's energy consumption, and looks into the sources of changes during the same period, using an Input-Output framework. We have developed a Structural Decomposition Analysis (SDA) in this paper.

The findings show that India's energy consumption increased by 519.28mtcr (Table 1), or 7% annually, during 1973-74 to 1989-90.

Two main forces behind these changes which are observed are (1) Final demand shift, (2) Production Technology Change.

The most significant role, as revealed from the empirical results, has been played by the shift of final demand component. The changes in the final demand shift has increased India's total energy consumption by 540.88mtcr (Table 1), or 7% annually in 1973-74 to 1989-90. This was led by changes in the structure of level effect (i.e. 408.11mtcr i.e. 5.8% annually). But distribution and pattern effects have a marginal impact on final demand shift (88.81mtcr i.e. 1.2% annually) and 44.25mtcr (i.e. 0.62% annually), respectively. Among sectoral classifications, the crude oil and natural gas sector contributes more, due to final demand shift (367.97mtcr i.e. 6% annually), but the coal & lignite and electricity sector contributes a nominal impact (96.85mtcr and 76.06mtcr). Among the demand source concerning results from final demand shift was dominated by private consumption (i.e. 362.18mtcr) (Table 1). The rest was shared by gross capital formation as 155.94mtcr (Table 1), public consumption by 62.78mtcr, export by 83.91mtcr and import by 125.98mtcr.

On the other hand, the production technology changes component has reduced energy consumption marginally by 21.6mtcr (Table 1) or 0.30% annually out of it the contribution of crude oil sector to the energy savings was disproportionally large 131.75mtcr or 2.7% per annum; but the electricity and coal sector showed an opposite trend (i.e. they increased energy consumption by 60.9mtcr or 4% annually, and 49.25mtcr or 5% annually respectively). More specifically, the changes in energy input coefficients and non energy input coefficient both worked directly and indirectly to reduce energy consumption, but only marginally. In both cases the major share goes to the crude oil sector. In terms of sectoral contribution, the production technology changes in the petroleum products industry, basic metal industry, construction, transport, trade and other services were the most important sources of energy savings, due to the higher energy efficiency in the crude petroleum sector. But the electricity sector pushed up energy consumption.

Comparing the pattern of energy consumption changes of India with that of other less developed countries, such as China, it can be mentioned that between 1981 and 1987, China's total primary energy consumption increased by 263million tsce (i.e. 6% annually) (Lin and Polenske, 1993). Final demand shifts —the increase in the level of economic activities and shifts in spending mix towards more energy intensive products — was the main factor that pushed energy use upward. All else being equal, these shifts have increased energy consumption by 487 millions tsce (i.e. 13% annually). This upward pressure on energy demand depends, however, on changes in production technology, which reduced energy use by 224million tsce (i.e. 6% annually). All these energy savings came from improvements in energy efficiency —reductions in direct input coefficients reducing primary energy by 45.6%, 7.5% annually. Lin and Polenske's study has identified three macro economic factors which explain energy efficiency increases in the Chinese economy between 1981 and 1987: (1) energy conservation (2) improvements in macro economic performance and (3) increases in energy prices.

Nevertheless, the pattern in developed countries, such as Japan, in this context is quite the opposite. Its primary energy demand, however, increased by only 11% during 1975-1980, and 4% during 1980-85. As a result, the energy intensity of the Japanese economy. While the ratio dropped sharply from 65.61 BTU/YEN in 1975 to 58.87 BTU/YEN in 1980 (Han and Lakshmanan, 1994). The economic restructuring in Japan has taken place by shifting its industrial structure significantly away from resources energy intensive sectors (chemicals, iron and steel) towards high value added, knowledge intensive sectors (electrical machinery, precision instruments and motor vehicles). Such a shift, by itself, has altered the level and mix of energy use in the Japanese economy. Indeed, one of the major conclusion of Han and Lakshmanas's analysis is that, in the decade 1975-85, changes in the structure of final demand contributed more towards reducing the energy intensity of the Japanese economy, than the effect of changes in technology.

On the other hand, the performance of India's energy sector, as the findings of the study show, is rather discouraging. Instead of energy savings, energy consumption increased by 7% annually during the period 1973-74 to 1989-90. Although, technological changes have reduced energy consumption marginally, the consumption of energy has still gone up, due to a final demand shift. Various policies have been adopted by the government during these periods, in order to reduce energy consumption; but we can observe from the present study that since success has not been achieved in the desired direction (considering the above situation), it would be rather prudent, on our part, to point out a few important issues that should receive particular attention in the drawing up of future energy policy.

The results from our study have important policy implications, including one related to the final demand changes, and another related to technological changes. One way in which India's policy makers can avoid a rapid increase in energy consumption is to adopt policies that promote less energy intensive components of final demand. They can determine the types of policy in order to continue to bring about a change in the patterns of final expenditures to patterns that are less energy intensive. A suitable pricing policy can be adopted in order to achieve these goals. Adopting policies that will encourage industries to change to more energy efficient technologies is another way for policy makers to affect energy consumption. One of the most feasible policy options appears to be the introduction of new technology at a more rapid rate than in the past. For example, the reductions in energy intensity can be caused by changes in production technology in sectors such as basic metals, construction, transport and petroleum products.

To achieve this the government will have to provide fiscal incentives linked to energy savings. Apart from these measures, there is a need for a technological upgrading of the power supply systems, in generation, as well as transmission and distribution. A sufficiently strong R & D base will be needed. The R & D programme must include the development of technologies for decentralized power generation. Last, but not least, energy conservation, which also depends on proper R & D and technology development, should be enhanced.

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