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# Derivates of Energy Consumption and Energy Strength in Pakistan: An Application of Complete Decomposition Model

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**Abstract:** In present study complete decomposition model employed to decompose the changes in energy consumption and energy strength in Pakistan during 1960 to 1998. A general decomposition model raises a problem due to residual term. In some models the residual term is omitted that cause a large estimation error, while in some models the residual term is regarded as an interaction that might create a puzzle for the analysis. A complete decomposition model used here to solve this problem.

**Key words:** Complete decomposition model, energy consumption, energy strength and residual term

## INTRODUCTION

The National Economy could be disaggregated into two groups-one group consists of low-energy intensive sectors and other consists of high-energy intensive sectors. If decomposition model applies at this level called single level decomposition or decomposition at level one or decomposition at groups level. If each group could be further disaggregated into several sectors, and then decomposition at sector level will be attributed decomposition at level two (Fig. 1). If decomposition is carried out at more than one level is being called as a multilevel decomposition. For present analysis only a single level decomposition model is used to estimate the changes in energy consumption and changes in energy strength in Pakistan.

Actually, the decomposition models lead to an approximate decomposition. This kind of decomposition

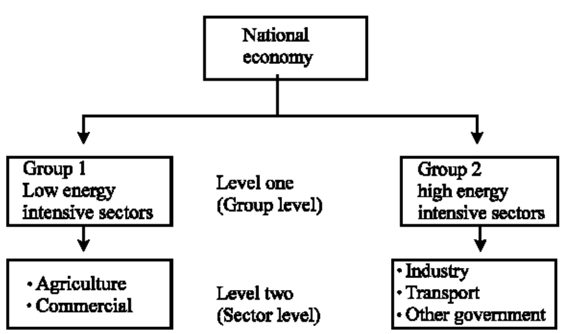


Fig. 1: Disaggregation of the economy at various levels

methods have been proposed by Hankinson and Rhys (1983), Reitler *et al.* (1987), Boyd *et al.* (1988), Doblin and Claire (1988), Howarth (1991), Howarth and Schipper (1992), Park (1992, 1993) and so on. The main imperfection of these methods is the residual term. The residual term in most studies was omitted (Hankinson and Rhys, 1983; Reitler *et al.* 1987; Boyd *et al.*, 1988; Doblin and Chaire, 1988; Howarth, 1991; Howarth and Schiper, 1992) and in some studies was called the interaction of effects (Park, 1992, 1993). The omitted residual causes a large estimation error, and regarded as an interaction that might create a puzzle for the analysis. The purpose of employing the Complete Decomposition Model (CDM) is to improve the reliability and accuracy of the analytical model Sun (1996).

The aim of the study is to decompose the changes in energy consumption and the changes in energy strength in Pakistan during the period 1960-1998. The change in energy consumption is decomposed into the scale of economic activity (the activity effect), the sectorial technological level (the strength effect) and the economic structure (the structural effect). While the change of energy strength is decomposed into sectorial energy strength effect and sectorial structural effect Sun (1998). The purpose of employing complete decomposition model is to decompose the change of energy use in Pakistan is to quantify the contribution of each effect and different energy intensive groups to the change of energy consumption and the change of energy strength in Pakistan during the period under consideration. In this

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study economy is divided into two groups-Group1consists of low energy intensive sectors and Group2 consists of high-energy intensive sectors.

Several studies in energy economics have employed the technique of decomposition to examine the changes of energy consumption and changes of energy strength. The studies by Liu *et al.* (1992) and Ang and Lee (1994) deal with decomposition technique that we shall refer to as the energy consumption approach, i.e. decomposition over time into contributions from changes in aggregate production (production effect), production structure (structural effect) and sectoral energy intensities (strength effect). While several analysts have also been proposed method, using the energy strength approach where decomposition is carried out on changes in aggregate energy strength. In the energy strength approach, changes in aggregate strength are decomposed into contributions from structural and strength effects only. Example of such studies are Jenne and Cattell (1983), Bending *et al.* (1987). The energy strength approach has been used in a large number of empirical and country specific studies Bossanyi (1979), Jenne and Cattell (1983) Ang (1994), Li *et al.* (1990), Gardner, (1993) and Huang, (1993).

## MATERIALS AND METHODS

**Complete decomposition model:** To study the impact of structural changes (i.e., shifts in the composition of total output) and energy consumption on aggregate energy efficiency improvement, the national energy strength will be decomposed with the help of Complete Decomposition Model (CDM). The general decomposition model leads to an approximate decomposition because it has a residual term. The residual influences the accuracy of model. In some studies residual was omitted that cause a large estimation error, the residual was regarded as an interaction that still leaves a new puzzle for analysis. The complete decomposition model has solved this problem. The complete decomposition model for explaining the relationship between energy consumption and the change of the energy strength could be written as follows:

**THE ENERGY STRENGTH MODEL (ESM):** Aggregate energy strength:
Change in aggregate energy strength:
Where,

$I^t$ = Aggregate energy strength in year t ($I^t = E^t/Y^t$)

- $S_i^t$ = Output share of group I (where I = 1,2) in GDP in year t ($S_i^t = Y_i^t / Y^t$).
- $I_i^t$ =Energy strength of group i (where i = 1,2) in year t ($I_i^t = E_i^t / Y_i^t$).

The changes in aggregate energy strength are attributed by the sectorial energy strength effect ($II_{effect}$) and the sectorial structural effect ($IS_{effect}$). Therefore the decomposition model for the change in energy strength would be:
where,

$$II_{effect} = \sum_i S_i^o \Delta I_i + \frac{1}{2}\sum_i \Delta I_i \Delta S_i \quad (1)$$

$$IS_{effect} = \sum_i I_i^o \Delta S_i + \frac{1}{2}\sum_i \Delta S_i \Delta I_i \quad (2)$$

Thus contribution of the change of group i (where i = 1,2) to the total change of energy strength would be:

$$I_{groupi} = S_i^o \Delta I_i + I_i^o \Delta S_i + \Delta I_i \Delta S_i \quad (3)$$

First term of the above equation indicates the contribution of change in energy strength of group i. The second term represent the contribution of changes in production share of group i, while third term indicates the interaction between both factor changes in group i.

**Energy consumption model:**
Final energy consumption:
The change in energy consumption:
where,

- $E^t$ = Energy consumption in yeart t
- $E^o$ = Energy consumption in base year (t=0)
- $I_i^t$ = Energy strength of group i in year t
- $S_i^t$ = Output share of group i in year t
- $Y^t$=Aggregate output in year t

Since energy consumption and the change in energy consumption is influenced by the activity effect ($EY_{effect}$), structural effect ($ES_{effect}$) and strength effect ($EI_{effect}$), thus the decomposition model for the change in energy consumption would be:

$$\Delta E = EY_{effect} + ES_{effect} + EI_{effect} \quad (3)$$

This is an exact decomposition, where

$$EY_{effect} = \Delta Y \sum_i I_i^o S_i^o + \frac{1}{2}\Delta Y \sum_i (I_i^o \Delta S_i + S_i^o \Delta I_i) + \frac{1}{3}\Delta Y \sum_i \Delta I_i \Delta S_i \quad (4)$$

$$Es_{effect} = Y^o \sum_i I_i^o \Delta S_i + \frac{1}{2}\sum_i \Delta S_i (I_i^o \Delta Y + Y^o \Delta I_i) + \frac{1}{3}\Delta Y \sum_i \Delta I_i \Delta S_i \quad (5)$$

$$Ei_{effect} = Y^{\circ} \sum_i S_i^{o} \Delta I_i + \frac{1}{2} \sum_i \Delta I_i (S_i^{o} \Delta Y + Y^{\circ} \Delta S_i) + \frac{1}{3} \Delta Y \sum_i \Delta I_i \Delta S_i \quad (6)$$

Where, first term of above 3 equations represents the contribution of the change of factor Y(Production), S(Group share in total production) and I(Strength) respectively to the total change in energy consumption. The second term represents the contribution of change of one factor with sum of the partial changes of other two factors with respect to group *i*. The third term is the residual in the general decomposition model. It could be attributed either to Y(Production), I (Strength) or S (Group share of total production) by equal impact. That contribution is dependent on all of the three changes and if only one of them goes to zero the other effects disappears. When there is no reason to assume contrary, it is divided equally to Y, I's and S's contribution.

$Y_i^{o}$ = Aggregate output in base year (t = 0)
$I_i^{o}$ = Strength of gorup i (i = 1,2) in base year (t = 0)
$S_i^{o}$ = Output share of group i (i = 1,2) in base year (t = 0)
$\Delta Y$= Change in aggregate output (GDP)
$\Delta Y= Y^{t} - Y^{o}$
$\Delta I_i$= Change in strength of group i (where i = 1,2)
$\Delta I_i= I_i^{t}-I_i^{o}$
$\Delta S_i$= Change in output share of group i (where i = 1,2)
$\Delta s_i= S_i^{t}-S_i^{o}$

Therefore, contribution of the change of group *i* to the total change of energy consumption would be:

$$E_{group\,i} = I_i^{o} S_i^{o} \Delta Y + Y^{\circ}(S_i^{o} \Delta I_i + I_i^{o} \Delta S_i) + Y^{\circ} \Delta S_i \Delta I_i + I_i^{o} \Delta Y \Delta S_i + S_i^{o} \Delta Y \Delta I_i + \Delta Y \Delta I_i \Delta S_i \quad (7)$$

The first term represents the contributio of change in Y (Total production), second term indicates the sum of changes in I(Strength) and S (Group share in production) with other two factors at base year, third, fourth and fifth term represent the contribution of changes in two factors out of three with third factor at base year and last term attributed changes in all three factors.

## EXPERIMENTAL DATA

The annual data of Gross Domestic Product (GDP), between 1960 and 1998 in local currency of 1981 price, are collected from Pakistan Economic Survey and 50 Years of Pakistan, Federal Bureau of Statistics. Sectoral Energy consumption data are compiled from Pakistan Energy Data book and Pakistan Energy Yearbook, ministry of petroleum and natural resources, government of Pakistan. All are converted into tonnes of oil equivalent.

## RESULTS AND DISCUSSION

The commercial energy consumption, GDP and aggregate energy strength in Pakistan for various benchmark years is reported in Table 1. The commercial energy consumption in Pakistan during the period 1960-1998 increased by nine fold, which is greater than the GDP Growth During the Period. The aggregate energy strength of the national economy in the same period increased 3.9 toe/million Rs. at 1980-81 constant price from 23.38 toe/million Rs. in 1960 to 27.28 toe/million Rs. in 1998. The energy consumption in Group-1 (Low energy intensive sectors) was increased by 1.35 Mtoe from 0.16 Mtoe in 1960 to 1.51 Mtoe in 1998 while in Group-2 (High energy intensive sectors), it was increased by 14.6 Mtoe from 1.87 Mtoe in 1960 to 16.47 Mtoe in 1998. While GDP increased by Rs. 572.4 billion from Rs. 46.5 billion in 1960 to Rs.245.7 billion in 1998 in Group1, whereas GDP of Group 2 was increased by Rs. 238 billion from Rs. 22 billion in 1960 to Rs. 260 billion in 1998.

There are some interesting results about energy strength for both groups. The energy strength of low energy intensive group was increased by approximately two fold from 1960 to 1998 while the energy strength of high energy intensive group was decreased gradually by 25 percent of the strength of 1960. Group-1 contributes only 8.5% in total change of energy consumption, while group-2 contributes 91.5% during the period.

**Decomposition of the change in energy strength:** Table 2 reports the factor analysis of the change of energy strength. For the total strength change structural effect is found to be positive and strength effect was negative in all sub-periods and during the whole period (1960-1998). Which implies that, energy strength increased by 9.47 toe/million Rs. due the structural effect and decreased by 5.56 toe/million Rs. due to strength effect during the period under consideration. As a result, the increase in aggregate strength was 3.91 toe/million Rs. in the same period. The results indicate that, the increase in aggregate energy strength due mainly to structural effect because, in Pakistan structural changes were appeared to the significant during the same period. Consequently, it appears, that, aggregate energy efficiency reduced due to structural change in the country.

Contribution of groups to the total change in energy strength are reported in Table 3. Results indicate that high

Table 1: Final energy consumption, GDP and energy strength in Pakistan

| | 1960 | 1960-70 | 1970 | 1970-80 | 1980 | 1980-90 | 1990 | 1990-98 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| **Pakistan** | | | | | | | | | |
| EC | 2.02 | 2.18 | 4.20 | 2.73 | 6.93 | 6.30 | 13.23 | 4.75 | 17.98 |
| GDP | 86.60 | 77.40 | 164.00 | 97.00 | 261.00 | 213.00 | 474.00 | 185.00 | 659.00 |
| I | 23.38 | 2.24 | 25.61 | 0.93 | 26.54 | 1.36 | 27.90 | -0.62 | 27.28 |
| **Low energy intensive sectors (Group 1)** | | | | | | | | | |
| EC | 0.16 | 0.20 | 0.36 | 0.30 | 0.66 | .050 | 1.16 | 0.34 | 1.51 |
| GDP | 46.49 | 33.17 | 79.67 | 28.98 | 108.64 | 70.14 | 178.78 | 66.90 | 245.68 |
| I | 3.34 | 1.18 | 4.52 | 1.58 | 6.10 | 0.41 | 6.51 | -0.38 | 6.13 |
| **High energy intensive sectors (Group 2)** | | | | | | | | | |
| EC | 1.87 | 1.97 | 3.84 | 2.42 | 6.26 | 5.80 | 12.06 | 4.41 | 16.47 |
| GDP | 22.15 | 26.06 | 48.21 | 42.56 | 90.77 | 88.04 | 178.81 | 81.08 | 259.99 |
| I | 84.37 | -4.71 | 79.66 | -10.65 | 69.02 | -1.55 | 67.47 | -4.10 | 63.36 |

Unit:Energy consumption in million toe, GDP in billions Rs.1980-81, and energy strength in toe/million Rs. Source: Pakistan economic survey and Pakistan energy yearbook

Table 2: Factor analysis of the change of energy strength

| | Contribution to the total change by | | |
|---|---|---|---|
| Time period | Structural effect | Strength effect | Total change |
| 1960-1970 | 2.93 (130.80%) | -0.69 (-30.80%) | 2.24 (100.00%) |
| 1970-1980 | 3.63 (390.32%) | -2.70 (-290.32%) | 0.93 (100.00%) |
| 1980-1990 | 1.76 (128.47%) | -0.39 (-28.47%) | 1.37 (100.00%) |
| 1990-1998 | 1.10 (-174.60%) | -1.73 (274.60%) | -0.63 (100.00%) |
| 1960-1998 | 9.42 (240.92%) | -5.51 (140.92%) | 3.91 (100.00%) |

Unit: Toe /Million Rs

Table 3: Contribution of groups to the total change in energy strength

| | Contribution to the total change by | | |
|---|---|---|---|
| Time period | Low energy intensive group | High energy intensive group | Total change |
| 1960-1970 | 0.40 (17.86%) | 1.84 (82.14%) | 2.24 (100.00%) |
| 1970-1980 | 0.35 (37.63%) | 0.58 (62.37%) | 0.93 (100.00%) |
| 1980-1990 | -0.08 (-5.84%) | 1.45 (10.5.84%) | 1.37 (100.00%) |
| 1990-1998 | -0.18 (28.57%) | -0.45 (71.43%) | -0.63 (100.00%) |
| 1960-1998 | 0.49 (12.53%) | 3.42 (87.47%) | 3.91 (100.00%) |

Unit: Toe /Million Rs

Table 4: Factor analysis for the change of energy consumption

| | Contribution to the total change by | | | |
|---|---|---|---|---|
| Time period | Activity effect | Structural effect | Strength effect | Total change |
| 1960-1970 | 1.89 (87.10%) | 0.37 (17.05%) | -0.09 (-4.15%) | 2.17 (100.00%) |
| 1970-1980 | 2.55 (93.75%) | 0.77 (28.31%) | -0.60 (-22.06%) | 2.72 (100.00%) |
| 1980-1990 | 5.80 (92.06%) | 0.65 (10.32%) | -0.15 (-2.38%) | 6.30 (100.00%) |
| 1990-1998 | 5.11 (107.58%) | 0.62 (13.05%) | -0.98 (-20.63%) | 4.75 (100.00%) |
| 1960-1998 | 15.35 (96.30%) | 2.41 (15.12%) | -1.82 (-11.42%) | 15.94 (100.00%) |

Unit: million Toe

Table 5: Contribution of groups to the total change in energy consumption

| | Contribution to the total change by | | |
|---|---|---|---|
| Time period | Low energy Intensive group | High energy Intensive group | Total change |
| 1960-1970 | 0.20 (9.22%) | 1.97 (90.78%) | 2.17 (100.00%) |
| 1970-1980 | 0.30 (11.03%) | 2.42 (88.97%) | 2.72 (100.00%) |
| 1980-1990 | 0.50 (7.94%) | 5.80 (92.06%) | 6.30 (100.00%) |
| 1990-1998 | 0.34 (7.16%) | 4.41 (92.84%) | 4.75 (100.00%) |
| 1960-1998 | 1.34 (8.40%) | 14.60 (91.60%) | 15.94 (100.00%) |

Unit: Million Toe

energy intensive group (industry, transport and other government sectors) contributes 87.5% change in aggregate energy strength change, during the whole time period considered. In all sub-periods high energy intensive group shows large change and low energy intensive group shows small change in total energy strength changes. This could be a result of improved efficiency of energy use of relatively high energy intensive group.

**Decomposition of the change in energy consumption:** The factor analysis for the change of energy consumption is presented in Table 4. The energy consumption increased 14.82 Mtoe and 3.37 Mtoe by the activity effect and structural effect, respectively, however, the energy consumption decreased 2.24 Mtoe by strength effect (improvement of energy efficiency) during the period of consideration. Finally, the total energy consumption increased 15.94 Mtoe in the same period. In all sub-periods energy consumption has been increased by the activity effect and structural effect while aggregate energy consumption has been decreased by strength effect, which also reinforce earlier results that structural effect is appeared to more pronounced for the impact of energy efficiency in the country during the period under consideration.

Contribution of groups to the total change in energy consumption is reported in Table 5. Results show that, high-energy intensive group contributes large increase and low energy intensive group contributes small increase in total increase of aggregate energy strength during the period under consideration. From 1960 to 1998 total increases in aggregate energy strength was 16%, in which high-energy intensive group contributes 91.6% and low energy intensive group contributes only 8.4%. These results reconfirm preceding fidnings that high energy intensive group is mainly responsible for improved efficiency of energy use in the country, during the period under consideration.

## CONCLUSION

The complete decomposition model provides a method for factor analysis of aggregate energy strength and aggregate energy consumption. The present study has been conducted on the factor analysis for the change of energy strength and energy consumption in Pakistan in 1960-1998. The results show that increase in aggregate energy strength is mainly due to the structural effect while increase in aggregate energy consumption is due to both the activity effect and structural effect. This may leads to the conclusion that put inefficient use of energy in the country due to the change in economic structure and economic activities in the country. These results further indicate that improved efficiency of energy use could be due to the efficient use of energy by relatively high energy intensive group compare to the inefficient use of energy by low energy intensive group in the country. However, we do not know the reasons for inefficiency of energy use; there may be system loses, lack of system reliability, inefficient management, poor institutional frameworks and inefficient manpower. The policy implications for the improvement of energy efficiency are the adoption of explicit conservation policies that go beyond the steps involved in rational energy pricing, public awareness efforts, audits of energy use, and other methods to foster energy savings also should be promoted and supported.

## REFERENCES


Ang, B.W. and S.Y. Lee, 1994. Decomposition of industrial energy consumption. Some methodological and application issues, Energy Econ., 16: 83-92.

Ang, B.W., 1994. Decomposition of industrial energy consumption. The energy strength approach, Energy Econ., 16: 163-174.

Bending, R.C., R.K. Cattell and R.J. Eden, 1987. Energy and Structural Change in the United Kingdom and Western Europe, Annual Review of Energy, 12: 185-222.

Bossanyi, E., 1979. UK Primary Energy Consumption and the Changing Structure of Final Demand. Energy Policy, 7: 253-258.

Boyd, G.A., D.A. Hanson and T. Sterner, 1988. Decomposition of Changes in Energy Strength: A Comparison of the Divisia Index and Other Methods, Energy Econ., 10: 309-312.

Doblin, C.P. and P. Claire, 1988. Declining energy strength in the US manufacturing sector. Energy J., 9: 109-135.

Gardner, D.T., 1993. Industrial Energy Use in Ontario From 1962 to 1984, Energy Econ., 15: 25-33.

Hankinson, G.A. and J.M.N. Rhys, 1983. Electricity Consumption, Electricity and Industrial Structure, Energy Econ., 5: 146-152.

Howarth, B. Richard, 1991. Energy Use in U.S. Manufacturing: The Impacts of the Energy Shocks on Sectoral Output, Industry Structure, and Energy Strength. J. Energy and Dev., 14: 175-191.

Howarth, R.B. and L. Schipper, 1992. Manufacturing Energy Use in Eight OECD Countries: Trends Through 1988, Energy J., 12: 1540.

Huang, J.P., 1993. Industrial Energy Use and Structural Change: A Case Study of the Peoples' Republic of China. Energy Econ., 15: 131-136.

Jenne, C.A. and R.K. Cattell, 1983. Structural Change and Energy Efficiency in Industry, Energy Econ., 5: 114-123.

Li, J., R.M. Shrestha and W.K. Foell, 1990. Structural Change and Energy Use: The Case of the Manufacturing Sector in Taiwan, Energy Econ., 12: 109-115.

Liu, X.Q., B.W. Ang and H.L. Ong, 1992. The Application of Divisia Index to the Decomposition of Changes in Industrial Energy Consumption. The Energy J., 13: 161-177.

Park, S.H., 1992. Decomposition of Industrial Energy Consumption, Energy Econ., 13: 265-270.

Park, S.H., B. Dissmann and K.Y. Nam, 1993. A Cross-Country Decomposition Analysis of Manufacturing Energy Consumption, Energy, 18: 843-857.

Reitler, W., M. Rudolf and H. Schaefer, 1987. Analysis of the Factor Influencing Energy Consumption in Industry: A Revised Method, Energy Econ., 9: 145-148.

Sun, J.W., 1996. Quantitative analysis of energy consumption, efficiency and savings in the world, 1973-1990. Turku School of Economics Press.

Sun, J.W., 1998. Changes in energy consumption and energy strength: A complete decomposition model, Energy Econ., 20: 85-100.