Disaggregated Energy Consumption, Industrial Output and GDP
A Co integration Analysis

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2012

CERTIFICATE

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ACKNOWLEGDMENT

In the first place I would like to record my gratitude to Dr. Hasan M Mohsin for his supervision, advice, and guidance from the very early stage of this research as well as giving me extraordinary experiences throughout the work. Above all and the most needed, he provided me unflinching encouragement and support in various ways. I gratefully thank Dr. Arshad Khan for his constructive comments on this thesis. I am thankful that he went through the whole draft critically and suggested improvements.

I would like to thank my friends Imran Arif, Zohaib Umer, Muhammad Ramzan, Hamid Mehmood, Dr. Haroon and Waqas Saleem for their support. I do not have words to thank Mr. Ahmed Waqar Qasim and Waseem Asghar who extended enormous help from the very start till the submission of the thesis.

To

Sufian Ishaque

Ayesha Ishaque

&

Asma Ishaque

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ABSTRACT

This study analyzes the impact of disaggregate energy consumption on GDP, industrial output and agriculture output, separately, has been empirically tested using time series data from 1972-2010. The study uses ARDL approach to cointegration. The major findings of the study are; electricity consumption has no long run relationship with the GDP while positively affects GDP in the short run only. Oil and gas consumption has positive relationship with GDP in the long run while coal consumption has positive cointegration with GDP but with a small magnitude. When the impact of disaggregate energy on industrial output is analyzed, it is found that electricity and gas consumption has a positive long run relationship with GDP while Oil consumption has a connection with industrial output only in the short run. Coal consumption is found to have no linkage with industrial output both in shot run and long run. The existence of cointegration between disaggregated energy consumption and agricultural output was ruled out by the bounds test.

CHAPTER 1

INTRODUCTION

The energy sector holds the key towards unlocking the potential of future economic gains in the productive sectors of Pakistan economy. The rapidly increasing demand for energy indicates the increased reliance of emerging markets on this scarce resource. Pakistan has already been facing a serious energy crisis that has affected all the sectors of economy, particularly the manufacturing and the agriculture sectors. The persistent demand-supply gap is expected to prevail in the short term.

The adverse impact of the present energy crises on Pakistan's economy has been observed as decline in growth of GDP and industrial production post 2007 after the crises became severe.[1] The decline in growth after 2007 can partly be attributed to the worsened energy crises besides steep decline in investments due to law and order situation and fragile political scenario. It is an established fact that energy is a very important input, though it has largely believed as an intermediary input in the production process (Stern and Cleveland, 2003).

The role of energy in the economic growth may be assessed by observing the trends in economic growth and growth in consumption of different energy components i.e. electricity, oil, gas and coal. As the economy grew, it can be seen that on average consumption of all energy sources also increased.

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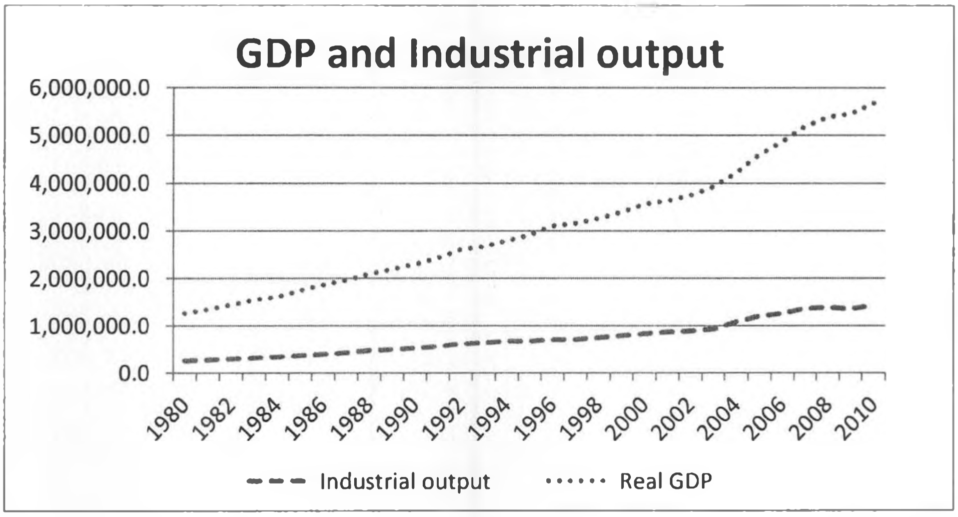
[1] The GDP growth declined from 6.8% in 2007 to 3.7% and 1.2% in the subsequent years. Similarly, the growth in industrial output fell from 8.8% in 2007 to 1.4% and -1.9% in 2008 and 2009 respectively. (Economic Survey 2009-10)

Figure 1: GDP and Industrial Output



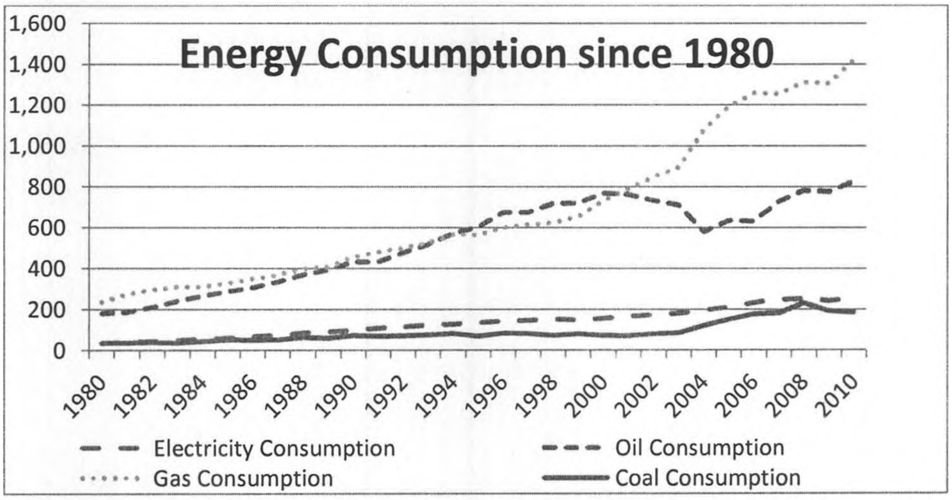
Source: State Bank of Pakistan

Figure 1 shows the trend of Pakistan's GDP and industrial output since 1980. Both the variables have shown increasing trend overtime. The rate of growth remained volatile but the magnitude of output has largely shown a constant increase which means that economy has been progressing and the share of agriculture, industry and services sector in GDP changed overtime. Rostow's stages of growth theory seemed to come into play and the economy's output mix changed from agriculture to industry and finally to the services sector as major contributor to the GDP.

The figure 2 below portrays the trend in the consumption of different components of energy. It is clear that the consumption of all the major components of energy also increased overtime, though with different magnitudes. As the economy grew and transformed structurally from an agrarian to services led economy, the energy consumption also followed an increasing trend. The growth consumption of gas was highest among all. Oil consumption remained affected by external factors but increased on average. Electricity and coal consumption showed a relatively steady growth trend.

Apparently a correlation can be witnessed by observing the long run trends in output and energy use but the economic relationship is unclear and the finding dependence of the variables on each other is highly relevant in the present scenario.

Figure 2: Energy Consumption since 1980



Source: Economic Survey 2009-10

Research reveals that energy, among other variables incorporated in the production function, plays a vital role for the developing countries at intermediate stages of economic development. To accurately forecast the current and future needs of energy, it is critical to assess the nature and determinants of demand for various sources of energy. It is therefore, necessary to analyze the nature of relationship between economic output and energy consumption. Such an analysis would also be important to assess the expenditures incurred on energy consumption, which may then be used to formulate, for future energy requirements, the energy demand management and development strategies.

It is pertinent to identify the short-run and long-run dynamics of this relationship to ascertain precisely the dependence of economy on the whole and different sectors on the energy sources. Once the relationships are determined, the policies can then be formulated accordingly for pricing, demand management and addressing supply-side issues. Energy mix can be optimized after knowing the contribution of every component of energy in the country's overall output. For instance, if electricity consumption has a strong positive relationship with GDP and its demand is price elastic, the prices of electricity then may not be allowed to increase drastically. The authorities, in this case, may subsidize the electricity, increase electricity generation or look for cheaper substitutes for electricity as a source of energy. The relationship under review in this study is important in the first instance to tackle the problem of energy shortages. The results of the study are aimed to present to the policy makers a clear picture of the role of energy components so that the resultant policy decisions are coherent with the characteristics of the economy with respect to energy use.

1.1 Objectives of the Study

This study attempts to provide experiential evidence on the relationship between disaggregate energy consumption[2], industrial output and GDP. The specific objectives of the study are

- To test the existence of relationship between disaggregate energy consumption, industrial output and GDP
- To find the long run and short run estimates of co integration between disaggregate energy consumption and GDP
- To find the long run and short run estimates of co integration between disaggregate energy consumption and industrial output

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[2] Disaggregate energy refers to the different sources of energy e.g. electricity, oil, gas etc.

1.2 Organization of the Study

This study is divided into six chapters. Chapter one is devoted to the introduction, Chapter two provides the energy trends in Pakistan. Chapter three reviews the relevant literature, Chapter four describes the Data and methodology used in present study. Chapter five presents empirical results and their analysis. Conclusion and policy implications of this study are given in Chapter six.

CHAPTER 2

ENERGY SECTOR IN PAKISTAN

Pakistan's energy requirement has grown rapidly through the course of its economic development. The primary energy consumption in Pakistan rose by 27 million tons oil equivalent (TOE) to 61 million TOEs since 1994-95 which is an increase of over 80% in the last 15 years. The table below presents the comparison of some selected economies in terms energy use per capita. Energy use per capita in Pakistan rose from 383 KGOE in 1990 to around 502 KGOE in 2009.[3] The economies listed in the table 1 below exceed Pakistan in energy use especially the emerging economies like Malaysia, Thailand and China showed a remarkable increase in per capita energy use. The strong economic performance of emerging economies and a significant increase in their energy use further builds the case for energy growth nexus.

Table 1: Energy Use (Kilogram of oil equivalent per capita)

Country	1990	2009
Pakistan	382.92	501.60
India	372.85	584.96
Indonesia	549.66	850.83
Malaysia	1207.54	2390.97
Thailand	734.97	1503.74
United States	7671.55	7045.17
China	760.19	1695.31

Source: World Development Indicators 2010

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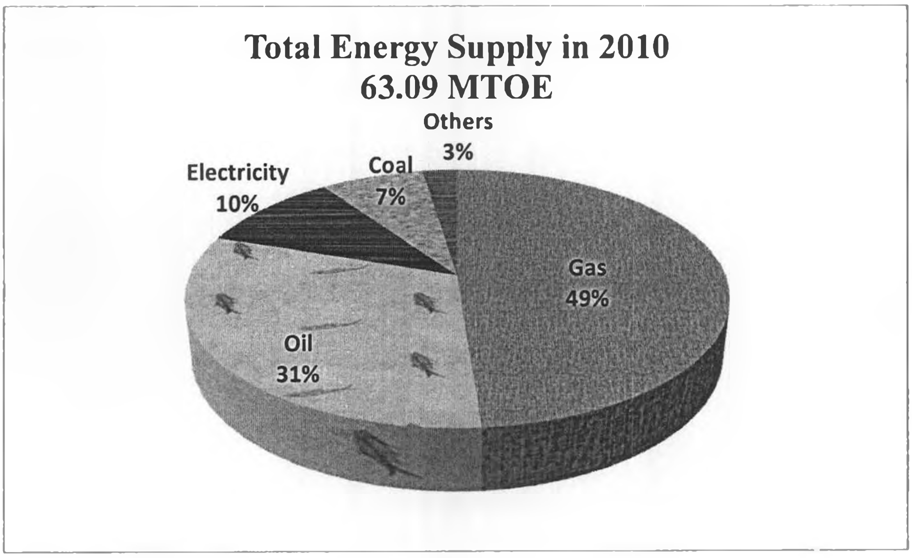
[3] Latest figure available in WDI is for 2009

The country's current energy supply is mainly contributed by domestic natural gas and oil imports which are 49% and 31% respectively of the total energy mix. Rest of the sources including hydel, coal and nuclear energy contribute 10%, 7% and 3% respectively of the energy mix. Over the past few decades indigenous supply of natural gas has significantly reduced the dependence of economy on expensive oil imports besides enabling the construction of an extensive gas transmission and distributional grid in the country.

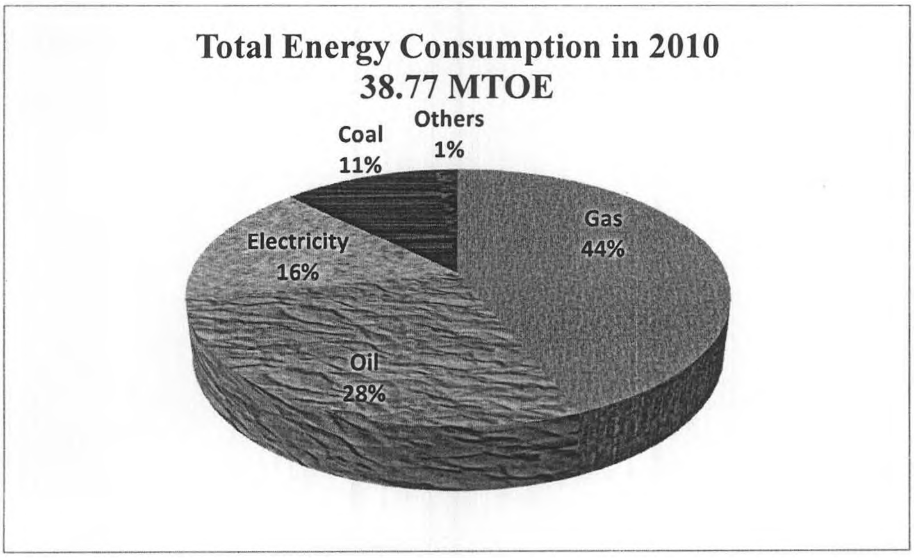
Figure 3: Total Energy Supply in 2010



Source: Pakistan Energy Year Book 2010

It is clear from figure 3 that Pakistan's economy is highly dependent on oil and natural gas for its energy supply. Oil and Gas together contribute 80% to the total energy supply (31% and 49% each, respectively). Electricity and coal contribute 10% and 7% respectively to the energy supply while 3% is contributed by other sources. The primary energy supply in 2010 was 63.09 MTOE. Presently, Pakistan fulfills 66% of its energy requirements from domestic sources that include production of natural gas, oil and hydroelectricity. Remaining 34% of energy requirements are being managed by imports, which mainly consists of imported oil, whose share may likely remain the same in the near future energy mix (Husain 2010). Share of Natural gas has rapidly increased over time and it is now the dominant component in the energy mix. Figure 4 explains the source wise energy consumption in Pakistan in 2010.

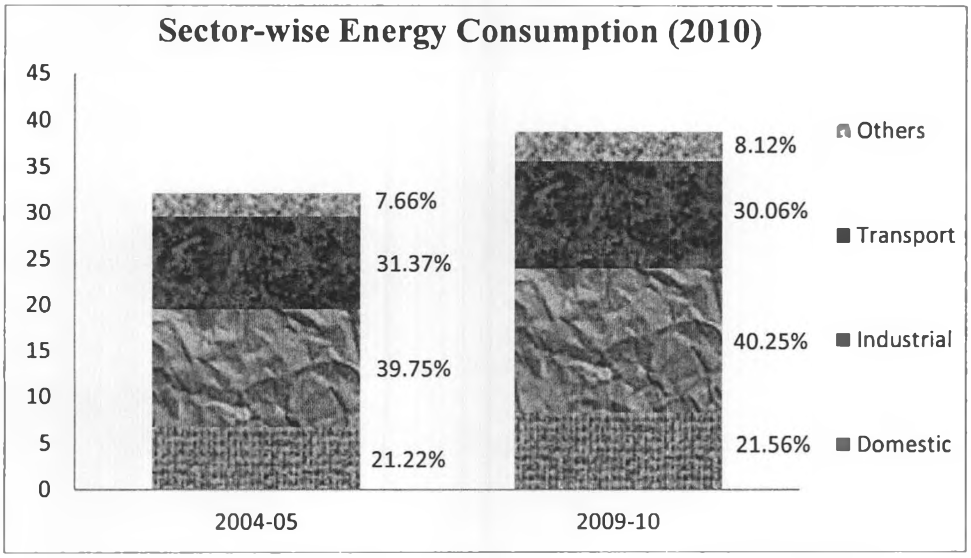
Figure 4: Total Energy Consumption in 2010



Source: Pakistan Energy Year Book 2010

The percentage share of gas in total energy consumption in 2010 was 44% followed oil, 28%. The consumption of electricity, coal and others was 15%, 11% and 2% respectively. The consumption of these sources of energy by different sectors of the economy is highlighted in the following figure. It can be seen that industrial sector consumes most of the energy (44% of the total consumption). Around 30% is consumed by the transport sector, followed by transport, 21.6% and 8% by others sectors including 2.2% by agriculture. The sectoral consumption of energy remained almost the same in 2005 as in 2010.

Figure 5: Sector-wise Energy Consumption (2010)



Source: Pakistan Energy Year Book 2010

The indicator of energy intensity i.e. Ratio of growth rate of energy use to growth rate of output produced was around 0.92 during 1970–2009(Table 2). The energy intensity coefficient for electricity is 1.32 for electricity use during past three decades. The coefficients for oil, gas and coal use during this period were 1.02, 1.45 and 0.75 respectively. The energy intensity, however, of various energy sources including electricity, petroleum products and natural gas varied considerably over time (Siddiqui 2004). The table below shows that coefficient of oil use decreased significantly compared to the other sources of energy. The coefficients of energy intensity may decrease either with the efficient use of fuel or due to technological advancements or the reduction in energy wastage. The use of higher quality fuels reduces the energy required to produce a dollar's worth of GDP (Schur and Netshert, 1960). This suggests that Pakistan should focus more on the expansion of energy sources as well as the efforts to enhance the efficiency of energy use.

Table 2: Coefficients of Energy Intensity (1971–2009)

Years	Total Energy KTOE (T1)	Electricity GWh (E1)	Oil Tonnes (O1)	Gas Mmcft (G1)	Coal metric tons (C1)
1973-1980	0.86	1.47	1.01	2.16	0.59
1980-1990	0.92	1.83	1.51	1.23	1.43
1990-2000	1.01	1.24	1.48	1.31	0.33
2000-2009	0.82	0.83	0.11	1.57	0.78
1973-2009	0.92	1.32	1.02	1.45	0.75

Notes: Energy intensity is defined as the ratio of growth rate of energy to growth rate of output.
T1= Coefficient of total energy intensity. (Total Energy is in KTOE units).
E1= Coefficient of energy intensity for electricity use.
O1= Coefficient of energy intensity for oil.
G1= Coefficient of energy intensity for natural gas.
C1= Coefficient of energy intensity for coal.

According to Hagler-Bailley report 2008, the projected energy deficit in 2025 would be around 122 MTOE or about 62% of the energy requirement. The energy requirements in 2025 are projected to be around 176 MTOE, a threefold increase compared to the current energy requirements. Based on the discussion above, a number of important questions arise. For instance, how is economic output affected by changes in energy consumption, what the determinants of supply and demand of different sources of energy are, how is the inter-fuel substitution affected by different pricing policies and what impact the foreign direct investment has on energy sector. This study analyses the first question in detail.

CHAPTER 3

LITERATURE REVIEW

3.1. Introduction

This section discusses different studies aimed at finding the relationship between energy consumption and overall economic performance. Findings of different types of studies and their conclusions are analyzed by classifying them into three sub-sections. An overall analysis of the empirical literature on the subject relationship is done in section 3.2. Section 3.3 summarizes the studies done on the relationship between GDP or economic growth and energy consumption at aggregate level. Section 3.4 presents the relationship found by different studies by using disaggregated energy consumption. Finally, section 3.5 discusses the research done on the topic in Pakistan's context whether employing aggregate or disaggregate energy consumption. Finally, section 3.6 concludes the chapter.

3.2. Relationship between GDP/Economic Growth and Aggregate Energy Consumption

The empirical literature gives conflicting results on energy-growth/GDP relationship due to variety of reasons. Mixed results are largely due to use of different econometric methodologies and data sets, country specific characteristics and also due to different energy consumption patterns. With respect to the subject topic, four generations of contribution can be acknowledged. First generation studies constitute the work of Kraft and Kraft (1978), Erol and Yu (1987), Yu and Choi (1985), Abosedra and Baghestani

(1989). These studies used traditional vector autoregression (VAR) models and found the evidence of causality between income and energy consumption. Some of the first generation studies also considered stationarity of variables as an assumption before examining the direction of causality among them. Second generation studies include Nachane et al. (1988), Cheng and Lai (1997), Glasure and Lee (1998). They explained stationarity and formed the basis of cointegration to find the long run relationships between energy consumption and economic growth. The second generation literature used Engle and Granger (1987) two-step procedure to test the co-integration between pairs of variables and then used estimated error-correction models to test for Granger causality. Third generation studies applied multivariate approach developed by Johansen (1991). Johansen's multivariate approach allows studying the co-integration relationship for more than two variables. These studies include Masih and Masih(1997), Stern (2000), Asafu-Adjaye (2000), Soytas and Sari (2003), Oh and Lee (2004). Finally, the fourth generation studies employed ARDL approach, recently developed by Pesaran et al. (2001) and panel-econometric methods to test for unit roots and cointegration relationships.

The studies named above, used energy consumption at aggregated and disaggregated level and much of the work done focused on finding the direction of causality. The following sections summarize them separately and finally the studies done on Pakistan are recapitulated.

Study	Countries and Data	Findings
(Lise and Monfort 2005)	- Turkey - Annual Data from 1970-2003	- Long run relationship between energy consumption and economic growth - *Economic Growth → Energy Consumption*
(Apergis and Payne 2009)	- 6 Central American Countries - Annual Data from 1980-2004	- Long run and Short run relationship between energy consumption and economic growth - *Energy Consumption → Economic Growth*
(Rufael 2009)	- Seventeen African Countries - Annual Data from 1971-2004	- *Economic Growth → Energy Consumption* for Morocco, Tunisia, Senegal, Egypt, Zambia, Sudan, Nigeria and Ivory Coast - *Energy Consumption → Economic Growth* for Algeria, Benin and South Africa

(Apergis and Payne 2009)	Eleven countries of commonwealth of independent states 1991-2005	Bidirectional long run relationship between energy consumption and economic growth Short run causality from *Energy Consumption →* *Economic Growth*
(Ozturk, Aslan and Kalyoncu 2010)	51 Lower and middle income countries 1971-2005	Co-integration between GDP and energy consumption for all income group countries Causality test results reveal that for low income countries, there is long-run Granger causality running from GDP to EC and for middle income countries, there is bidirectional causality between GDP and EC.
(Soytas, Sari and Ozdemir 2001)	Turkey Annual Data from 1960-1995	Energy consumption has long and short run effects on income *Energy Consumption →* *Income*

(Sa'ad 2010)	• Nigeria • Annual Data from 1971-2006	• Existence of co-integration and unidirectional causality-running from GDP to energy

3.3. Relationship between GDP/Economic Growth and Disaggregate Energy Consumption

Most studies have also used aggregate energy data. There only a few studies which have employed disaggregate data: For example, Sari and Soytas (2004) using variance decomposition analysis for Turkey on alternative energy consumption sources, employment and GDP found that employment explains from 23% to 26% of the forecast error variance in Turkish GDP. Erbaykal (2008) using time series data for Turkey concluded that Electricity and oil consumption both have significant and positive short-run impact on economic growth. Oil and electricity consumption are found to be statistically insignificant in the long-run. Sari et al. (2008) using monthly data for USA found that employment and real output are long run forcing variables for almost all measures of disaggregate energy consumption.

A number of studies have included other variables (such as oil prices, government expenditure, employment, capital and labor) in the energy–income relationship analysis.

A brief summary of the studies done in this regard is presented in the table below.

Study	Countries and Data	Findings
(Sari, Ewing and Soytas 2008)	• USA • Monthly Data from 2001-2006	• Employment and real output are long run forcing variables for almost all measures of disaggregate energy consumption

		• Output and labor are the key determinants of fossil fuel, conventional hydroelectric power, solar, waste and wind energy consumption but do not have significant impact on natural gas and wood energy
(Yang 2000)	• Taiwan • Annual Data from 1954-1997	• Bidirectional causality between total energy consumption and GDP • Bidirectional causality b/w GDP and Coal and electricity • Unidirectional causality from GDP→Oil and Gas→GDP
(Sari and Soytas 2004)	• Turkey • Annual Data from 1969-1999	• variance decomposition analysis on alternative energy consumption sources, employment and GDP, employment explains from 23% to 26% of the forecast error variance in Turkish GDP • Apart from oil and waste, the

		alternative energy sources provide more information on forecast error variance on initial impact • Total energy consumption explains 21% of forecast error variance in income for three years period
(Ziramba 2009)	• South Africa • Annual Data from 1989-2005	• Reveal that industrial production explains the variation in oil consumption and electricity • Employment has not been found to have significant long-run impact on either electricity or oil consumption • There is no relationship between all other sources of energy and industrial production or employment
(Erbaykal 2008)	• Turkey • Annual data from	• Electricity and oil consumption both have

	1970-2003	significant and positive short-run impact on economic growth - Oil and electricity consumption are found to be statistically insignificant in the long-run
(Yemane and Rufael 2004)	- Shanghai - Annual data from 1952-1999	- Uni-directional Granger causality running from total energy, coke, coal and electricity consumption to real GDP - No evidence of Granger causality between real GDP and oil consumption found in any direction
(Yuan, et al. 2008)	- China - Annual data from 1963-2005	- long-run co-integration at disaggregate as well aggregate levels in China exists among capital, labor, output, and energy use - Granger causality runs from

		oil and electricity consumption to GDP, but no Granger causality exists from total energy consumption and coal consumption to GDP • Granger causality exists in the short-run from GDP to oil, coal, and total energy consumption but doesn't exist from GDP to electricity consumption

3.5. Relationship between GDP and Energy Consumption: Evidences from Pakistan

The following table presents summary of the studies done on the investigation of relationship between GDP and energy consumption in case of Pakistan. For example Siddiqui (2004) using annual data for Pakistan found positive impact of growth rate of petroleum products and electricity consumption on economic growth while no significant impact of gas consumption on economic growth was found. Khan and Ahmed (2008) observed that change in real per capita income positively affects coal and electricity consumption while any change in domestic price level has a negative effect on coal and electricity consumption. In the short-run, real per capita income and price changes negatively impact the gas consumption. Aqeel and Butt (2001), Shahbaz and Hooi (2001) and Khilji (2011) also contributed to the subject. The table below summarizes them briefly.

Study	Countries and Data	Findings
(Siddiqui, 2004)	• Pakistan • Annual Data from 1970-2003	• Found positive impact of growth rate of petroleum products and electricity consumption on economic growth • No significant impact of gas consumption on economic growth found

(Aqeel and Butt 2001)	• Pakistan • Annual Data from 1956-1996	• Economic growth causes total energy consumption • Economic growth spurs growth in consumption of petroleum • Electricity consumption leads to economic growth without feedback • Either economic growth nor gasconsumption affect each other
(Khan and Ahmed, 2008)	• Pakistan • Annual Data from 1972-2007	• Change in real per capita income positively affects coal and electricity consumption while any change in domestic price level has a negative effect on coal and electricity consumption • In the short-run, real per capita income and price changes negatively impact the gas

		consumption. However, real income has a positive impact on gas consumption while domestic price is insignificant in the long-run
(Kakar and Khilji, 2011)	• Pakistan • Annual Data from 1980-2009	• There is a long run relationship between total energy consumption and economic growth
(Shahbaz and Hooi, 2011)	• Pakistan • Annual Data from 1971-2008	• Electricity consumption has a positive impact on GDP growth. • Furthermore, bi-directional Ganger causality between economic growth and electricity consumption is witnessed
(Shahbaz, Chandran and Azeem, 2011)	• Pakistan • Annual Data from	• In long-run, gas consumption has positive

	1972-2009	and significant impact on economic growth

3.6. Conclusion

From the review of different studies presented in preceding sections, it is noticeable that, none of the studies has comprehensively studied the short run and long run relationship between disaggregate energy consumption, Agriculture production, industrial production and GDP in the context of Pakistan economy. Further, the ARDL approach is fairly new which allows estimation of time series of different orders of integration and gives robust results for both short run and long run estimates. (Siddiqui 2004)employed the same approach 8 years ago but used Cobb-Douglas production function while others have used ARDL in univariate analysis. The contribution of our study is to provide aspects of energy-GDP nexus using latest available data and also extending the analysis for industrial and agriculture production.

CHAPTER 4

THEORETICAL CONSIDERATION

4.1 Energy in Production

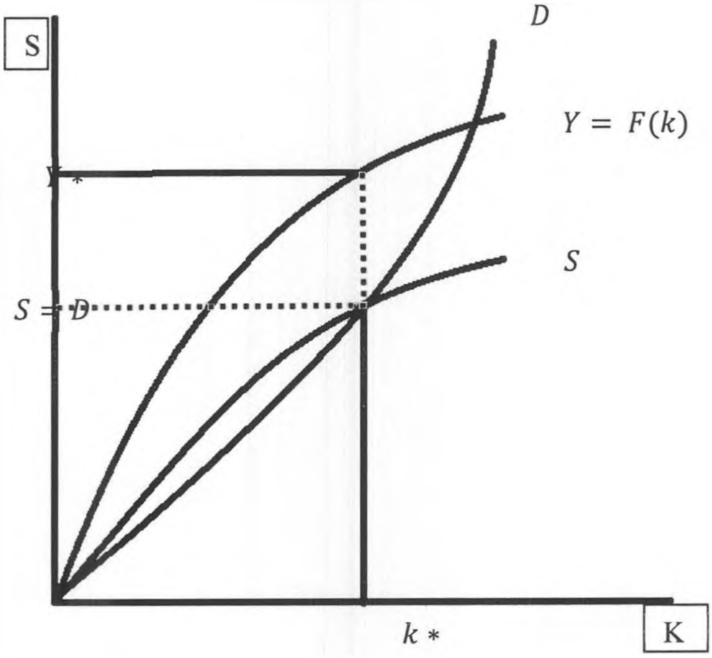
Mainstream economists consider land, labor and capital as primary factors of production which are not directly used up in the production process. The goods such as fuels and materials which are used up entirely in production are the intermediate inputs (Stern and Cleveland, 2003). The focus of growth theories has evidently been on the primary inputs i.e. labor and capital and much lesser on the role of energy in production and eventually in growth process. By treating energy only as an intermediate input means it is not critical to economic growth. This implies that GDP would not be affected much even by increasing the energy prices twofold.

Okun(1975) in neoclassical framework advocated the ‘small cost share’ of energy in total output relative to other inputs of production. Therefore, change in energy prices would also have a small impact on the economy. Perry (1977) went to the extent of stating that energy prices hardly have any effect on output, growth and productivity as it is nearly one of many components of production. From Perry’s argument, it may be concluded that the increase in energy prices would lead to substitution of labor for capital without having negative impact on growth and production Ebohon (1996). Berndt and Wood (1979) argued that the complementary relationship between capital and energy becomes more important than its cost share considering the substitutability of labor and energy. Okun (1975) witnessed that on one hand labor and energy while, on the other hand labor and capital are substitutable. Hence, energy induced decrease in output can be compensated by substitution of labor for capital. However, a unanimous agreement is yet to be arrived at, on the relationship between energy and capital.

4.2 Mainstream Theory of Growth:

Energy is also a crucial factor of production Stern (2002) but the basic model of economic growth by Solow (1956) did not consider energy at all. In this neo-classical model which assumes labor force as constant, output increases at a decreasing rate when the amount of capital used increases.

Figure 6: Relationship between Y and k



Relationship between Y and k is shown in the figure above.

Suppose the population, a constant multiple of labor saves a constant proportion of its income. These savings are used to build new capital, which then depreciates at a constant rate. When savings equal depreciation, the capital stock is said to be in equilibrium. In the figure, capital increases at an increasing rate when $k < k^*$ because saving rate is greater than the rate of depreciation. However, when $k < k^*$, the increment in capital does not add to the income as $\delta >$ & at $k = k^*$, capital stock is in equilibrium. In this basic growth model, an economy must reach a steady state if the savings rate remains constant.

An under-developed economy will have fast growth in capital stock as $k< k^*$ in such economies. Given constant growth rate of labor force, the total capital stock of quantity of output may increase but in equilibrium, capital per worker and output per worker remains constant.

According to neo-classical growth theory, the only cause of continuous economic growth is technological progress. It increases the quantity or quality of output with the same quantity of inputs. In other words it shifts the production function upwards and beats the diminishing return to capital that otherwise halt the growth. More recent growth model tend to endogenize the technological change which is assumed to be exogenous in models. In this setting $Y=AK$, the technological knowledge is endogenous and can be accumulated through R&D and other knowledge creating processes.

4.3 Energy and Growth:

In biophysical models of growth, increased use of energy as an input does not affect growth much unless accompanied by the increased use of labor and capital. However, little gains in output can be reaped by increasing only labor and capital use without increasing the use of energy. Therefore, in this view, increased use of energy only cannot drive economic growth although it is critical for production. But the inability to enhance use of energy with increased labor and capital may constrain economic output. The technological innovations led to increased energy supply at the beginning of the industrial revolution removed a constraint that prevented modern economic growth. After the industrial revolution, smooth supply of energy and the shift to more efficient fuels has played a vital role in maintaining world growth. But during 1970s and early 1980s the oil crises disrupted the supply and hurt the growth trend adversely.

To outline the factors that affect the relationship between economic growth and energy, let us start from the perspective of neoclassical production function which can be represented as:

$$(Q_1,\ldots,Qm) = f(A, X_1,\ldots, X_n, E_1,\ldots, E_p) \tag{4.1}$$

Where the Qi is the vector of various outputs, like manufactured items and services, the Xi are various inputs such as labor and capital, Ei are various energy sources taken as inputs to production i.e. Oil, coal, gas etc. A is the level of technology measured as total factor productivity indicator (Stern and Cleveland, 2003). The relationship between overall output i.e. GDP and energy can be affected by various factors, a few are discussed below:

4.4 Factors Affecting the Linkage between Energy and Growth

Substitution between energy and other inputs:

Out of the studies on the substitution and complementarity relationship between capital and energy by (Stern, 1997) and (Berndt and Wood, 1979), it seems that energy and capital appear more as compliments in the short-run while substitutes in the long-run. According to (Apotolakis, 1990), they may be gross substitutes but net complements.

Technological change - a change in A:

Berndt (1990) studied at the different mechanisms through which use of energy may affect Total Factor Productivity (TFP) growth. Jorgenson observed that energy use moved parallel to the technological change which implies that the cost share of energy tends to increase over time with advancement in technology. Technical advancement induces use of more household and commercial energy appliances and energy saving techniques in the industry (Stern, 2002).

Shifts in the composition of the energy input:

Schurr and Netschert (1960) produced seminal work discussing energy quality for the first time in energy-growth literature. They noted that the use of energy has varied significantly over time and argued that the energy required to produce a dollar worth of GDP requires lesser use of energy once households and businesses shift to higher quality fuels. Berndt (1990) also observed that if the role played by shifting energy consumption towards more efficient energy inputs are ignored the TFP growth is apparently overstated than the real growth. This idea was originally introduced by Jorgenson and Griliches (1967) regarding quality of energy and capital.

Shifts in the composition of output:

The outputs mix, generally changes over time during the process of economic development. In the early stages of economic development there is a general shift to heavy industry from agriculture and agro-based manufacturing. In later stages of development, light manufacturing and services tend to replace the high share of heavy and resource extractive industry. Energy intensities vary from industry to industry. It is generally believed that the energy requirement per unit of output is high in the early stages of development while it decreases in later stages with the shift towards services sector and efficient fuel use in different sectors of the economy.

4.5 Conclusion:

Energy is an important input into the growth process and has a strong linkage with growth in either direction as found by various studies done on the subject.[4] Energy was not considered as a primary input initially and the growth models didn't incorporate energy to study the growth dynamics. The role of resources which include energy besides others, has been incorporated in the growth models by resource economists but these ideas are yet confined only to the field of resource economics. Ecological economists, on the other hand, often ascribe to energy the central role in economic growth. The nexus between energy and growth is affected by different factors during the course of development of the economy and changing energy needs and energy resources. This study focus only on the relationship between energy at disaggregated level and output; industrial and overall.

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[4] See chapter 3on literature review

CHAPTER 5

DATA AND METHODOLOGY

5.1 Introduction

In this chapter deals in the discussion on data, construction of variables econometrics considerations involved in the estimation process. Section 5.2 discusses the data sources and a brief description of the variables used in the econometrics analysis. Descriptive statistics of the variables is given in Section 5.3. Finally, the details regarding unit root tests and Autoregressive Distributive Lag (ARDL) approach to co-integration is discussed in the last section.

5.2 Data Description

The data on the variables used in this study are taken from various sources. The description of variables and their data sources are quoted in the Table below.

Table 3: Variable description and Data sources

Variables	Description	Source
GDP	Log of Real Output at constant factor cost of 1999-2000	Handbook of Statistics on Pakistan Economy 2010
IP	Log of Industrial Output at constant factor cost of 1999-2000	Handbook of Statistics on Pakistan Economy 2010

Agri	Log of Agricultural Output at constant factor cost of 1999-2000	Handbook of Statistics on Pakistan Economy 2010
Elec	Log of Commercial Electricity Consumption	Handbook of Statistics on Pakistan Economy 2010
Oil	Log of Commercial Oil Consumption	Handbook of Statistics on Pakistan Economy 2010
Gas	Log of Commercial Gas Consumption	Handbook of Statistics on Pakistan Economy 2010
Coal	Log of Commercial Coal Consumption	Handbook of Statistics on Pakistan Economy 2010

Brief definitions of variables used are given below

Gross Domestic Product (GDP)

GDP at constant factor is the amount of goods and services produced in a particular year at constant prices of 1999-2000 using GDP deflator. GDP series from 1972-2010 has been adjusted using 1999-2000 as a base year.

Industrial Production

It is the output produced by industrial sector valued at 1999-200 base prices. Industrial sector's output comprises of Mining and Quarrying, Large and small scale manufacturing, construction and electricity and gas distribution.

Electricity Consumption

It is the consumption of energy by different sectors of the economy in the form of electricity, measured in GWh. The electricity consumed comes from different sources i.e. Oil (38%), (Hydel (29.4%), Gas (29.4%), Nuclear and others (3.3%).

Oil Consumption

It is the consumption of petroleum products by various sectors of the economy, measured in million Tonnes. Petroleum products consist of Aviation fuel, Motor spirit, High octane blending content, high speed diesel, Light diesel oil and Furnace oil.

Gas Consumption

It is the consumption of natural gas as a source of energy, measured in million cubic feet (Mmcft), by different sectors of the economy.

Coal Consumption

It is the consumption of coal as a source of energy. The unit of measurement generally used for coal consumption is metric tonne.

The data on all the variables ranges from 1972-2010. GDP, IP and Agri are measured in Rupees Million while the disaggregated components of energy i.e. Elec, Oil, Gas and Coal are converted into single standard unit i.e. British Thermal Units (BTU).

5.3 Descriptive Statistics

Descriptive statistics of the variables used in the study are given in table 4 below. Two measures of central tendencies have been used i.e. mean and median. We can see in the table below that the mean and median are almost the same for all the six variables which means that they all have symmetrical distribution. The mean of Coal, Electricity, Gas, Oil, GDP and Industrial Production is lesser than the median which implies that they are negatively skewed.

Coefficient of Variation which is defined as Standard Deviation divided by Mean measures the spread of variables. In this case, GDP and Industrial Production have the least variation ranging from 15.55 to 13.61 and 14.17 to 11.93 respectively. However, all the energy variables are relatively volatile as evident from the maximum and minimum ranges in the table below.

Table 4: Descriptive Statistics

	Mean	Median	Maximum	Minimum	Coefficient of Variation
COAL	4.15	4.24	5.44	3.19	0.15
ELEC	4.43	4.68	5.53	2.89	0.19
GAS	6.10	6.17	7.26	4.74	0.12
GDP	14.64	14.70	15.55	13.61	0.04
IP	13.14	13.25	14.17	11.93	0.05
OIL	5.93	6.06	6.72	4.79	0.11

5.4 Econometrics Methodology and Related Issues

5.4.1 Unit Root Test

Time series analysis requires the data series to be stationary i.e. there is no unit root. Therefore, the unit root test is applied before estimation to check whether the series is stationary or not. If there is a unit root, the series is considered to be non-stationary and the results of estimation may be spurious. Augmented Dickey-Fuller (ADF) tests and Phillips-Perron (PP) Tests are used in the study to check the stationarity of the data series. ADF test assumes that the errors follow a white noise process. Thus, an error term should be uncorrelated with the others, and have a constant variance. PP test is actually a generalized version of ADF test which allows for a set of weaker assumptions regarding error process. Both ADF and PP tests deal differently with the autocorrelation in errors of test regression. In contrast to ADF test, which uses lag of dependent variables to rectify the autocorrelation problem in errors, the PP test corrects for heteroskedsaticity and serial autocorrelation in the errors of regression by modifying the test statistics. ADF statistics have the similar asymptotic distribution as the PP test statistics.

5.5 Econometric Modeling

5.5.1 Testing of Long run Relationship: Preliminaries

Granger gave the idea of cointegration in 1981 and further enhanced by Engle Granger (1987), there are some also other tests of cointegration such as (Johanson and Juselius 1990), Maximum likelihood based Johansen (1991, 1995) cointegration test. But the problem with these tests is that they are low powered and contain problems the most common of which is; they do not incorporate difference of stationarity and required the variables to be integrated of degree one and thus requires a pre testing (Pesaran et al., 2001). Because of these shortcomings a new technique of cointegration, OLS based ARDL, became increasingly famous in recent years.

This technique has many benefits. Firstly, ARDL does not require all the variables to be integrated of the same order, rather it can be applied to the both integrated of order zero *I* (0) and order one *I* (1) and on mutually integrated variables. So in this way, ARDL avoids the pre-testing of variables. Secondly, ARDL also allows for different lags for different variables which were not allowed in other techniques. Thirdly, ARDL is an efficient and unbiased technique as it also performs better when sample size is relatively small (Narayan, 2004). Fourthly, an error correction model can also be derived from ARDL through a linear transformation (Shreshta and Chowdury 2005) estimated $(p+1)^k$ regressions where 'p' refers to the optimal lags that can be used in the regression. The number of variables in equation is represented by 'k'. Schwarz Bayesian or Akiake Information criterions are used to select the model.

The application of ARDL is a two-step procedure. In the first step, a bounds test is conducted to test the presence of any long run relationship between the given variables. The long run relation is tested through the Wald or F-test. A joint restriction of zero is tested on the values of ECM if the F-test is used (Narayan 2004). The distribution of F-test is non-standard and depends upon: whether the variables included are *I* (o) or *I* (1); total number of regressors in the model and the presence of intercept and trend. Two set of critical values are given by (Pesaran et al., 2001) lower bound and upper bound. Lower bound values assume that all the variables are integrated of zero and upper bound critical values are simulated for the variables which are integrated of degree one. The presence of long run relation is tested on the null hypothesis of no cointegration. If the computed F-stat exceeds the upper critical bound value on a given number of 'k' and the selected probability, it is concluded that the null hypothesis is rejected and thus the long run relation is present among the variables. Whereas, if the computed F-stat falls below the lower bound critical value, the null hypothesis cannot be rejected and a conclusion of no cointegration among the variables is reached. If the computed F-stat falls between the lower and upper bound critical values, no inference can be made without knowing the integration order of the variables. At this point ARDL requires knowing if or not the variables are integrated of $I(0)$ and $I(1)$.

5.5.2 ARDL Model Specification

The ARDL procedure mainly consists of three steps. First step involves the test of existence of long run relationship through error correction mechanism, the second step explores long run relationship among the variables, and the final step estimates the short run parameters through equilibrium correction mechanism and long run estimates. The following discussion elaborates these steps in detail. The study is aimed at finding the long run and short run relationship between disaggregate energy consumption, industrial production, Agriculture production and the Gross domestic product.

On the basis of the hypothesis, the Unrestricted Error Correction Mechanism (UECM)can be specified for Industrial production, Agriculture production and GDP separately as;

$$\Delta GDP_t = \alpha_1 + \sum_{i=1}^{n} \theta_{1i}\Delta GDP_{t-i} + \sum_{i=1}^{n} \theta_{2i}\Delta ELEC_{t-i} + \sum_{i=1}^{n} \theta_{3i}\Delta OIL_{t-i} + \sum_{i=1}^{n} \theta_{4i}\Delta GAS_{t-i} + \sum_{i=1}^{n} \theta_{5i}\Delta COAL_{t-i} + \gamma_1 ELEC_{t-1} + \gamma_2 OIL_{t-1} + \gamma_3 GAS_{t-1} + \gamma_4 COAL_{t-1} + \epsilon_t \qquad (5.1)$$

Where ϵ_t is white noise error and Δ is the first difference operator or changes from period t-1 to t.

In the following equation, we test the existence of cointegration between industrial production and the disaggregated energy components.

$$\Delta IP_t = \alpha_1 + \sum_{j=1}^{n} \pi_{1j}\Delta IP_{t-j} + \sum_{j=1}^{n} \pi_{2j}\Delta ELEC_{t-j} + \sum_{j=1}^{n} \pi_{3j}\Delta OIL_{t-j} + \sum_{j=1}^{n} \pi_{4j}\Delta GAS_{t-j} + \sum_{j=1}^{n} \pi_{5j}\Delta COAL_{t-j} + \gamma_1 ELEC_{t-1} + \gamma_2 OIL_{t-1} + \gamma_3 GAS_{t-1} + \gamma_4 COAL_{t-1} + \epsilon_t \qquad (5.2)$$

And finally we perform the above procedure by taking Agriculture Production as dependent variable.

$$\Delta Agri_t = \alpha_1 + \sum_{k=1}^{n} \mu_{1k}\Delta Agri_{t-k} + \sum_{k=1}^{n} \mu_{2k}\Delta ELEC_{t-k} + \sum_{k=1}^{n} \mu_{3k}\Delta OIL_{t-k} + \sum_{k=1}^{n} \mu_{4k}\Delta GAS_{t-k} + \sum_{k=1}^{n} \mu_{5k}\Delta COAL_{t-k} + \gamma_1 ELEC_{t-1} + \gamma_2 OIL_{t-1} + \gamma_3 GAS_{t-1} + \gamma_4 COAL_{t-1} + \epsilon_t \qquad (5.3)$$

5.5.3 Bounds Testing:

In our analysis, because the size of data set is small so in order to get more degrees of freedom, we have used maximum of two lags of first difference of variables. The Hypothesis which will be tested at this stage is 'there is non-existence of long run relationship' can be shown as;

$$H_0: \gamma_1=\gamma_2=\gamma_3=\gamma_4=0 \tag{5.4}$$

$$H_1: \gamma_1 \neq 0, \ \gamma_2 \neq 0, \gamma_3 \neq 0, \gamma_4 \neq 0 \tag{5.5}$$

In order to test the Hypothesis of joint significance equations 5.1, 5.2 and 5.3 are estimated through simple OLS and then the F-test of joint significance is applied. This computed F value is then compared with the F-Table reproduced by (Pesaran, Smith and Shin, Bounds Testing Approaches to the Analysis of Long-run Relationships 1999).The F-table reproduced by Pesaran *et al.* provide sets of two critical values, i.e. upper bound and lower bound, upper value obtained by considering all variables are *I (1)* process and lower value obtained by considering all variables are *I (0)* process. If the computed value falls outside the critical value bounds then a conclusive inference can be drawn, however, if computed F value falls within the critical bounds then the inference would be inconclusive. For the existence of cointegration the computed F value should be greater than the upper bound of F table. Once the cointegration is established then we move to second step.

If long run relationship exists, the long run parameters can be found using the following equations. This step involves the selection of model among Akiake, Schwarz, Hannan and Quinn, and R^2 model selection procedures. We adopted Schwarz Bayesian Criterion (SBC) for model selection because SBC give less mean prediction error (Ma and Jalil 2008).

$$GDP_t = \alpha_1 + \sum_{i=1}^{n} \theta_{11i} GDP_{t-i} + \sum_{i=0}^{n} \theta_{12i} ELEC_{t-i} + \sum_{i=0}^{n} \theta_{13i} OIL_{t-i} + \sum_{i=0}^{n} \theta_{14i} GAS_{t-i} + \sum_{i=0}^{n} \theta_{15i} COAL_{t-i} + \epsilon_{1t} \qquad (5.6)$$

$$IP_t = \beta_1 + \sum_{j=1}^{n} \pi_{11j} IP_{t-j} + \sum_{i=0}^{n} \pi_{12j} ELEC_{t-j} + \sum_{j=0}^{n} \pi_{13j} OIL_{t-j} + \sum_{j=0}^{n} \pi_{14j} GAS_{t-j} + \sum_{j=0}^{n} \pi_{15j} COAL_{t-j} + \epsilon_{2t} \qquad (5.7)$$

$$Agri_t = \gamma_1 + \sum_{k=1}^{n} \mu_{11k} Agri_{t-k} + \sum_{k=0}^{n} \mu_{12k} ELEC_{t-k} + \sum_{k=0}^{n} \mu_{13k} OIL_{t-k} + \sum_{k=0}^{n} \mu_{14k} GAS_{t-k} + \sum_{k=0}^{n} \mu_{15k} COAL_{t-k} + \epsilon_{3t} \qquad (5.8)$$

Third step entails the estimation of equilibrium correction mechanism using the differences of variables in order to find the short run relation among the variables. The ARDL specification for the short-run dynamics can be found by estimating the following equations.

$$\Delta GDP_t = \quad \alpha_2 + \sum_{i=1}^{n} \theta_{21i}\Delta GDP_{t-i} + \sum_{i=0}^{n} \theta_{22i}\Delta ELEC_{t-i} + \sum_{i=0}^{n} \theta_{23i}\Delta OIL_{t-i}$$

$$+ \sum_{i=0}^{n} \theta_{24i}\Delta GAS_{t-i} + \sum_{i=0}^{n} \theta_{25i}\Delta COAL_{t-j} + \varphi_1 ECM_{1t-1} + \mu_{1t} \qquad \mathbf{(5.9)}$$

Where, the Error Correction term i.e.ECM₁ is defined as

$$ECM_{1t} = GDP_t - \alpha_1 - \sum_{i=1}^{n} \theta_{11i}GDP_{t-i} - \sum_{i=0}^{n} \theta_{12i}ELEC_{t-i} - \sum_{i=0}^{n} \theta_{13i}OIL_{t-i}$$

$$+ \sum_{i=0}^{n} \theta_{14i}GAS_{t-i} - \sum_{i=0}^{n} \theta_{15i}COAL_{t-i} \qquad \mathbf{(5.10)}$$

The short term dynamics for Industrial Production are;

$$\Delta IP_t = \quad \beta_2 + \sum_{j=1}^{n} \pi_{21j}\Delta IP_{t-j} + \sum_{j=0}^{n} \pi_{22j}\Delta ELEC_{t-j} + \sum_{j=0}^{n} \pi_{23j}\Delta OIL_{t-j}$$

$$+ \sum_{j=0}^{n} \pi_{24j}\Delta GAS_{t-j} + \sum_{j=0}^{n} \theta\pi_{25j}\Delta COAL_{t-j} + \varphi_2 ECM_{2t-1} \qquad \mathbf{(5.11)}$$

Where

$$ECM_{2t} = IP_t - \beta_1 + \sum_{j=1}^{n} \pi_{11j}IP_{t-j} - \sum_{j=0}^{n} \pi_{12j}ELEC_{t-j} - \sum_{j=0}^{n} \pi_{13j}OIL_{t-j}$$

$$- \sum_{j=0}^{n} \pi_{14j}GAS_{t-j} - \sum_{j=0}^{n} \theta\pi_{15j}COAL_{t-j} \qquad \mathbf{(5.12)}$$

And finally the Error correction representation for Agriculture output is as follows;

$$\Delta Agri_t = \gamma_2 + \sum_{k=1}^{n} \mu_{21k}\Delta Agri_{t-k} + \sum_{k=0}^{n} \mu_{22k}\Delta ELEC_{t-k} + \sum_{k=0}^{n} \mu_{23k}\Delta OIL_{t-k} + \sum_{k=0}^{n} \mu_{24k}\Delta GAS_{t-k} + \sum_{k=0}^{n} \mu_{25k}\Delta COAL_{t-k} + \varphi_3 ECM_{3t-1} \qquad \mathbf{(5.13)}$$

Where

$$ECM_{3t} = Agri_t - \gamma_1 - \sum_{k=1}^{n} \mu_{11k}Agri_{t-k} - \sum_{k=0}^{n} \mu_{12k}ELEC_{t-k} - \sum_{k=0}^{n} \mu_{13k}OIL_{t-j} - \sum_{k=0}^{n} \mu_{14k}GAS_{t-k} - \sum_{k=0}^{n} \mu_{15k}COAL_{t-k} \qquad \mathbf{(5.14)}$$

In the above equations, the parameters which are associated with summation signs represent the short-run parameters and the coefficient of ECM in above equations (φ) represents how speedily the system adjusts to long-run equilibrium. Coefficient of ECM φ has to be negative and statistically significant in order to converge to long-run equilibrium.

CHAPTER 6

EMPIRICAL RESULTS

6.1 Introduction:

This chapter presents the empirical results of various econometrics models proposed in chapter 5and their interpretation. Results of unit root are presented in section 6.2. Section 6.3 discusses the results of bound test of co-integration. An autoregressive distributed lag (ARDL) methodology is discussed in chapter 5 has been used to get the long run and short run parameters. The results of both short run and long run estimates are discussed in section 6.4.

6.2 Unit Root Tests:

The process of estimation begins by testing the stationarity of the time series data by using the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. To check the stationarity of data, Unit Root tests are carried out. If the series is stationary at levels, it is considered to be integrated of first order I (0) and if it's stationary at first difference, it is I (1). The tests also ensure that variables are not I (2). According to Ouattar (2004), F-statistics for bounds test provided by Pesaran et al. (2001) remains valid if and only if the variables used in the model are either I (0) or I (1) and not I (2). The results of ADF and PP tests are presented in Table 5.

Table 5: Results of Unit Root Tests

Variable	ADF test statistics		PP test Statistics		Order of Integration	
	Level	First Difference	Level	First Difference	(ADF test)	(PP test)
LGDP	-1.78	-4.59*	-1.64	-4.60*	I(1)	I(1)
LIP	-1.67	-4.74*	-1.67	-4.74*	I(1)	I(1)
LELEC	-3.06*	-5.38	-2.64**	-5.46	I(0)	I(0)
LOIL	-1.68	-2.74**	-1.55	-5.56*	I(1)	I(1)
LGAS	-2.68	-8.30*	-2.67	-8.17*	I(1)	I(1)
LCOAL	-3.97*	-6.51	-2.56	-6.50*	I(0)	I(1)

*Note: The statistics significance at 5 % and 10% levels are indicated by * and ** respectively*

The Unit Root test results indicate that GDP, Industrial Production, Oil and Gas Consumption are integrated of the order 1. All the I (1) variables are significant at 5% level of significance in both ADF and PP tests except Oil which is significant at 10% in case of ADF and at 5% in PP test. Electricity consumption is stationary at level in both ADF and PP at 5% and 10% respectively. This implies that the condition for application of bounds testing is met that requires the series to be either I (0) or I (1) but not I (2).

6.3. Estimations of the Models

The results and interpretation of the models (5.1, 5.2 and 5.3) in which dependent variables are real GDP, Industrial Output and Agricultural Output respectively and independent variables are the disaggregated components of energy consumption are reported in table 6 below. The regression analysis follows 2 lags from the standard lag length selection criterion for the regression of ARDL econometric model. The given procedure in estimating the equations uses Schwarz Bayesian Criteria for lag length selection. The maximum number of lags to be allowed has been selected as two as the data set is not large enough to allow for more lags. It captures all that lags which may have desirable significance power in term of statistical inference.

Since, the dependent variable in Model I (equation 5.1) is real GDP and its reaction along with set of independent variables is mentioned below. The value of R-squared and adjusted R-squared is 0.70 and 0.48, respectively that shows 70 percent variation in the determination of real output is explained by the model. The value of Durbin-Watson statistics is 2.28 that satisfies to the desirable level and validates the rejection of null hypothesis of serial autocorrelation at any order. The unique model selection or information criteria mentioned by Akiake Information Criteria (AIC) and Schwarz Criteria that is 97.88 and 85.21 respectively.

Table 6: Estimated Models

Regressor	Model I	Model II	Model III
	Coefficient[P-Value]	Coefficient [P-Value]	Coefficient [P-Value]
C	4.41 [0.02]	4.06 [0.05]	5.33 [0.00]
DLGDP(-1)	-0.06 [0.77]	-	-
DLGDP(-2)	0.09 [0.65]	-	-
DLIP(-1)	-	0.00 [0.99]	-
DLIP(-2)	-	0.11 [0.57]	-
DLAGRI(-1)	-	-	0.03 [0.89]
DLAGRI(-2)	-	-	0.05 [0.82]
DLELEC(-1)	0.01 [0.93]	-0.18 [0.41]	0.32 [0.37]
DLELEC(-2)	0.00 [1.00]	-0.01 [0.94]	0.21 [0.42]
DLOIL(-1)	-0.18 [0.12]	-0.21 [0.09]	-0.45 [0.06]
DLOIL(-2)	-0.12 [0.12]	-0.13 [0.21]	-0.38 [0.03]
DLGAS(-1)	-0.19 [0.02]	-0.14 [0.18]	-0.15 [0.32]
DLGAS(-2)	-0.15 [0.02]	-0.35 [0.00]	0.03 [0.84]
DLCOAL(-1)	0.01 [0.86]	-0.01 [0.93]	-0.12 [0.26]
DLCOAL(-2)	0.03 [0.49]	0.07 [0.28]	-0.04 [0.68]
LGDP(-1)	-0.41 [0.05]	-0.37 [0.16]	-0.65 [0.01]
LELEC(-1)	0.09 [0.43]	0.39 [0.01]	-0.37 [0.22]
LOIL(-1)	0.00 [0.99]	-0.24 [0.08]	0.48 [0.09]
LGAS(-1)	0.21 [0.05]	0.20 [0.11]	0.18 [0.19]

LCOAL(-1)	0.01 [0.94]	-0.13 [0.20]	0.27 [0.06]

R-Squared	0.70	0.77	0.51
Adjusted R-Square	0.48	0.59	0.26
DW-Statistic	2.29	0.27	2.21
AIC	97.88	81.79	81.80
SBC	85.21	69.13	69.13

*(-1) and (-2) indicate 1st and 2nd lags of the variables

** [.] Indicates P-values

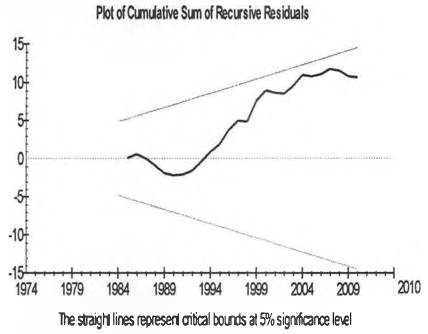
Diagnostic and Stability Tests of Estimated Models

	Model I		**Model II**		**Model III**	
	F-Stats	**Probability**	**F-Stats**	**Probability**	**F-Stats**	**Probability**
χ^2_{NORM}	0.18	0.91	3.91	0.14	2.35	0.76
χ^2_{WHITE}	0.19	0.66	5.14	0.23	4.05	0.14
χ^2_{RAMSEY}	0.36	0.55	3.14	0.76	2.08	0.23
$\chi^2_{Serial Corr}$	2.84	0.19	9.36	0.20	7.60	0.19

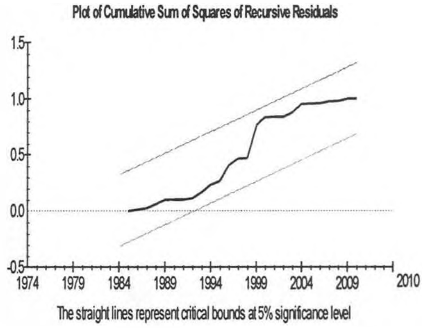
Note: For normality test, we report Jeque-Bera statistics. χ^2_{NORM}, χ^2_{WHITE}, χ^2_{RAMSEY}, χ^2_{ARCH}, $\chi^2_{Serial Corr}$ are non-normal errors normality test, white heteroskedsaticity test, Ramsey Regression Specification Error Test, and Auto regressive Conditional Heteroskedsaticity (ARCH Test), Serial correlation Lagrange Multiplier Test (LM-type Breusch-Godfrey-Test). These statistics are distributed as Chi-square values and explain the degree of freedom at last column.

All diagnostic and stability test such as heteroskedsaticity, normality, serial correlation, autoregressive conditional heteroskedsaticity (ARCH) test and functional-form misspecification (Ramsey Regression Specification Error Test) are reported in table 6. For normality test, we report Jeque-Bera statistics that takes non-normal errors, its value is 0.184 along with probability value 0.912 and also indicate the presence of normal distribution. The null hypothesis of heteroskedsaticity is rejected with the probability value 0.658 that support the evidence of no heteroskedsaticity across the terms. There also does not designate the evidence of serial autocorrelation that support to the idea of no autocorrelation across the terms. Ramsey test indicates that the result is in favor of stability of parameters.

The plots of CUSUM and CUSUM-square statistics of estimated equation (5.1), shown below, are in critical bounds and do not diverge from that critical region that specifies the stability of coefficient in the estimated model. They also confirm the stability of long and short-run estimates of the models in ARDL estimation. The absence of divergence and presence of convergence mainly support to the long-run as well as short-run stability of the model, particular to the long-run estimates that just require the normalization process.


Plot of Cumulative Sum of Recursive Residuals

The straight lines represent critical bounds at 5% significance level


Plot of Cumulative Sum of Squares of Recursive Residuals

The straight lines represent critical bounds at 5% significance level

The test statistics of the estimations of Model II (equation 5.2) show that 77 percent variation in the determination of real industrial output is explained by the model. All diagnostic and stability test such as heteroskedsaticity, normality, serial correlation, autoregressive conditional heteroskedsaticity (ARCH) test and functional-form misspecification (Ramsey Regression Specification Error Test) are reported in table 6 above. The explanation and meanings of the statistics are already explained for model 5.1. The Durbin Watson statistic and all the diagnostic tests confirm he normality of the model and the stats are in the desirable range. The plots of CUSUM and CUSUM-square statistics of estimated equation (5.2), shown in Appendix, are in critical bounds and do not diverge from that critical region that specifies the stability of coefficient in the estimated model.

The results and interpretation of the Model III (equation 5.3) in which dependent variable is Agricultural Output and independent variables are the disaggregated components of energy consumption also follows 2 lags from the standard lag length selection criterion for the regression of ARDL econometric model.

The value of R-squared and adjusted R-squared is 0.51 and 0.2647, respectively that shows only 51 percent variation in the determination of real Agricultural output is explained by the model. The value of Durbin-Watson statistics is 2.21 that satisfies to the desirable level and validates the rejection of null hypothesis of serial autocorrelation at any order. The unique model selection or information criteria mentioned by Akiake Information Criteria (AIC) and Schwarz Criteria that is 81.79 and 69.183 respectively. All diagnostic and stability test such as heteroskedsaticity, normality, serial correlation, autoregressive conditional heteroskedsaticity (ARCH) test and functional-form misspecification (Ramsey Regression Specification Error Test) are reported in table 6 above. The plots of CUSUM and CUSUM-square statistics of estimated equation (5.2), shown in Appendix, are in critical bounds and do not diverge from that critical region that specifies the stability of coefficient in the estimated model.

6.4 Bounds Tests for cointegration

The test for the presence of cointegration or long-run relation among the series require the application of Bounds testing approach in which all long-run coefficient are restricted/ tested with the equality of zero. The result of bound testing is reported in table 8, below that take the values of F-statistics of the three models with GDP, IP and AGRI as dependent variables. The critical values of F-statistics with different level of significance and along with lower and upper bounds are also reported in table 8. In addition to that, the calculated values among the first two models lie above the upper *I(1)*critical value of F-statistics, indicating the evidence of cointegration or long-run relation. However, the computed value of F-statistics lies below the lower bound when Agri is taken as dependent variable, indicating that the long run relationship could not be found by this approach.

Table 9: F-Stats for Bounds Testing

Equation	Computed F-Statistics	Critical F-Statistics at 5% level		Cointegration
		I (0)	I (1)	
F(GDP │ Elec, Oil, Gas, Coal)	4.0381	2.86	4.01	Yes
F(IP │ Elec, Oil, Gas, Coal)	4.6250	2.86	4.01	Yes
F(Agri │ Elec, Oil, Gas, Coal)	2.5683	2.86	4.01	No

In first two cases where GDP and IP are the dependent variables, the computed F-Statistics is greater than the upper bound critical value. This indicates that a long run relationship exists in both these specifications. However, in the third specification with Agri as dependent variable, the computed F-statistics is lower than the upper bound critical value which means that there is no long run relationship between Agriculture and disaggregated energy components. Therefore, only first two models will be analyzed further for long run and short run relationship.

6.5 Real GDP and Disaggregate energy Consumption

The F-Statistics verified the existence of long run relationship between GDP and disaggregate components of energy. Now we move on to finding the ARDL estimates for the short run and long run relation between them. The results obtained from estimation are represented below

Long Run Coefficients

$$LGDP_t = 9.8517 - 0.87308\ LELEC + 0.31064\ LOIL + 0.38457\ LGAS + 0.27120\ LCOAL \quad \textbf{(6.1)}$$

(0.000) (0.653) (0.056) (0.000) (0.002)

Short Run Coefficients

$$\Delta GDP_t = 2.8916 + 0.70649\ \Delta GDP_{t-1} + 0.17846\ \Delta LELEC + 0.028213\ \Delta LOIL \quad \textbf{(6.2)}$$

(0.002) (0.000) (0.008) (0.529)

$$- 0.1455\ \Delta LOIL_{t-1} - 0.005\ \Delta LGAS + 0.0796\ \Delta LCOAL - 0.29351\ ECM_{t-1}$$

(0.000) (0.904) (0.021) (0.004)

(R-Squared 0.69, Adjusted R-Square 0.59, DW-Statistic 2.33, F-Statistic 10.13[0.01])

The coefficient of electricity is insignificant in the long run while it is positively significant in the short run. We can see the long term of electricity consumption which has not varied significantly since1980 as the GDP grew. A very steep upward sloping curve of GDP is accompanied by a relatively straighter line for electricity consumption. This is because consumption of Oil and Natural gas rose over time and dominated the energy mix in the long run while electricity consumption increased slowly. Therefore, our results depict the same phenomenon that electricity consumption in the long run is not a significant contributor to GDP. The result is supported by (Siddiqui, 2004). In short run the coefficient of electricity consumption is positive and significant. The result is supported by (Shahbaz and Hooi, 2011) who also found strong positive relationship between electricity consumption and GDP in the short run. The substitutability of electricity in short run is not possible at least in the large scale manufacturing sector. This actor makes the role of electricity significant in the short run. Smooth flow of supply and higher consumption results in higher output and vice versa. However, in the long run it does not appear to be significant because there is room in long term to change the energy input mix from electricity to oil or gas depending upon the nature of production process and cost effectiveness of the substitution.

The results show that consumption of oil has positive and significant impact on GDP in the long run while in the short run it's the first lag which is significant. This implies that the consumption of oil affects the GDP in short run after a lag of one year and does not immediately shows the impact. The results are also supported by (Siddiqui, 2004) and (Aqeel and Butt, 2001) both of whom found positive cointegration between petroleum consumption and GDP in case of Pakistan. The results are also evident from figure 2 that the long term oil consumption trend is upward sloping and quite commensurate with the rise of GDP. The consumption of oil has significantly increased over time and currently it is the second largest component of energy consumed after natural gas. It plays a positive role in the long run and the same has been found by our analysis.

The consumption of gas has significantly positive impact on GDP in the long run. (Shahbaz and Hooi, 2011) also found significant long run relationship between GDP and gas consumption. The consumption of gas rose sharply since 1972 when it was 114.5 trillion BTU to 1420 trillion BTU in 2010. Natural gas consumption has been the most rapidly increasing among all the energy components over past 40 years and it's not surprising to find a strong positive relationship with GDP in the long run. However, coefficient gas consumption is not significant in the short run.

Coal consumption is significant both in the short run and long run but its magnitude is very small as our economy is not heavily dependent upon coal as a source of energy. (Ishida, 2012) found the significant relationship between fossil fuels and GDP in a panel analysis for countries across the world.

6.6 Industrial Production and Disaggregate Energy Consumption:

The results for the long run and short run relationship between disaggregate energy consumption and industrial production is reproduced below;

Long Run Coefficients

$$\begin{aligned} LIP_t &= \underset{(0.000)}{9.637} + \underset{(0.008)}{0.65903}\, LELEC - \underset{(0.301)}{0.1975}\, LOIL + \underset{(0.041)}{0.2177}\, LGAS + \underset{(0.137)}{0.1304}\, LCOAL \qquad \textbf{(6.3)} \end{aligned}$$

Short Run Coefficients

$$\begin{aligned}\Delta LIP_t = {} & \underset{(0.000)}{4.0068} + \underset{(0.000)}{0.5842}\,\Delta LIP_{t-1} + \underset{(0.000)}{0.27401}\,\Delta LELEC + \underset{(0.044)}{0.1425}\,\Delta LOIL \\ & - \underset{(0.001)}{0.2128}\,\Delta LOIL_{t-1} + \underset{(0.113)}{0.0905}\,\Delta LGAS + \underset{(0.232)}{0.0542}\,\Delta LCOAL - \underset{(0.000)}{0.4046}\,ECM_{t-1}\end{aligned} \tag{6.4}$$

(R-Squared 0.70, Adjusted R-Square 0.63, DW-Statistic 2.22, F-Statistic 11.19[0.00])

When disaggregated components are regressed against industrial production, electricity consumption has strong positive and significant impact on the industrial production both in short run and long run. Industrial sector is the largest consumer of energy (44% of total energy consumption) and among different components, electricity is the major input. Industrial production has a straightforward relationship with electricity consumption; higher the consumption, higher the output and vice versa. While studying the relationship with GDP, we noted that different sectors could manage to substitute other cheaper sources for electricity but in industrial sector. Even if the substitution takes place in the industry in long run, it does not affect the positive relationship between industrial output and electricity consumption. This effect is also translated into GDP as we have seen the positive impact of electricity consumption on GDP. This result is supported by the fact that industrial sector is the major consumer of all the energy component especially the large scale manufacturing sector depends heavily on electricity.

Coefficient of oil consumption is positive and significant in the short run while it is not significant in the long run. Here again, the insignificance in the long run can be attribute to substitutability factor as the price differential between oil and natural gas is very high and in the long run industries may shift to gas to minimize input costs. The coefficient of gas consumption is positive and significant in the long run while slightly insignificant in the short run while it is. However, the consumption of coal is insignificant both in short run and long run as coal is not a major energy input in the production processes in the industrial sector of Pakistan.

Finally, the process of adjustment to long-run equilibrium is captured by coefficient of ECM (φ). If φlies between 0 and –1, the correction to GDP in period t is a part of the error in period t-1. In this case, the ECM causes the GDP to converge monotonically to their long-run equilibrium path in response to the changes in the exogenous variables of their respective models. If the ECM is positive or less than –2, this will cause GDP to diverge. If the value is between –1 and –2, the ECM will cause dampened oscillations in GDP around their equilibrium path. In both the models ECM is between 0 and –1 and is statistically significant. This will lead the error correction process to converge monotonically to equilibrium path. In equation 6.2, the coefficient of ECM is -0.293and is significant. It implies that deviation of GDP from the equilibrium level in the current period will be adjusted by 29.3 % in the next period. In equation 6.2, the coefficient of ECM is -0.404 and is also significant. It implies that deviation of IP from the equilibrium point in the current period will be corrected by 40.4 % in the next period.

The graphs of CUSUM and CUSUMQ statistic of both models are given in appendix. As the plots of CUSUM and CUSUMSQ statistics are found within the critical bonds of 5 %

level of significance. Hence null hypothesis of stability of coefficient is not rejected. So this confirms the reliability of all ARDL models.

CHAPTER 7

SUMMARY AND CONCLUSION

The relationship between energy and economic performance has been of great interest as energy is considered to be one of important the driving forces of economic growth. The dependence of all the sectors of economy justifies the association of energy with overall economic growth. Therefore, deficient supply of energy sources may inhibit growth activities. Various studies attempted to find the relationship between energy consumption and economic growth or GDP. Most of them aimed at finding the direction of causality between energy consumption and economic growth using aggregate energy use. This study, however, tried to find the relationship of disaggregate energy consumption with GDP, industrial output and agriculture output. In, Pakistan there is hardly any study that comprehensively analyzes such a relationship at disaggregate level and at sectoral level.

The impact of disaggregate energy consumption on GDP, industrial output and agriculture output, separately, has been empirically tested using time series data from 1972-2010. The study uses ARDL approach to cointegration. The major findings of the study are; electricity consumption has positive relationship with the GDP in the short run while it is insignificant in the long run. Oil and gas consumption has positive relationship with GDP in the long run while coal consumption has positive relationship with GDP but with a small magnitude.

When the impact of disaggregate energy on industrial output is analyzed, it is found that electricity and gas consumption has a positive long run relationship with GDP while Oil consumption has a connection with industrial output only in the short run. Coal consumption is found to have no linkage with industrial output both in shot run and long run.

The existence of cointegration between disaggregate energy consumption and agricultural output was ruled out by the bounds testing. The value of F-Statistic lied below the lower bound critical value indicating the absence of any long run relationship. In such a case, all the explanatory variable appear as insignificant.

It can therefore, be concluded that energy consumption is vital to the industry and overall output of the economy. All the components of energy affect GDP and Industry either in the short run or long run or even in both. On the basis of these results, following policy implications can be drawn;

- Natural gas consumption has become the most widely used fuel in Pakistan economy and its relationship to GDP and industrial output is positive so the smooth and uninterrupted supply of gas is very important for industry and economy. Import of gas is much needed and IPI and TAPI gas pipeline projects may be crucial.
- Inter fuel substitution results from change in pricing structures and this appears to have taken place when economy shifted to gas consumption as its price as low compared to other sources of energy. The pricing policies should thus be revised to eliminate the price differential between natural gas and other fuels because it is a non-renewable resource.
- The dependence on oil has significantly reduced due to shift towards natural gas as international oil prices have risen sharply in last two decades. There is a need

to make use of renewable sources of energy to vitiate the burden on natural gas whose supply can't even match toady's demand.

- Coal consumption has a positive link to GDP so it can be aa good substitute to make use of. Coal gasification and its use is suggested by experts due to non-extractability of the coal reserves in Pakistan. This may help curb current energy crisis to some extent.

APPENDIX

Autoregressive Distributed Lag Estimates (GDP and Energy)

Table 7: ARDL (1, 1, 2, 1, 0) selected based on Schwarz Bayesian Criterion

Dependent variable is LGDP

37 observations used for estimation from 1974 to 2010

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
LGDP(-1)	.70	.09	7.60[.00]
LELEC	.18	.063	2.82[.01]
LELEC(-1)	-.20	.081	-2.51[.02]
LOIL	.03	.044	.64[.53]
LOIL(-1)	-.08	.053	-1.56[.13]
LOIL(-2)	.14	.04	3.99[.00]
LGAS	-.00	.04	-.122[.90]
LGAS(-1)	.12	.05	2.35[.02]
LCOAL	.08	.033	2.43 [.02]
C	2.8916	.84735	3.4125[.002]
R-Squared	0.69		R-Bar-Squared 0.50
S.E. of Regression	.01		F-stat.F(9, 27) 8053.7[.00]

Mean of Dependent Variable	14.69	S.D. of Dependent Variable	.55
Residual Sum of Squares	.00	Equation Log-likelihood	116.15
Akaike Info. Criterion	106.16	Schwarz Bayesian Criterion	98.10
DW-statistic	2.33	Durbin's h-statistic	-1.23[.22]

Table 8: Diagnostic Tests

Test Statistics	LM Version	F Version
A: Serial Correlation	CHSQ (1) = 1.70[.19]	F (1, 26) = 1.25[.27]
B: Functional Form	CHSQ (1) = 2.04[.15]	F (1, 26) = 1.52[.23]
C: Normality	CHSQ (2) = .83[.66]	Not applicable
D: Heteroskedsaticity	CHSQ (1) = 1.13[.29]	F (1, 35) = 1.10[.30]

Figure 7: Plot of Cumulative Sum of Squares of Recursive Residuals

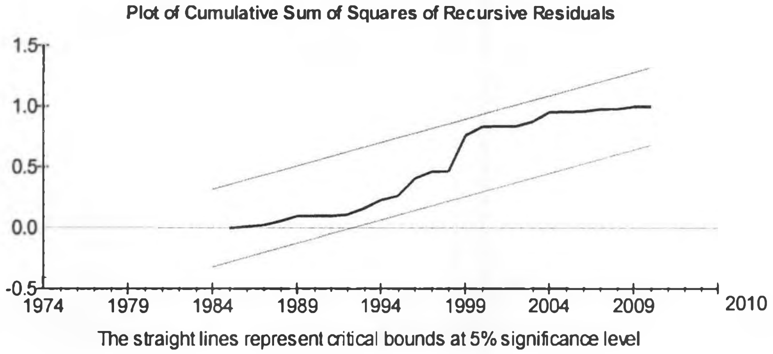
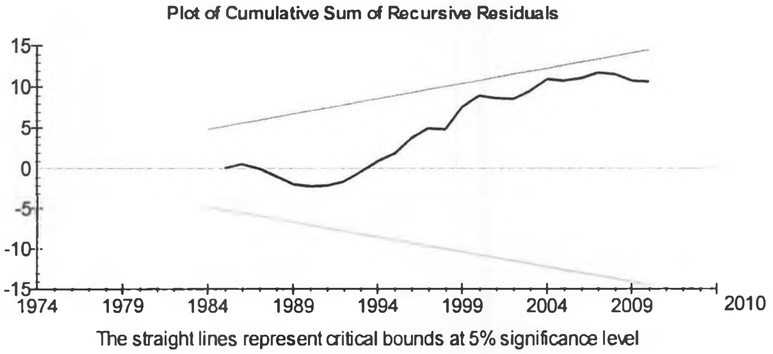


Figure 8: Plot of Cumulative Sum of Recursive Residuals



Autoregressive Distributed Lag Estimates (IP and Energy)

Table 9: ARDL (1, 0, 2, 0, 0) selected based on Schwarz Bayesian Criterion

Dependent variable is LIP

37 observations used for estimation from 1974 to 2010

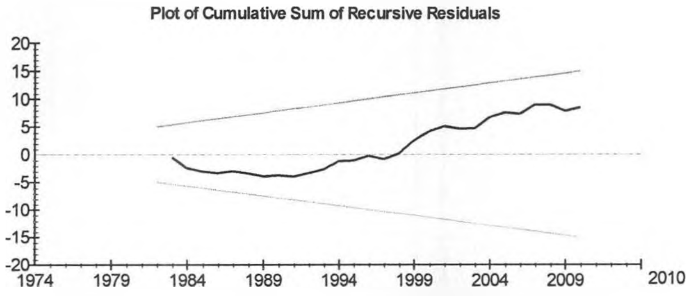
Regressor	Coefficient	Standard Error	T-Rati0 [Prob]
LIP(-1)	.58	.10	5.68[.00]
LELEC	.27	.06	4.53[.00]
LOIL	-.14	.06	-2.10[.04]
LOIL(-1)	-.15	.08	-1.87[.07]
LOIL(-2)	.21	.06	3.72[.00]
LGAS	.09	.05	1.63[.11]
LCOAL	.05	.04	1.22[.23]
C	4.01	.76	5.26[.00]

R-Squared	.70	R-Bar-Squared	.63
S.E. of Regression	.020	F-stat.F(7, 29)	5016.7[.00]
Mean of Dependent Variable	13.20	S.D. of Dependent Variable	.64
Residual Sum of Squares	.012	Equation Log-likelihood	95.73
Akaike Info. Criterion	87.73	Schwarz Bayesian Criterion	81.28
DW-statistic	2.22	Durbin's h-statistic	-.88[.38]

Table 10: Diagnostic Tests

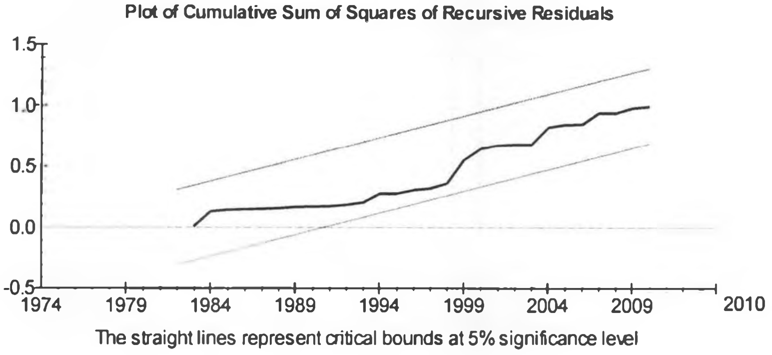
Test Statistics	LM Version	F Version
A: Serial Correlation	CHSQ (1)= 1.34[.25]	F(1, 28)= 1.05[.314]
B: Functional Form	CHSQ (1)= 7.04[.08]	F(1, 28)= 6.58[.016]
C: Normality	CHSQ (2)= .95[.62]	Not applicable
D: Heteroskedsaticity	CHSQ (1)= .72[.4]	F(1, 35)= .69[.41]

Figure 9: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure 10: Plot of Cumulative Sum of Squares of Recursive Residuals



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