© *The Pakistan Development Review*
53:4 Part II (Winter 2014) pp. 477–490

Energy Sources and Gross Domestic Product: International Evidence

WASEEM AHMAD and TANVIR AHMED

INTRODUCTION

The relationship between energy consumption and economic growth received a significant amount of attention in energy economics literature [Al-Iraiani (2006)]. Rufael (2006) stated that different energy sources are a necessary requirement for economic and social development and no country in the world has progressed from subsistence economy without the use of energy. In this regard, four views have emerged over time about the relationship between energy consumption and output growth. One point of view is that energy is the prime source of value and other factors like labor and capital cannot do without energy. Many studies argue that the impact of energy use on growth depends on the structure of the economy and the stage of economic growth of the country concerned [Ghali and Sakka (2004)]. The bulk of the literature reports a uni-directional causality from energy consumption to economic growth. When the causality runs from energy consumption to economic growth, it is also called 'growth hypothesis'. Table 1 provides a list of the studies, which show such results. It implies that an increase in energy consumption has a significant impact on economic growth and if it is positive, then energy conservation policies have a detrimental impact on economic growth. Alternatively, if an increase in energy consumption has significant negative impact on GDP, it implies that growing economy needs a less amount of energy consumption, may be due to shift towards less energy intensive sectors [Payne (2010)]. Second point of view is that economic growth has a positive influence on energy consumption. There may be uni–directional causality from economic growth to energy consumption. Table 1 displays a list of studies showing such results. When the causality runs from economic growth to energy consumption, it is often referred to as 'conservation hypothesis'. It implies that energy conservation policies formulated to reduce energy consumption may not adversely affect economic growth. Third point of view is that the cost of energy use is very small compared to GDP and consequently its impact on economic growth is non-significant. There may be no causality between energy consumption and GDP; it is often referred to as 'neutrality hypothesis". A list of studies showing such results is given in Table 1. It implies that energy consumption has not a significant influence on economic

Waseem Ahmad <waseem@uaf.edu.pk> is Assistant Professor, Institute of Business Management Sciences, University of Agriculture, Faisalabad. Tanvir Ahmed is Associate Professor, Department of Economics, Forman Christian College (A Charted University), Lahore.

Table 1

Studies Showing Various Types of Causality from Energy Consumption to Economic Growth

Country	Authors	Period	Methodology
	Causality from Energy Consumption to Economic Growth		
USA	Stern (2000)	1948-1994	Co-integration, Granger causality
Turkey	Soytas, *et al.* (2001)	1960-1995	Co-integration, Granger causality
Taiwan	Lee and Chang (2007a)	1955-2003	Granger causality, co-integration, VECM
Hong Kong	Ho and Siu (2007)	1966-2002	Co-integration , VEC model
	Causality from Economic Growth to Energy Consumption		
USA	Kraft and Kraft (1978)	1947-1974	Granger causality
India	Cheng (1999)	1992-1995	Co-integration, ECM, Granger causality
Pakistan	Aqeel and Butt (2001)	1955-1996	Hsiao's version of Granger causality Method, Co-integration
Iran	Zamani (2007)	1967-2003	Granger causality, Co-integration, VECM
Turkey	Karanfil (2008)	1970-2005	Granger Causality Test, Co-integration test
China	Zhang and Cheng (2009)	1960-2007	Granger causality
	No Causality between Economic Growth and Energy Consumption		
New Zealand	Fatai, *et al.* (2002)	1960-1999	Granger causality, ARDL, Toda and Tamamoto test
Turkey	Halicioglu (2009)	1960-2005	Granger causality, ARDL, co-integration
USA	Payne (2009)	1949-2006	Toda-Yamamoto causality test
Turkey	Belloumi (2009)	1960-2000	Toda-Yamamoto causality test
	Bi-directional Causality between Economic Growth and Energy Consumption		
Korea	Glasure (2002)	1961-1990	Co-integration, error correction, variance decomposition
Canada	Ghali and El-Sakka (2004)	1961-1997	Co-integration,, VEC, Granger causality
India	Paul and Bhattacharya (2004)	1950-1996	Co-integration and Granger causality
Turkey	Erdal, *et al.* (2008)	1970-2006	Pair-wise Granger causality, Johansen co-integration

growth, which means that neither conservation nor expansive policies pertaining to energy consumption have any effect on economic growth [Ozturk (2010)]. Fourth point of view is that when output and energy consumption are moving together towards a long-run equilibrium, and energy consumption and GDP are interdependent, and affect each other at the same time, there may be bi-directional causality [Payne (2010); Ozturk (2010)]. It implies that an increase (decrease) in GDP causes an increase (decrease) in energy consumption and similarly an increase (decrease) in GDP results in an increase (decrease) in energy consumption. It is also called ‘feedback’ hypothesis. A list of studies reporting such results is given in Table 1.

Different forms of causality between energy consumption and the economic growth have been reported by many studies in different countries (Table 2). Further multi-country studies also show similar results (Table 3). Thus empirical studies conducted on the energy consumption and economic growth yielded mixed results in terms of the above hypotheses; that is, some studies show causality running from energy consumption to economic growth, others report causality running from economic growth to energy consumption, while some studies find no causality or bi-directional causality. There is absence of consensus on the relationship between energy consumption and growth.

Table 2

Studies Showing Different Energy Consumption and Economic Growth Causality for the Selected Countries

Countries	Causality Relationship			
	GDP→EC	EC→GDP	EC←→GDP	GDP-----EC
India	Cheng (1999)	Masih (1996)	Paul and Bhattacharya (2004)	Soytas and Sari (2003)
Japan	Cheng (1998), Lee (2006)	Soytas and Sari (2003)	Erol and Yu (1987)	–
Korea	Yu and Choi (1985), Soytas and Sari (2003)	Oh and Lee (2004)	Glasure (2002)	–
Malaysia	Ang (2008)	Chiou-Wei, *et al.* (2008)	–	Masih (1996)
Turkey	Lise and Van Montfort (2007), Karanfil (2008)	Murray and Nan (1996), Soytas, *et al*. (2001), Soytas and Sari (2003)	Erdal, *et al.* (2008)	Altinay and Karagol (2004), Altinay and Karagol (2007), Karanfil (2008), Soytas and Sari (2009), Halicioglu (2009)
USA	Kraft (1978), Abosedra and Baghestani (1989)	Stern (2000), Soytas and Sari (2006), Bowden and Payne (2009)	Lee (2006)	Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), Yu and Jin (1992), Cheng (1995), Soytas and Sari (2003), Chiou-Wei, *et al*. (2008), Payne (2009)

Table 3

Causal Relationships between Energy Consumption and Economic Growth for Multi-Country Studies

Authors	Period	Countries	Methodology	Causality Relationship
Soytas and Sari (2003)	1950–1992	G-7 Countries	Co-integration and Granger causality	EC←→ GDP (Argentina) GDP→EC (Italy, Korea) EC→GDP (Turkey, France, Japan, Germany)
Lee (2005)	1975–2001	18 Developing Countries	Panel VECM	EC→GDP
Lee (2006)	1960–2001	11 Developed Countries	Granger causality test	GDP- ---EC(Germany, UK) EC←→ GDP (Sweeden, USA) EC→GDP (Belgium, Netherlands, Canada, Switzerland)
Soytas and Sari(2006)	1960–2004	G-7 Countries	Multivariate co-integration, ECM, generalised variance decompositions	GDP→EC (Germany) EC→GDP (France, USA) EC←→GDP (Canada, Italy, Japan, UK)
Lee and Chang(2007b)	1965–2002 1971–2002	22 Developed Countries,18 Developing Countries	Panel VARs and GMM	GDP→EC (developing countries) EC←→GDP (developed countries)
Chiou-Wei, *et al.*(2008)	1954–2006	Asian Countries and USA	Granger causality	GDP- ---EC(USA, Thailand, South Korea) GDP→EC (Philippines, Singapore) EC→GDP (Taiwan, Hong Kong, Malaysia, Indonesia)
Chang, *et al.* (2013)	1970-2010	12 Asian Countries	Panel causality analysis	EC----GDP (China, Indonesia, Japan, Malaysia, Pakistan, Philippines, Singapore, South Korea, Taiwan) EC→GDP (Philippines) GDP→EC (India) EC←→GDP (Thailand and Vietnam)

Karanfil (2009) has suggested that any future research using the same methods, variables and changing study period have no more potential to make a contribution to the existing energy consumption—economic growth literature. In order to avoid conflicting and unreliable results, Ozturk (2010) has suggested the use of new approaches, including panel data approach. Further, a majority of studies (Tables 1 to 3) estimate the causal relationship between aggregate energy consumption and economic growth. Use of aggregate energy consumption may mask the differential impact associated with various forms of energy consumption like gas, oil, electricity and coal [Payne (2010)]. The aim of this paper is to empirically investigate the relationship between output and energy use of various forms. We use a framework of neoclassical production economics where labour, capital and various forms of energy (i.e. gas, oil, electricity and coal) are treated as separate inputs. Within this framework, we use cross country panel data over the period 1990–2011. The results of the translog production function show that labor, capital, gas, oil and electricity have positive and significant impact on the GDP, while the coal has negative significant impact. This paper contributes in the following ways, first we use panel data approach to estimate the impact of energy consumption on economic growth. Second, we use the cross country data of countries having different levels of income to estimate the relation, which has not been done so far. Third, we estimate the relationship between energy consumption of various forms along with labor and capital on output.

The remainder of the paper is organised as follows. Section 2 is concerned with the data and variables, and reports methodology along with the description of the model. Section 3 presents the empirical results and Section 4 deals with the conclusion and policy implications.

DATA AND VARIABLES

In this study, cross country data have been used to estimate the production function by using real GDP as dependent variable and factors like total labour force, gross capital formation, and consumption of gas, oil, electricity and coal as independent variables. Besides these variables, dummy variables have been included in the model to capture the region specific, income level and climate effects. Data for real GDP are measured in constant 2005 US dollar and are obtained from the *World Development Indicators* [WDI, The World Bank (2011)]. Labour is a conventional input and is measured in millions, capital is measured in terms of gross capital formation in million US$ and is considered as a reliable proxy for capital stock [Jin and Yu (1996) and Shan and Sun (1998)]. The data for total labor force and gross capital formation are obtained from World Development Indicators [WDI, The World Bank (2011)]. Natural gas consumption is measured in billion cubic meters. Oil products include all liquid hydrocarbons obtained by refining of crude oil and NGL and by the treatment of natural gas, in particular LPG (liquid petroleum gas) production; it is measured in million tons. Electricity is measured in terawatt hours; it includes electricity consumption of private, public and industrial sectors. Coal is measured in million tons. The data for gas, oil, electricity and coal are obtained from *Global Statistical Yearbook* (http:// yearbook.enerdata.net/). Regional dummy variables are included to capture the regional specific effects. These regions are Europe, Commonwealth of Independent States, North America, Latin America, Asia, Pacific, Africa and Middle East. All World Bank countries have been divided into three groups on the basis of gross national income per capita i.e. low income ($1035 or less), middle income ($1036 to $12615) and high income ($12616 or more) (http://data.worldbank.org/about/country-classifications/ country-and-lending-groups). Dataset are available from 1990 to 2011 about the above variables only for 40 countries. These countries are either in the middle income or in high income group. Therefore only one dummy variable is used in the analysis. A list of countries included in this study is given in Appendix. The Koppen climate classification system divides the world's climate into 5 types on the basis of annual and monthly averages of temperature and precipitation. For the purpose of this study, last two types of climate i.e. Moist Continental Mid-latitude climate - E category (where the winter is cold and average temperature of the coldest month is less than –3 C^0) and Polar Climates - D category (where the soil is permanently frozen to depths of hundreds of meters or where the soil surface is permanently covered with snow and ice) have been grouped into one category. A dummy variable assumes a value of one if the country is mainly located in either of the above two climate zones, otherwise zero.

The descriptive statistics show that the average GDP of countries included in the sample is 833139 million US $. It may be noted that the countries included in the sample belong to the high income or middle income categories. The average value of dummy variable for middle income group shows about 48 percent countries included in the sample belong to the middle income category and 52 percent countries in the sample belong to the high income category. Due to non-availability of data about the low income countries, we could not include them in the analysis. The average value of electricity is 243.83 terawatt hour and the mean value of gas and oil are 45.30 million cubic meter and 58.60 million tons respectively (as shown in Table 4). The regional dummies show that about 35 percent countries included in the analysis are from European region and 15 percent countries included in the analysis are each from Latin America and Asian region. Dummy for climatic region shows that about 20 percent countries included in the analysis belong to D or E region.

Table 4

Descriptive Statistics of Variables Used in the Analysis

Variable[a]	Mean	Standard Deviation
GDP	833139	1844001.00
G	45.30	96.74
O	58.62	126.67
E	243.83	548.80
C	72.58	164.07
L	34.14	67.79
K	164277.70	348603.40
Deu	0.35	0.48
Dcis	0.08	0.26
Dnamerica	0.05	0.22
Dlamerica	0.15	0.36
Dasia	0.15	0.36
Dpacific	0.05	0.22
Dmiddle	0.48	0.50
Dcold	0.20	0.40

[a]Definitions of variables are given in Table 5.

The Model

The present study examines the relationship between gross domestic product (GDP) and various factors in production function framework such as total labor, gross capital formation and energy; energy is further divided into different forms such as oil, gas, electricity and coal. Mathematically it can be written as:

$$GDP = f(L, K, G, O, E, C) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where *GDP* represents the gross domestic product (GDP), *L* denotes total labor, *K* shows the capital, *G* represents gas, *O* denotes oil, *E* shows electricity and *C* indicates the coal consumption.

In this study a Translog function has been used; this function can be approximated by second order Taylor series. The Translog functional form imposes fewer restrictions on the production technology. It does not impose any a priori restriction on returns to scale and elasticity of substitution. Because of above mentioned reasons, it is widely used in the production economics literature [Kim (1992)]. We also used dummies for different regions, income levels and climatic zone. The detailed functional form can be written as follows:

$$\begin{aligned}
LnGDP_{jt} &= \beta_0 + \beta_1 LnL_{jt} + \beta_2 LnK_{jt} + \beta_3 LnG_{jt} + \beta_4 LnO_{jt} + \beta_5 LnE_{jt} + \beta_6 LnC_{jt} \\
&+ \frac{1}{2}(\beta_{11} LnL_{jt} LnL_{jt} + \beta_{22} LnK_{jt} LnK_{jt} + \beta_{33} LnG_{jt} LnG_{jt} + \beta_{44} LnO_{jt} LnO_{jt} + \beta_{55} LnE_{jt} LnE_{jt} \\
&+ \beta_{66} LnC_{jt} LnC_{jt}) + \beta_{12} LnL_{jt} LnK_{jt} + \beta_{13} LnL_{jt} LnG_{jt} + \beta_{14} LnL_{jt} LnO_{jt} + \beta_{15} LnL_{jt} LnE_{jt} + \beta_{16} LnL_{jt} LnC_{jt} \\
&+ \beta_{23} LnK_{jt} LnG_{jt} + \beta_{24} LnK_{jt} LnO_{jt} + \beta_{25} LnK_{jt} LnE_{jt} + \beta_{26} LnK_{jt} LnC_{jt} + \beta_{34} LnG_{jt} LnO_{jt} \\
&+ \beta_{35} LnG_{jt} LnE_{jt} + \beta_{36} LnG_{jt} LnC_{jt} + \beta_{45} LnO_{jt} LnE_{jt} + \beta_{46} LnO_{jt} LnC_{jt} + \beta_{56} LnE_{jt} LnC_{jt} + \gamma_1 Deu \\
&+ \gamma_2 Dcis + \gamma_3 Dnamerica + \gamma_4 Dlamerica + \gamma_5 Dasia + \gamma_6 Dpacific + \gamma_7 Dmiddle + \gamma_8 Dcold + \mu_{jt}
\end{aligned}$$

Where GDP_{jt} is gross domestic product of *j*th country in year *t*, L_{jt} is total labor of *j*th country at *t* year, K_{jt} is gross capital formation of jth country at *t* year, G_{jt} is total gas consumption of *j*th country at *t* year, O_{jt} is total consumption of oil products in *j*th country at *t* year, E_{jt} is total domestic consumption of electricity in jth country at *t* year, C_{jt} is total consumption of coal in *j*th country at *t* year, Deu, Dcis, Dnamerica, Dlamerica, Dasia, Dpacific are different regional dummies, Dmiddle shows the dummy for middle income countries, Dcold denotes the dummy for cold climatic zone and μ_{jt} is the random error term.

The elasticity of GDP with respect to each input i.e. labor, capital, gas, oil, electricity and coal would be calculated by using:

$\varepsilon_i = \dfrac{\partial LnGDP}{\partial LnX_i}$ where X_i represents labour, capital, gas, oil, electricity and coal. So the elasticity of each input can be written as:

$$\begin{aligned}
\varepsilon_L &= \beta_1 + \beta_{11}\overline{LnL} + \beta_{12}\overline{LnK} + \beta_{13}\overline{LnG} + \beta_{14}\overline{LnO} + \beta_{15}\overline{LnE} + \beta_{16}\overline{LnC} \\
\varepsilon_K &= \beta_2 + \beta_{22}\overline{LnK} + \beta_{12}\overline{LnL} + \beta_{23}\overline{LnG} + \beta_{24}\overline{LnO} + \beta_{25}\overline{LnE} + \beta_{26}\overline{LnC} \\
\varepsilon_G &= \beta_3 + \beta_{33}\overline{LnG} + \beta_{13}\overline{LnL} + \beta_{23}\overline{LnK} + \beta_{34}\overline{LnO} + \beta_{35}\overline{LnE} + \beta_{36}\overline{LnC} \\
\varepsilon_O &= \beta_4 + \beta_{44}\overline{LnO} + \beta_{14}\overline{LnL} + \beta_{24}\overline{LnK} + \beta_{34}\overline{LnG} + \beta_{45}\overline{LnE} + \beta_{46}\overline{LnC} \\
\varepsilon_E &= \beta_5 + \beta_{55}\overline{LnE} + \beta_{15}\overline{LnL} + \beta_{25}\overline{LnK} + \beta_{35}\overline{LnG} + \beta_{45}\overline{LnO} + \beta_{56}\overline{LnC} \\
\varepsilon_C &= \beta_6 + \beta_{66}\overline{LnC} + \beta_{16}\overline{LnL} + \beta_{26}\overline{LnK} + \beta_{36}\overline{LnG} + \beta_{46}\overline{LnO} + \beta_{56}\overline{LnE}
\end{aligned}$$

Where $\overline{LnL}, \overline{LnK}, \overline{LnG}, \overline{LnO}, \overline{LnE}$ and $\overline{LnC}$ represent the average values.

The definition of variables and their expected signs are presented in Table 5.

Table 5

Variable Definitions and Expected Signs

Variables	Variable Description	Expected Sign
GDP	Gross domestic product (million US $)	
L	Total labor force (millions)	+ve
K	Gross capital formation (million US $)	+ve
G	Gas domestic consumption (million cubic meters)	+ve
O	Oil products domestic consumption (million tons)	+ve
E	Electricity domestic consumption (terawatt hour)	+ve
C	Coal and lignite domestic consumption (million tons)	+ve
Deu	Deu=1 if the observation belongs to European region, otherwise 0	
Dcis	Dcis=1 if the observation belongs to Commonwealth of Independent States region, otherwise 0	
Dnamerica	Dnamerica=1 if the observation belongs to North American region, otherwise 0	
Dlamerica	Dlamerica=1 if the observation belongs to Latin American region, otherwise 0	
Dasia	Dasia=1 if the observation belongs to Asian region, otherwise 0	
Dpacific	Dpacific=1 if the observation belongs to Pacific region, otherwise 0	
Dmiddle	Dmiddle=1 if the observation belongs to middle income country, otherwise 0	
Dcold	Dcold=1 if the observation belongs to a country which is located in D and/or E Koppen climate classification system, otherwise 0	

Results

For estimation purpose, Translog model has been used on panel data of 40 countries from 1990 to 2011. In this regard likelihood ratio, heteroscedasticity and auto correlation tests were used for diagnostic purposes.

Likelihood ratio test is used to test the nested hypothesis of the model, in this regard; we compare the restricted (Cobb Douglas) and unrestricted (Translog) model. LR test helps us to identify whether the imposition of restriction holds or not. The LR test statistic is 535.09 and this value is significant at 1 percent level of significance. It indicates that the unrestricted model (Translog) performs better than Cobb Douglas.

In the presence of heteroscedasticity the estimates are unbiased but inefficient [Gujarati (2007)]. We use likelihood ratio test for testing existence of heteroscedasticity in the panel data [Ahmad and Anders (2012)]. The χ^2 value is 1063.15, which is significant at 1 percent level of significance. It shows that there is a problem of heteroscedasticity in the data.

Serial correlation in panel data model biases the standard error and makes the results inefficient. In the present study, we use Wooldridge test to test for serial correlation in the model. This test is easy to implement and requires relatively less assumptions [Drukker (2003)]. The result of the Wooldridge test statistic is 260.51, which is significant at 1 percent level of significance. The result of the test shows that there is a problem of autocorrelation in the data.

To fix the problem of heteroskedasticity and autocorrelation, we applied feasible generalized least square approach. It gives us unbiased and consistent results.

In the present study, we also applied Wald test to see the joint significance of different regions. The value of Wald test is 891.36 and it is significant at 1 percent level of significance. Thus on the basis of results of the model, the null hypothesis that there are no regional differences is strongly rejected as a composite hypothesis. Thus different regions have jointly significant impact on the GDP of the country.

The results of the estimated model are presented in Table 6. It presents the estimated coefficients and their standard errors. Overall results of model show that most of the coefficients are statistically significant. Based on the Translog production function estimates shown in Table 6, we derive the returns to scale and output elasticities with respect to the inputs. By taking sum of six output elasticities, we can get the value of return to scale. This value comes out to be 1.084 showing almost constant returns to scale.

Table 6

Estimates of the Inter Country Translog Production Function

Variable	Coefficient	Variable	Coefficient	Variable	Coefficient
Constant	9.522* (0.581)	$lngcapital^2$	0.089* (0.006)	Lnelectgcapital	–0.123* (0.038)
Lngas	–1.503* (0.125)	Lngasoil	–0.267* (0.029)	Lncoaltlabor	0.008 (0.006)
Lnoil	1.596* (0.342)	Lngaselec	–0.009 (0.020)	Lncoalgcapital	–0.058* (0.009)
Lnelectric	0.564** (0.305)	Lngascoal	–0.031* (0.008)	Lntlaborgcapital	–0.063 (0.026)
Lncoal	0.198* (0.070)	Lngastlabor	0.057* (0.019)	Dcold	0.026 (0.032)
Lntlabor	0.901* (0.204)	Lngasgcapital	0.211* (0.016)	Deu	0.638* (0.041)
Lngcapital	–0.762* (0.088)	Lnoilelec	0.003 (0.076)	Dcis	–0.312* (0.065)
$Lngas^2$	0.003 (0.006)	Lnoilcoal	0.091* (0.016)	Dnamerica	–0.030 (0.077)
$Lnoil^2$	0.106** (0.057)	Lnoiltlabor	0.075 (0.048)	Dlamerica	0.468* (0.037)
$Lnelec^2$	0.142* (0.044)	Lnoilgcapital	–0.159* (0.041)	Dasia	0.165* (0.039)
$Lncoal^2$	–0.006* (0.002)	Lneleccoal	0.047* (0.021)	Dpacific	0.681* (0.062)
$Lntlabor^2$	–0.051* (0.013)	Lnelectlabor	–0.071* (0.034)	Dmiddle	–0.130* (0.032)

Estimates obtained by using FGLS procedure.

Standard error of the Coefficient is given in the parenthesis.

* and ** represent statistical significance at 5 percent and 10 percent level of significance respectively.

The estimated elasticities of different inputs are given in Table 7. The elasticity estimates show that the coefficients of conventional inputs labor and capital are 0.04 and 0.43 respectively. These coefficients show that if there is 1 percent increase in labor, it will increase the GDP by 0.04 percent while 1 percent increase in the capital will result in an increase of 0.43 percent. A number of studies show that economic growth is influenced by the amount of energy as well as primary inputs i.e. labor and capital [Beaureau (2005)]. Lie and Liu (2011) reported the mean GDP elasticity with respect to labor and capital over the 10 years study period to be 0.302 and 0.614 respectively. Thus the study results show that capital intensive technology will be more beneficial for countries. The GDP elasticity estimates of gas, oil and electricity are positive; these results show that these energy inputs have positive impact on the GDP.

The GDP elasticity of gas, oil and electricity are 0.001, 0.19 and 0.45 respectively. These results show that among the various forms of energy, electricity is the most important factor in influencing the GDP. It is important to ensure its supply for sustainable economic development. These results indicate that electricity increase has the largest effect on the GDP while gas increase has the lowest positive impact on the GDP. The GDP elasticity of electricity shows that an increase of electricity by 1 percent will increase the GDP by 0.45 percent.

Table 7

Elasticities Estimates of Different Inputs

Input	Elasticity Estimate
G	0.0018*
O	0.1914*
E	0.4521*
C	–0.0328*
L	0.0438*
K	0.4280*

*Represents statistical significance at 5 percent level of significance.

The GDP elasticity with respect to coal is negative. It shows that an increase in consumption of coal by 1 percent will decrease GDP by 0.03 percent. This results due to the fact that the average domestic consumption of coal showed either decreasing or stagnant behavior during the first thirteen years of study period. However, there was an increasing trend in the use of coal during the last nine year. Many countries showed substantial reduction in the domestic consumption of coal. For example, coal domestic consumption decrease from 448.81 million tons (MT) to 238.0 MT in Germany, 106.68 MT to 51.22 MT in United Kingdom, and 149.85 MT to 72.85 MT in Ukraine over the period 1990 to 2011. There was also reduction in coal consumption in Belgium, France, Romania, Spain, Kazakhstan, Uzbekistan and Columbia. However, there was an increase in the domestic consumption of coal in India from 220.86 MT to 703.28 MT, Indonesia from 8.27 MT to 71.25 MT and Turkey from 54.42 MT to 102.06 MT. Japan, Chile, Mexico, Malaysia, Thailand, South Africa also experienced an increase in coal consumption. Other countries like Italy, Netherlands, Portugal, Sweden, Egypt, Argentina, Nigeria, Algeria, Pakistan, Kuwait, Norway etc. either experience stagnant behavior or negligible use of coal.

CONCLUSION AND POLICY IMPLICATIONS

The paper determines the relationship between energy consumption in different forms and conventional inputs i.e. labour and capital with real gross domestic product in a production function framework. A Translog production function model is used on panel data of forty countries from 1990 to 2011. Feasible generalised least squares approach is applied in order to fix the problem of heteroskedasticity and autocorrelation. The results of the study show that all the independent variables included in the analysis have positive and significant impact on GDP except the coal variable. The study reveals that different regions, income level and climatic zones have significant impact on the GDP. Energy consumption in the form of electricity has the strongest impact on GDP than any other variable. The GDP elasticity estimate of electricity is 0.45, which shows that 1 percent increase in the electricity increases GDP by 0.45 percent. The GDP elasticity of electricity is substantially higher than any other form of energy. This suggests that policy maker should ensure sustainable electricity supply and place more emphasis on this form of energy. Any shocks to electricity supply will adversely affect the real GDP growth. In order to avoid the adverse effects of electricity supply, it is necessary for countries, especially developing countries facing its shortage, to plan and develop generation capacity to meet the electricity demand of their countries.

APPENDIX

Belgium, Finland, France, Germany, Italy, Netherlands, Poland, Portugal, Romania, Spain, Sweden, United Kingdom, Norway, Turkey, Kazakhstan, Ukraine, Uzbekistan, Canada, United States, Argentina, Brazil, Chile, Columbia, Mexico, Venezuela, India, Pakistan, Indonesia, Japan, Malaysia, Thailand, Australia, New Zealand, Algeria, Egypt, Nigeria, South Africa, Kuwait, Saudi Arabia, United Arab Emirates.

REFERENCES

Abosedra, S. and H. Baghestani (1989) New Evidence on the Causal Relationship between United States Energy Consumption and Gross National Product. *Journal of Energy Development* 14, 285–292.

Ahmad, W. and S. Anders (2012) The Value of Brand and Convenience Attributes In Highly Processed Food Products. *Canadian Journal of Agricultural Economics* 60, 113–133

Akarca, A. T. and T. V. Long (1980) On the Relationship between Energy and GNP: A Reexamination. *Journal of Energy Development* 5, 326–331.

Al-Iriani, M. A. (2006) Energy—GDP Relationship Revisited: An Example from GCC Countries Using Panel Causality. *Energy Policy* 34, 3342–3350.

Altinay, G. and E. Karagol (2004) Structural Break, Unit Root, and the Causality between Energy Consumption and GDP in Turkey. *Energy Economics* 26:6, 985–994.

Ang, J. B. (2008) Economic Development, Pollutant Emissions and Energy Consumption in Malaysia. *Journal of Policy Modeling* 30, 271–278.

Aqeel, A. and M. S. Butt (2001) The Relationship between Energy Consumption and Economic Growth in Pakistan. *Asia Pacific Development Journal* 8:2, 101–110.

Beaudreau, B. C. (2005) Engineering and Economic Growth. *Structural Change and Economic Dynamics* 16, 211–220.

Belloumi, M. (2009) Energy Consumption and GDP in Tunisia: Co-integration and Causality Analysis. *Energy Policy* 37:7, 2745–2753.

Bowden, N. and J. E. Payne (2009) The Causal Relationship between US Energy Consumption and Real Output: A Disaggregated Analysis. *Journal of Policy Modeling* 31:2, 180–188.

Chang, T., H. P. Chu, and W. Y. Chen (2013) Energy Consumption and Economic Growth in 12 Asian Countries: Panel Data Analysis. *Applied Economic Letters* 20, 282–287.

Cheng, B. (1995) An Investigation of Co-integration and Causality between Energy Consumption and Economic Growth. *Journal of Energy Development* 21, 73–84.

Cheng, B. S. (1998) Energy Consumption, Employment and Causality in Japan: A Multivariate Approach. *Indian Economic Review* 33:1, 19–29.

Cheng, B. S. (1999) Causality between Energy Consumption and Economic Growth in India: An Application of Co-integration and Error-Correction Modeling. *Indian Economic Review* 34, 39–49

Chiou-Wei, S. Z., C. F. Chen, and Z. Zhu (2008) Economic Growth and Energy Consumption Revisited—Evidence from Linear and Non-linear Granger Causality. *Energy Economics* 30:6, 3063–3076.

Drukker, D. M. (2003) Testing for Serial Correlation in Linear Panel Data Models. *The Stata Journal* 3:2, 168–177.

Erdal, G., H. Erdal, and K. Esengun (2008) The Causality between Energy Consumption and Economic Growth in Turkey. *Energy Policy* 36:10, 3838–3842.

Erol, U. and E. S. H. Yu (1987) On the Causal Relationship between Energy and Income for Industrialised Countries. *Journal of Energy Development* 13, 113–122.

Fatai, K., L. Oxley, and F. Scrimgeour (2002) Energy Consumption and Employment in New Zealand: Searching for Causality. Paper presented at NZAEC on France, Wellington, 26–28 June.

Ghali, K. H. and M. I. T. El-Sakka (2004) Energy Use and Output Growth in Canada: A Multivariate Co-integration Analysis. *Energy Economics* 26, 225–238.

Glasure, Y. U. (2002) Energy and National Income in Korea: Further Evidence on the Role of Omitted Variables. *Energy Economics* 24, 355–365.

Gujarati, D. N. and Sangeetha (2007) *Basic Econometrics.* Fourth Edition. Tata McGraw Hill Publishing Company Limited New Delhi.

Halicioglu, F. (2009) An Econometric Study of CO_2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey. *Energy Policy* 37, 1156–1164.

Ho, C-Y. and K. W. Siu (2007) A Dynamic Equilibrium of Electricity Consumption and GDP in Hong Kong: An Empirical Investigation. *Energy Policy* 35:4, 2507–2513.

Jin, J. C. and E. S. H. Yu (1996) Export-led Growth and the US Economy: Another Look. *Applied Economics Letters* 3, 341–344.

Karanfil, F. (2008) Energy Consumption and Economic Growth Revisited: Does the Size of Unrecorded Economy Matter? *Energy Policy* 36:8, 3029–3035.

Kraft, J. and A. Kraft (1978) On the Relationship between Energy and GNP. *Journal of Energy and Development* 3, 401–403.

Lee, C. C. (2005) Energy Consumption and GDP in Developing Countries: A Co-integrated Panel Analysis. *Energy Economics* 27, 415–427.

Lee, C. C. (2006) The Causality Relationship between Energy Consumption and GDP in G-11 Countries Revisited. *Energy Policy* 34, 1086–1093.

Lee, C. C. and C. P. Chang (2007a) The Impact of Energy Consumption on Economic Growth: Evidence from Linear and Nonlinear Models in Taiwan. *Energy* 32:1, 2282–2294.

Lee, C. C. and C. P. Chang (2007b) Energy Consumption and GDP Revisited: A Panel Analysis of Developed and Developing Countries. *Energy Economics* 29, 1206–1223.

Lise, W. and K. Van Montfort (2007) Energy Consumption and GDP in Turkey: Is There a Co-integration Relationship? *Energy Economics* 29, 1166–1178.

Masih, A. and R. Masih (1996) Energy Consumption and Real Income Temporal Causality, Results for a Multi-country Study Based on Co-integration and Error-Correction Techniques. *Energy Economics* 18, 165–183.

Murray, D. A. and G. D. Nan (1996) A Definition of the Gross Domestic Product-Electrification Inter Relationship. *Journal of Energy and Development* 19, 275–283.

Oh, W. and K. Lee (2004) Causal Relationship between Energy Consumption and GDP: The Case of Korea 1970–1999. *Energy Economics* 26:1, 51–59.

Ozturk, I. (2010) A Literature Survey on Energy-Nexus. *Energy Policy* 38, 340-349.

Paul, S. and R. N. Bhattacharya (2004) Causality between Energy Consumption and Economic Growth in India: A Note on Conflicting Results. *Energy Economics* 26:6, 977–983.

Payne, J. E. (2009) On the Dynamics of Energy Consumption and Output in the US. *Applied Energy* 86:4, 575–577.

Payne, J. E. (2010) Survey of the International Evidence on the Causal Relationship between Energy Consumption and Growth. *Journal of Economic Studies* 37, 53–95.

Rufael, Y. W. (2006) Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries. *Energy Policy* 34, 1106-1114

Shan, J. and F. Sun (1998) Export-Led Growth Hypothesis for Australia: An Empirical Re-investigation. *Applied Economics Letters* 5, 423–428.

Soytas, U., R. Sarı and O. Ozdemir (2001) Energy Consumption and GDP Relation in Turkey: A Co-integration and Vector Error Correction Analysis. In *Economies and Business in Transition: Facilitating Competitiveness and Change in the Global Environment Proceedings*. Global Business and Technology Association, pp. 838–844.

Soytas, U. and R. Sari (2003) Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets. *Energy Economics* 25, 33–37.

Soytas, U. and R. Sari (2006) Energy Consumption and Income in G7 Countries. *Journal of Policy Modeling* 28, 739–750.

Soytas, U. and R. Sari (2009) Energy Consumption, Economic Growth, and Carbon Emissions: Challenges Faced by an EU Candidate Member. *Ecological Economics* 68:6, 1667–1675.

Stern, D. I. (2000) Multivariate Co-integration Analysis of the Role of Energy in the US Macro-economy. *Energy Economics* 22, 267–283.

Yu, E. S. H. and B. K. Hwang (1984) The Relationship between Energy and GNP: Further Results. *Energy Economics* 6, 186–190.

Yu, E. S. H. and J. Y. Choi (1985) The Causal Relationship between Energy and GNP: An International Comparison. *Journal of Energy and Development* 10, 249–272.

Yu, E. S. H. and J. C. Jin (1992) Co-integration Tests of Energy Consumption, Income, and Employment. *Resources and Energy* 14, 259–266.

Zamani, M. (2007) Energy Consumption and Economic Activities in Iran. *Energy Economics* 29:6, 1135–1140.

Zhang, X. P. and X. M. Cheng (2009) Energy Consumption, Carbon Emissions, and Economic Growth in China. *Ecological Economics* 68:10, 2706–2712.