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Dynamic Relationship between Energy and Economic Growth: Evidence from D8 Countries

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INTRODUCTION

Energy is vital to economic growth and it was best demonstrated during the 1973–1974 oil embargo. When oil-producing nations of the Middle East restricted the output, prices increased fourfold in a span of a few months, resulting in serious disruption in the industrialised countries as well as the supplies of raw material from the developing countries.

The energy crisis of the seventies attracted significant investigation into the relationship between energy consumption and economic growth. Overtime, numerous studies conducted to examine this relationship have produced conflicting results: some studies suggest that energy use is highly positively correlated with GDP growth [for example; Chebbi and Boujelbene (2008), Jumbe (2004), Siddiqui (2004) etc.], others support a negative relationship [for example; Okonkwo and Gbadebo (2009), Noor and Siddiqi (2010) etc.]. Similarly, while some studies report non-causality of the relationship [for example; Sarkar, *et al.* (2010), Yusma and Wahilah (2010) etc.], others have reported bi-directional causality [for example; Pradhan (2010), Loganathan, *et al.*, (2010), Omotor (2008) etc.]. Thus, the empirical evidence is varying and conflicting about direction of causality.

D8, also known as Developing-8, is an arrangement for development of co-operation among the following Muslim countries: Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey. The idea of cooperation among major Muslim developing countries was raised during a seminar on "Cooperation in Development" held in Istanbul in October 1996. It was after a series of preparatory meetings that D-8 was set up officially and began its activities with the 'Istanbul Declaration' issued at the end of 'The Summit of Heads of State and Government' held in Istanbul on June 15, 1997.

The energy sector is likely to play a vital role in the development of the D8 countries. The complexity of relationship among the variables of energy use and economic activity requires a re-examination of long-term and short-term linkages between energy consumption and real output in the D8 because if the causality in these countries runs from energy to GDP, the energy constraints can have serious implications for the pace of development in these

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economies. The main objective of this study is to investigate the dynamic correlation between energy consumption and economic growth in the D8 countries.

I. ENERGY AND ECONOMIC GROWTH: REVIEW OF LITERATURE

This section reviews some of the previous studies on the relationship between energy and economic growth along with the role of energy sector in economic growth as discussed in the mainstream economic literature.

I.1. Theoretical Background

Although business and financial economists pay significant attention to the impact of oil and other energy prices on economic activity, the conventional theory of economic growth pays little or no attention to the role of energy or any other natural resources in facilitating or promoting economic growth [Stern (2003)]. A fully worked out model of the growth process in which energy is explicitly recognised as a determinant does not seem to exist in economic literature but extensive empirical work has examined the role of energy in the growth process.

Energy is an essential input for growth and development and energy use is also expected to be a limiting factor to economic growth, as other factors of production cannot work properly without energy. It can also be argued that the impact of energy use on growth depends on the structure of the economy, energy intensity and the stage of economic growth of the country concerned. Some service activities may not require the direct processing of materials. However, this can only be true at the micro level and at the macro-level all economic processes require the direct and indirect use of materials, in either the maintenance of labour or the production of capital.

Although the classical economists did not explicitly recognise energy *per se* as a factor of production, they understood clearly the limits which land (nature) imposes on economic activities, especially in agriculture. When classical economists speak of the *"fertility of nature"* (Adam Smith), *"the productive and indestructible powers of the soil*" (David Ricardo), "*the natural and inherent powers of the soil"* (John McCulloch), or speak of the earth as *"a wondrous chemical workshop wherein many materials and elements are mixed together and worked on* (Jean-Baptiste Say)," their language conveys a clear understanding of the contributions of nature to the economy [Alam (2006)]. Hall, *et al.* (1986) argued that energy is the primary factor of production, and labour and capital are intermediate factors of production. Primary is used in the sense of 'cannot be produced or recycled from any other factor' [Hall, *et al.* (1986)].

As discussed by Stern (2003), the neoclassical economists do not even implicitly include energy into their macro-economic framework. The argument is based on the rejection of land as a factor of production since the neoclassicals subsume land under capital. Energy from non-human sources e.g., coal, oil, electricity, food or fertiliser etc, enters the economy only as an intermediate input. The basic model of economic growth, the Nobel-prize winning work by Solow (1956), does not include resources at all in the basic framework. Also, the extensions of this model, that include energy in any form, are only applied in the context of debates about environmental sustainability, not in standard macro-economic functions [Stern (2003)].

Table 1

Evidence from Some Previous Studies

Author(s)	Analysed Countries and Periods	Variables Used	Methodology	Findings/Causality
Khan and Qayyum (2007)	Pakistan, Bangladesh, India, Sri Lanka (1972–2004)	real output, energy, capital and labour	Bound test ARDL	energy consumption to GDP
Asafu-Adjaye (2000)	India, Indonesia, Philippines and Thailand (1973-1995)	energy consumption and income	Granger causality, cointegration and ECM	short-run: from energy to income long-run: 2 cointegrating vectors, energy and price effects were weak.
Chiou-Wei, *et. al.* (2008)	USA, Taiwan, South Korea, Singapore, Hong Kong, Indonesia, Malaysia, Philippines and Thailand (1954-2006).	total energy consumption and real GDP	linear and nonlinear Granger causality tests	short-run: energy consumption causes GDP (Indonesia), bi-directional (Malaysia), nonlinear causal relations
Mehrara (2007)	Iran, Kuwait and Saudi Arabia (1971–2002)	real GDP per capita and energy use per capita	ECM and Toda-Yamamoto procedure	economic growth to energy consumption
Abbasian, *et al.* (2010)	Iran (1967-2005)	national income consumption of electricity, natural gas, coal, petroleum, solid biomass and total energy consumption	VAR, granger causality and also Toda-Yamamoto causality tests.	natural gas consumption leads to economic growth
Loganathan, *et al.* (2010)	Malaysia (1971-2008)	energy consumption and economic performance	Ordinary Least Square Engel-Granger, Dynamic Ordinary Least Square, ARDL, bounds test and ECM.	bi-directional co-integration effect
Islam, *et al*. (2011)	Malaysia (1971-2008)	Energy consumption, population, aggregate production, and financial development	ARDL and cointegration	Cointegrated, economic growth and financial development cause energy use.
Omotor (2008)	Nigeria (1970-2005)	National income, coal, electricity and oil consumption	cointegration and Hasio's Granger Causality test	bi-directional causality
Adeniran (2009)	Nigeria (1980-2006)	Oil consumption, real GDP, coal consumption, and electricity consumption	granger causality and cointegration	Cointegrated and energy consumption causes economic growth
Okonkwo and Gbadebo (2009)	Nigeria (1970-2005)	Economic growth and crude oil, electricity and coal	cointegration and OLS	Cointegrated and positive relationship between current growth and energy

Continued—

Table 1—(*Continued*)

Siddiqui (2004)	Pakistan (1970-2003)	GDP, capital stock, labour force, human capital, exports and energy(electricity, natural gas and petroleum)	granger causality and ARDL	Energy causes economic growth
Abosedra and Ghosh (2007)	Turkey, India, Philippines and Korea(Jan 1985 to Jan 2005) Pakistan (Jun 1994 to Jan 2005)	oil prices and economic growth	cointegration and granger causality	Not cointegrated Short-run: oil prices cause economic growth in Pakistan and Philippines.
Pradhan (2010)	Bangladesh, India, Nepal, Pakistan and Sri Lanka (1970-2006)	Economic growth and energy consumption	cointegration and ECM	energy causes economic growth
Soytas, *et al.* (2001)	Turkey (1960-1995)	GDP and energy consumption	Cointegration and VECM	energy causes economic growth
Lise and Montfort (2005)	Turkey (1970-2003)	GDP and energy consumption	Cointegration and OLS, VECM and granger causality	Cointegrated and GDP causes energy consumption
Altinay and Karagol (2005)	Turkey (1950-2000)	electricity consumption and real GDP	Zivot and Andrews test, Dolado–Lutkepohl test and granger causality test	Electricity consumption causes economic growth
Chontanawat, *et al.* (2006)	30 OECD and 78 non OECD countries	Energy consumption and GDP	Hsiao procedure, cointegration tests and ECM	Bi-directional causality in OECD countries
Joyeux and Ripple (2007)	seven East Indian Ocean countries (1971-2001)	Income and household electricity consumption	Panel cointegration	Not cointegrated
Imran and Siddiqui (2010)	Bangladesh, India, and Pakistan (1971-2008)	economic growth, energy consumption, capital stock and labour	panel cointegration, granger causality and Dynamic OLS	Short-run: neutrality, long-run: Cointegrated, energy consumption causes economic growth
Noor and Siddiqi (2010)	Bangladesh, India, Nepal, Pakistan, and Sri Lanka, (1971-2006)	per capita GDP and per capita energy consumption	Panel cointegration test, granger causality test and FMOLS	short-run: per capita GDP causes per capita energy consumption long-run: negative relationship
Joyeux and Ripple (2011)	26 non-OECD (1971-2007), 30 OECD (1960-2007)	income and total electricity consumption, residential electricity consumption, total energy consumption	Panel cointegration and causality	Cointegrated and income causes energy consumption.

Nicholas Georgescu-Roegen (1972, 1976) was one of the first to comment on the absence of energy in economic thinking of the Marxists and neoclassical economists as they take resources and energy flows for granted and ignore the economy's output of wastes. Roegen (1976) argued that standard economics does not recognise that *"terrestrial resources of energy and materials are irrevocably used up and the harmful effects of pollution on the environment accumulate."*

Overall there is a strong link between rising energy use and economic growth. However, the linkage between these two can be mitigated by a number of factors including shifting to higher quality fuels and technological change aimed at general increases in economic productivity. As explained above there is an inbuilt bias in mainstream production and growth theory to downplay the role of energy resources in the economy. Although there is nothing inherent in economics that restricts this potential role in the economy but there seems to be no particular theoretical work in conventional economic literature today that explicitly recognises this critical role.

II. INVESTIGATING ENERGY USE AND GROWTH LINKAGE: METHODOLOGY

Introduction

Following Soytas, *et al.* this analysis consisted of three key steps. The first step was checking for the stationarity of the series, the second step was testing for cointegration, and the third step was testing for causality in long and short run by developing a VECM and VAR Granger Causality respectively.

Rest of the chapter is organised as; Section 1 discusses the test of stationarity; lag length selection and cointegration test are explained in Section 2; Vector Error Correction Modeling (VECM) is established in Section 3; VAR Granger Causality/Block Exogeneity Wald Tests are discussed in Section 4 and; Section 5 provides the data description.

II-1. Test of Stationarity

To check for stationarity of the series, the Augmented Dickey-Fuller (1979) (ADF) unit root test was utilised. Stock and Watson (1989) and Nelson and Plosser (1982) are among the economists who argue that the causality tests are very sensitive to the stationarity of the series and many macroeconomic series are non stationary [Soytas (2001)]. Therefore, before taking any further step in our analyses, it was necessary to check for the stationarity of Natural Log of Energy Use (Lneu) and Natural Log of Real GDP (Lngdpc) series. The ADF test was conducted from the Ordinary Least Squares estimation of the following equation:

$$\Delta Y_t = \alpha_0 + \beta T + (\rho - 1)Y_{t-1} + \sum_{i=1}^{N} \alpha_i \Delta Y_{t-i} + \varepsilon_t \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

where Y is the variable of interest, α_0 is the intercept, T is a linear time trend, Δ is the first difference operator, and ε_t is the error term with zero mean and constant variance. The test regression for ADF includes lagged differences of the dependent variable (Y) as independent variables to account for higher-order serial correlation. The hypothesis (H_0: ρ–1=0) that Y is a non-stationary is rejected if the test fails to reject the alternative

hypothesis (H_1: $(\rho-1) < 0$). If the ADF test fails to reject the null hypothesis in levels but rejects it in first differences, then the series contains one unit root and is of integrated order one I (1). MacKinnon (1991) finite sample critical values were used to determine the statistical significances.

II-2. Lag Length Selection and Cointegration Test

Given the importance of selecting the appropriate lag length, selection was based on The Akaike Information Criteria (AIC) and Schwarz Criteria (SC). Johansen Cointegration test was used to determine the number of cointegrating vectors. As explained by Rathinam and Raja (2008), Johansen's methodology takes its starting point in the VAR of order k given by:

$$Z_t = A_0 D_t + A_1 Z_{t-1} + A_2 Z_{t-2} + \cdots + A_k Z_{t-k} + \in_t, \qquad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where A_i's are (n *x* n) matrix of parameters, Z is an (n *x* 1) vector containing all n variables in the system (Lngdpc and Lneu), D is a vector of all deterministic terms (intercept, trend, etc.), and $\in_t$ is an (n *x* 1) vector of white noise error terms. This unrestricted base VAR could be represented as a VECM as

$$\Delta Z_t = A_0 D_t + \Pi Z_{t-1} + \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \in_t . \qquad \ldots \quad (3)$$

$\Gamma_j \Delta Z_{t-j}$ is the first differenced component in the VAR system, where Γ_j is an (n *x* n) matrix of short term coefficients associated with the lagged values of variables in the system Z_t. ΠZ_{t-1} is the error-correction component, where Π is an (n *x* n) matrix of cointegrating parameters which characterize the long run relationship among the variables and long run adjustment coefficients in the VEC system. Thus Π consists of (n *x* r) dimension matrices α and β, where $\Pi = \alpha\beta'$.

The rank of Π matrix indicates the number of possible cointegrating relationship i.e. long run equilibrium relationship among the variables in the system. The rank of Π can be determined by λ_{trace} or λ_{max} test statistics as proposed by Johansen (1988). If the Π matrix has full rank then all the variables in the system are stationary and the error correction mechanism does not exists. If the rank of Π matrix is zero, the short-term dynamics depends only on lagged changes in all variables. The existence of co-integration between the two variables suggests the presence of causality between the variables in at least one direction [Engle and Granger (1987)].

II-3. VEC Modeling

As Engel and Granger (1987) suggest, if cointegration exists between two variables in the long run, then, there must be either unidirectional or bi-directional causality between these variables, thus Vector Error Correction Model (VECM) can be applied to study the direction of long-run relationship between the selected variables as cointegration test does not specify the direction of causality. The VECM for this study can take the following form:

$$\Delta LNGDPC_t = \beta_0 + \sum_{j=1}^{M} \beta_{1j} \Delta LNEU_{t-j} + \sum_{j=1}^{N} \beta_{2j} \Delta LNGDPC_{t-j} + \alpha E_{t-1} + u_{1t} \qquad \ldots \quad (4)$$

$$\Delta LNEU_t = \delta_0 + \sum_{j=1}^{K} \delta_{1j} \Delta LNEU_{t-j} + \sum_{j=1}^{L} \delta_{2j} \Delta LNGDPC_{t-j} + \lambda C_{t-1} + u_{2t} \quad \ldots \quad (5)$$

where Lngdpc is the natural log of Real Gross Domestic Product and Lneu is the natural log of energy consumption. E_{t-1} and C_{t-1} are the error correction terms, Δ is the first difference and *u*'s are serially uncorrelated random error terms with mean zero. (M and N), and (K and L) are the optimal lag lengths. $C_{t-1}$is the lagged value of the residuals from the cointegration regression of Lngdpc on Lneu, and E_{t-1} is the lagged value of the residuals from the cointegration regression of Lneu on Lngdpc. Equation (4) can be used to test the causality running from energy use to economic growth while to test the causation from economic growth to energy use, Equation (5) can be used.

Within the VECM formulation of above equations, energy use does not cause economic growth if all βs and α is zero in Equation 4, and economic prosperity, measured by GDP, does not cause energy use if all δs and λ is zero in Equation 5. VECM approach allows us to determine the direction of causality in long run. Significant error correction terms (α and λ) implies long-run causal relationship. Error correction term contains the long-run information since it is derived from the long-run cointegrating relationship. It should be noted that the coefficient of error correction term is a short-run adjustment coefficient correcting long run disequilibrium in dependent variables in each short period. Thus the stability of long-run equilibrium can also be judged from the sign and significance of the error correction term as if it is negatively significant, it shows convergence towards the equilibrium i.e., a stable long-run equilibrium.

II-4. VAR Granger Causality/ Block Exogeneity Wald Tests

The VAR Granger Causality tests were used to determine the short run causal relationship between the two focus variables; energy use and real GDP. The VAR Granger Causality test also provides the direction of causality in short run. In a n-variable VAR of order p, Block-Exogeneity test looks at whether the lags of any variable Granger-cause any other variable in the system. Sargent (1976) has proposed a simple procedure called the direct Granger procedure for testing causality. Consider two stationary variables *Y* and *X* for which the regression equations are

$$Y_t = \sum_{i=1}^{p} \alpha_{iY_{t-1}} + \sum_{i=1}^{p} \beta_i X_{t-1} + u_t$$

$$Y_t = \sum_{i=1}^{p} \delta_{iY_{t-1}} + \sum_{i=1}^{p} \gamma_i X_{t-1} + v_t$$

The Wald test is used to test whether all the lagged values of *X* in the *Y* equation are simultaneously equal to zero. *X* Granger causes *Y* if $\sum \beta \neq 0$ and, if both $\sum \delta \neq 0$ and $\sum \beta \neq 0$, then there exists a bidirectional causality between *Y* and *X*.

II-5. Data Description

The annual data for the D8 countries; Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan, and Turkey from the year 1980 to 2007 is used. The data for

energy consumption, measured by energy use (kg of oil equivalent per-capita) and GDP in million US dollars at year 2000 constant prices is collected from 'The World Development Indicators (2010)' by the World Bank. The data for total population is also gathered to convert the energy use (kg of oil equivalent per-capita) to total energy use (kg of oil equivalent).

III. INVESTIGATING ENERGY USE AND GROWTH LINKAGE: RESULTS AND DISCUSSION

In this section, the results of the estimation conducted on the data of all the D8 countries are discussed. The estimation was done using the statistical package of Eviews 5 and the obtained results are presented below.

III-1. Results of Stationary Test

The results of ADF test of stationarity are summarised in Table 2. For all countries, evidence was found in favour of the null hypothesis that both series contain unit roots at level, as t-statistics for all variables are less than the critical values at, respectively, 1 percent, 5 percent and 10 percent levels from ADF test. However, we reject the null hypothesis for the first differences of all series i.e., the results of the first differenced variables show that the ADF test statistics for all the series are greater than the critical values at 5 percent and 10 percent levels. Therefore, it is concluded that both series are integrated of the order 1 i.e., I (1) for all the countries. Thus cointegration tests can be applied for all countries.

Table 2

Results of ADF Test

Country	Variables	ADF test		Order of Integration
		Level	First diff.	
	Lngdpc	0.26	–5.68*	I(1)
Bangladesh	Lneu	0.34	–3.51*	I (1)
	Lngdpc	–0.89	–2.66*	I (1)
Egypt	Lneu	–2.15	–5.07*	I (1)
	Lngdpc	–1.27	–3.77*	I (1)
Indonesia	Lneu	–1.00	–5.50*	I (1)
	Lngdpc	0.75	–3.86*	I (1)
Iran	Lneu	–0.21	–7.21*	I (1)
	Lngdpc	–0.51	–4.01*	I (1)
Malaysia	Lneu	–0.65	–7.45*	I (1)
	Lngdpc	1.75	–4.91*	I (1)
Nigeria	Lneu	–1.18	–4.91*	I (1)
	Lngdpc	–0.75	–3.31*	I (1)
Pakistan	Lneu	–2.14	–4.31*	I (1)
	Lngdpc	–0.31	–5.94*	I (1)
Turkey	Lneu	–0.43	–5.89*	I (1)

*Statistically Significant , 5 percent critical value = –2.981038, 10 percent critical value 2.629906.

III-2. Lag Length Selection

The optimal lag length selection was based on the results of two criteria Akaike Information Criteria (AIC) and Schwarz Criteria (SC).

Table 3

VAR Lag Order Selection Criteria

Country	Lags	0	1	2
Bangladesh	AIC	–3.26	–10.98	**–11.04***
	SC	–3.16	**–10.69***	–10.56
Egypt	AIC	–2.97	–8.99	**–9.03***
	SC	–2.88	**–8.70***	–8.55
Indonesia	AIC	–2.36	**–7.16***	–7.15
	SC	–2.27	**–6.87***	–6.67
Iran	AIC	–1.12	–5.59	**–5.99***
	SC	–1.02	–5.30	**–5.51***
Malaysia	AIC	–1.86	**–6.67***	–6.62
	SC	–1.77	**–6.38***	–6.13
Nigeria	AIC	–3.60	**–8.94***	–8.66
	SC	–3.51	**–8.65***	–8.18
Pakistan	AIC	–4.09	**–10.84***	–10.68
	SC	–3.99	**–10.55***	–10.20
Turkey	AIC	–3.84	–8.24	**–8.34***
	SC	–3.74	**–7.95***	–7.85

*Indicates lag order selected by the criterion.

The suggested optimal lag lengths by both the AIC and SC are presented in the Table 3. Although for most of the countries, the selected number of lags to be included was same by both criteria like in the case of Indonesia, Iran, Malaysia, Nigeria and Pakistan, but under circumstances where there was a discrepancy between the appropriate lag order, for example in case of Bangladesh, Egypt and Turkey, the selected lag order for the respective country was chosen on the basis of the results of SC as it is more accurate and thus is preferred by most of the economists including Geweke and Messe (1981).

III-3. Results of Short-run Causality between Energy Use and GDP

The results of investigation of short-run relationship between energy use and GDP by application of VAR Granger Causality/Block Exogeneity Wald Tests are presented in Table 4.

Table 4

VAR Granger Causality/Block Exogeneity Wald Tests

	Dependent Variable			Dependent Variable			
		Lneu			Lngdpc		
Country	Excluded	Chi-sq	Prob.	Excluded	Chi-sq	Prob.	Causality
Bangladesh	Lngdpc	5.26*	0.02	Lneu	0.25	0.61	GDP→Eu
Egypt	Lngdpc	13.14*	0.00	Lneu	0.03	0.86	GDP→Eu
Indonesia	Lngdpc	0.53	0.46	Lneu	1.53	0.22	Neutrality
Iran	Lngdpc	2.21	0.33	Lneu	10.38*	0.00	Eu→GDP
Malaysia	Lngdpc	15.50*	0.00	Lneu	0.16	0.68	GDP→Eu
Nigeria	Lngdpc	1.62	0.20	Lneu	25.33*	0.00	Eu→GDP
Pakistan	Lngdpc	9.02*	0.00	Lneu	0.97	0.32	GDP→Eu
Turkey	Lngdpc	2.95*	0.08	Lneu	0.21	0.65	GDP→Eu

*Indicates statistically significant.

From the results of VAR granger causality test above, it is concluded that there is a uni-directional short-run causality from real GDP to energy use in Bangladesh, Egypt, Malaysia, Pakistan and Turkey, as the null hypothesis of non-causality is rejected at 5 percent or 10 percent level of significance. However, this is not the case for test of causality from energy use to real GDP as the null hypothesis cannot be rejected for these countries. Thus in the short run higher rate of economic prosperity encourages energy use in Bangladesh, Egypt, Malaysia, Pakistan and Turkey but higher rates of energy use do not have an effect on the economic development in the short-run. For the energy exporters Iran and Nigeria, the opposite direction of causality can be observed as energy use significantly causes the economic growth even in the short-run as the null hypothesis of non-causality is rejected at 5 percent or 10 percent level of significance in both states without a feedback affect. In Indonesia, however, the neutrality hypothesis could not be rejected in the short-run i.e. neither energy use nor the economic growth caused each other in the short-run in Indonesia as the null hypothesis of non-causality could not be rejected at 5 percent level of significance.

III-4. Results of Long-run Cointegration between Energy Use and GDP

The results of Johansen Cointegration test are summed up in the Table 5. The Johansen cointegration technique has been used because of its ability to capture the properties of time series, to produce estimates of all possible cointegrating vectors and to provide test statistics for the number of cointegrating vectors.

Table 5

Results of Johansen's Cointegration Test (between Lngdpc and Lneu)

Country	No. of CE's	Trace Statistic	Critical Value	Max-Eigen Statistic	Critical Value	Conclusion
Bangladesh	H_0: None*	39.27	20.26	33.15	15.89	Cointegrated
	H_0:At most 1	6.12	9.16	6.12	9.16	
Egypt	H_0: None*	24.69	23.34	17.11	17.23	Cointegrated
	H_0:At most 1	7.58	10.67	7.58	10.67	
Indonesia	H_0: None*	21.16	20.26	14.01	15.89	Cointegrated
	H_0:At most 1	7.15	9.16	7.15	9.16	
Iran	H_0: None*	27.05	20.26	19.55	15.89	Cointegrated
	H_0:At most 1	7.51	9.16	7.51	9.16	
Malaysia	H_0: None*	13.18	12.32	13.18	11.22	Cointegrated
	H_0:At most 1	0.00	4.13	0.00	4.13	
Nigeria	H_0: None*	24.87	20.26	15.79	15.89	Cointegrated
	H_0:At most 1	9.08	9.16	9.08	9.16	
Pakistan	H_0: None*	18.74	20.26	16.30	15.89	Cointegrated
	H_0:At most 1	2.43	9.16	2.43	9.16	
Turkey	H_0: None*	33.70	20.26	27.85	15.89	Cointegrated
	H_0:At most 1	5.85	9.16	5.85	9.16	

*Denotes rejection of the hypothesis at the 0.05 or 0.1 level.

The estimated cointegration results between energy use and real GDP for all countries indicate that the two series have at least one cointegrating relationship in all countries. This is because the null hypothesis of H_0: $r = 0$ against $r \leq 1$ is rejected at 5 percent or 10 percent level by either one or both of the criteria. One cointegrating equation means that there exists either a uni-directional or bi-directional long run relationship between energy use and GDP in these countries, and any change in one or both variables would most likely have implications on each other in the long term. These results suggest that the annual time series data from 1980 to 2007 appears to support the proposition that in the D8 countries there is a dynamic relationship between energy use and GDP.

III-5. Results of Long-run Causality between Energy Use and GDP

The VECM results for long-run causality and stability of the long run equilibrium relationship between energy use and economic prosperity are displayed in the Table 6.

Table 6

Summary of VECM Results (Dependent Variable= Lngdpc)

Country	Dependent Variable =Lngdpc	ECT		Causality
		D(Lngdpc)	D(Lneu)	
Bangladesh	0.55***	0.05***	0.11***	GDP↔Eu
	(5.72)	(5.30)	(3.83)	
Egypt	0.11	–0.60***	–0.47	GDP→Eu
	(1.57)	(–4.51)	(–1.06)	
Indonesia	1.15***	0.13**	0.249***	GDP↔Eu
	(12.60)	(1.97)	(3.92)	
Iran	0.71***	–0.15***	–0.30***	GDP↔Eu
	(10.28)	(–2.22)	(–4.34)	
Malaysia	0.55***	–0.02***	–0.02***	GDP↔Eu
	(23.67)	(–3.58)	(–2.49)	
Nigeria	1.69***	0.05	0.09***	Eu→GDP
	(7.40)	(1.09)	(4.36)	
Pakistan	1.11***	0.27***	0.45***	GDP↔Eu
	(50.20)	(2.21)	(4.48)	
Turkey	1.04***	0.82***	1.06***	GDP↔Eu
	(52.52)	(3.73)	(5.94)	

*, **, *** indicates significant at 10 percent, 5 percent and 1 percent respectively.
t-values in parenthesis.

III-5-i. ***Bangladesh***

For Bangladesh in the long run, there exists a bi-directional causality between the focus variables, as indicated by the significant error correction terms. The results also indicate that there is a positive relationship between energy and economic growth and one time relative increase in energy use will lead to 0.55 times relative increase in real GDP, as is indicated by the high level of significance and positive sign of the coefficient of Lneu.

Both the error correction terms for Bangladesh are highly significant. The error correction terms are positive which means that any exogenous shock in one of the variables will lead to divergence from equilibrium. An exogenous shock in the energy use will lead to 11 percent movement away from the original equilibrium every year while in case of a shock in the GDP, there will be 5 percent divergence from equilibrium per year. Thus the equilibrium is unstable in case of Bangladesh. Thus it can be concluded that in the net energy importer Bangladesh, energy use drives the economic development and the economic progress also has an influence on the energy use in the long-run.

III-5-ii. ***Egypt***

The VECM results, reported in table, provide evidence of weak long-run relationship between the two variables for Egypt as the coefficient of energy use is not significant. The weak relationship can be attributed to the fact that Egypt's main exports consist of non-petroleum products such as ready-made clothes, cotton textiles, medical

and petrochemical products, citrus fruits, rice and dried onion, and more recently cement, steel, and ceramics along with natural gas. Egypt's main imports consist of pharmaceuticals and non-petroleum products such as wheat, maize, cars and car spare parts (Wikipedia)

The adjustment coefficient for GDP is significantly negative as it should be, suggesting that the speed of adjustment of energy use towards the equilibrium in the long run in case of an exogenous shock is very high at 60 percent per year. On the other hand the error correction term for energy use, although negative, is insignificant indicating that all the adjustment towards the equilibrium is being done by the GDP. Thus it can be concluded that there is uni-directional causality between the focus variables in the short as well as long run where causality runs from GDP to energy consumption in the short-run as well as the long run. The long run findings are consistent with the findings of Costantini and Martini (2010) who also found the direction of causality running from GDP to energy use in the long run for their panel of OECD and non-OECD countries.

III-5-iii. ***Indonesia***

In the long run in Indonesia, causality runs from the real GDP to energy use with a feedback affect and one time relative increase in energy use will lead to 1.15 times relative increase in the GDP. The error correction terms for GDP and energy use in Indonesia are highly significant. Thus feedback affect in the long run is found as the error correction terms (or adjustment coefficients) are significant.

The adjustment coefficient for energy use is positive and the speed of divergence from equilibrium as a result of an exogenous shock is of 25 percent a year. Also the adjustment coefficient for energy use is positive and significant. An external shock in GDP in Indonesia will lead to divergence of 13 percent per year so it can be concluded that in Indonesia there is bi-directional long run causality between economic growth and energy use but the equilibrium is unstable. Therefore, in Indonesia the energy use causes real GDP in the long run with a feedback affect. The findings for Indonesia are similar to the findings of Asafu-Adjaye (2000).

III-5-iv. ***Iran***

The results provide a positive link between energy use and economic growth in case of Iran i-e one time relative increase in energy use will lead to a relative increase of 0.71 times in GDP. Iran is the second largest oil and natural gas producer in the world. High oil prices in recent years have enabled Iran to increase its export revenue and amass $100 billion in foreign exchange reserves through its exports. Thus an increase in energy use in the economy would lead to higher exports revenues (Wikipedia).

The adjustment coefficients are negative in both cases, suggesting that the speed of adjustment of energy use, in case of an exogenous shock, towards the equilibrium in the long run is 30 percent every year. Thus the equilibrium is stable. The error correction term for GDP is also negative indicating that in case of disequilibrium due to an exogenous shock, GDP will lead to convergence towards equilibrium at the rate of 15 percent every year. Thus there is uni-directional causality between the focus variables where energy use leads to economic growth in the short- run but bi-directional causality exists in the long run in Iran.

III-5-v. ***Malaysia***

The VECM results for Malaysia provide evidence in favour of a significant bi-directional causality between economic development and energy consumption. The adjustment coefficients are highly significant advocating the long run bi-directional causality from energy use to real GDP in Malaysia. Moreover the relationship between the two is positive i-e onetime relative increase in energy use will bring relative increase 0.55 times in real GDP. The error correction term for a shock in GDP is highly significant and negative, therefore suggesting there is a long-run causal correlation from economic growth to energy use and the per year speed of adjustment towards equilibrium is slow at 2 percent in case of a disequilibrium caused by an external shock in GDP. The adjustment coefficient for energy use is also negatively significant.

Thus the long run equilibrium in Malaysia is stable and any disequilibrium due to an external shock will be corrected at the speed of 2 percent adjustment every year. Thus it can be concluded that energy consumption is influenced by economic growth in Malaysia with a feedback affect. These results are similar to inferences drawn by Loganathan, *et al.* (2010).

III-5-vi. ***Nigeria***

In the long run, as suggested by the VECM results, there is uni-directional causality between the energy use and real GDP where there is a positive correlation between energy use and GDP and one time relative increase in energy use leads to a relative increase of 1.69 times in economic development.

The adjustment coefficient for energy use is highly significant, therefore suggesting there is a long run causal correlation from energy use to economic growth with no feedback and the per year speed of divergence from equilibrium is 9 percent in case of a shock in energy use because the sign of the error correction term for energy use is positive. Thus the equilibrium is an unstable one for Nigeria as it shows divergence from equilibrium in the long-run. The adjustment coefficient of GDP, although insignificant, also has a positive sign indicating to an insignificant causality from GDP to energy use in long run.

This can be attributed to the heavy dependence on oil as a source of revenue exposes the vulnerability of the Nigerian economy to global energy dynamics. Thus it can be concluded that energy use influences economic growth in Nigeria where increased energy use boosts GDP but the equilibrium in the long run is unstable. Adeniran (2009) also established long-run causality from energy to economic growth in Nigeria.

III-5-vii. ***Pakistan***

In the long-run, as suggested by the VECM results, there is bi-directional causality between the energy use and real GDP where there is a positive correlation between energy use and GDP and one time relative increase in energy use leads to a relative increase of 1.11 times in economic development as indicated by the positive sign of energy use coefficient.

The adjustment coefficients are highly significant for energy use and GDP, therefore suggesting there is a long-run causal correlation from economic growth to energy use with feedback. The per year speed of divergence of adjustment coefficient of real GDP from equilibrium is 27 percent in case of an external shock because the sign of

the error correction term of GDP is positive. Thus the equilibrium is an unstable one for Pakistan as it shows divergence from equilibrium in the long-run. The adjustment coefficient of energy use is also positively significant indicating to an unstable relationship between the two in long-run. Any external shock in the energy use will disturb the equilibrium and will lead to 45 percent divergence every year.

This can be attributed to the fact Pakistan is net importer of oil and virtually imports most of its fuel from other countries. The heavy dependence on oil imports to keep the production afloat exposes the vulnerability of the Pakistani economy to global energy dynamics. Thus it can be concluded that energy consumption and economic growth are influenced by each other in Pakistan where increased energy use boosts GDP but the equilibrium in the long run is very unstable. These results are in coherence with the findings of Pradhan (2010).

III-5-viii. *Turkey*

In the long-run there is evidence of bi-directional causality from the VECM results for Turkey, where causality runs from real GDP to energy consumption with a feedback affect. The relationship is also positive and highly significant i.e., onetime relative increase in the energy consumption will bring a relative increase of 1.04 times in real GDP.

The error correction terms are highly significant and both are positive. These results indicate that there is a long run bi-directional causality between energy use and economic growth but the long run equilibrium is not stable as suggested by the positive sign of the error correction terms. Thus any external shock will lead to a divergence in GDP of 82 percent every year and even higher in energy use. In the long run the economic situation of Turkey and energy use both affect each other. Moreover, for the period of 1980-2007, Turkey's long run equilibrium is very unstable. The same direction of causality was found by Aktas and Yilmaz (2008).

III-6. The Essence of Gathered Evidence

Apergis and Payne, (2009) synthesised the often conflicting results obtained by the literature into four hypothesis. According to the "growth hypothesis", energy consumption is a complement of labour and capital in producing output and, as a consequence, it contributes to growth. The "conservation hypothesis" implies that real GDP is not affected by energy conservation policies aiming at curtailing energy consumption and waste and improving energy efficiency. If the "neutrality" hypothesis holds energy consumption and real output will not have a significant connection. Finally, the "feedback" hypothesis suggests that more energy consumption results in increases in real GDP, and *vice versa*.

Table 7

Direction of Short-Run Causality in the D8 Countries

Feedback Hypothesis	Growth Hypothesis	Conservation Hypothesis	Neutrality Hypothesis
–	Iran	Bangladesh	Indonesia
–	Nigeria	Egypt	–
–	–	Malaysia	–
–	–	Pakistan	–
–	–	Turkey	–

From the gathered evidence, in the short run, the "growth hypothesis" is true for Iran and Nigeria, both energy exporters, where support for the hypothesis that energy use contributes to growth has been established. Thus energy use is an important determinant of economic development in both of these countries in the short-run and a shortage of energy would have serious repercussions for the pace of development and prosperity.

The "conservation hypothesis" where GDP is not affected by the energy use but itself has implications for energy use has been proved for Bangladesh, Egypt, Malaysia, Pakistan and Turkey in the short-run. In these countries, energy use does not have an influence on the growth process while GDP has an effect on energy use. Therefore, in these five countries, energy conservation may be viable without being detrimental to economic growth in short-run.

The estimation results support a "neutrality hypothesis" for Indonesia in the short-run pointing out that for the selected sample, the energy use and real GDP did not have significant implications for each other at least in the short-run. While in no case a support of the "feedback hypothesis" was established in the short-run.

Table 8

Direction of Long-run Causality in All D8 Countries

Feedback Hypothesis	Growth Hypothesis	Conservation Hypothesis	Neutrality Hypothesis
Bangladesh	Nigeria	Egypt	–
Indonesia	–	–	–
Malaysia	–	–	–
Pakistan	–	–	–
Turkey	–	–	–
Iran	–	–	–

In the long run, the results confirm that the "growth hypothesis" is true for the sample period in Nigeria. Therefore in Nigeria energy consumption has important insinuations for the growth and prosperity of the economy. Nigerian economy, as explained in the situation analysis, is overwhelmingly dependant on the exports of oil. Despite its huge energy reserves, the country faces acute shortage of financial resources and infrastructure to fully utilise them and as a result is still an under-developed economy. The Nigerian government heavily relies on the oil exports as they form the principal contributor in the total national revenue. The results of estimation suggest that in Nigeria, energy conservation policies may hinder economic growth in the long-run. Thus it is not a superior choice for Nigerian government to adopt energy conservation policies without diversifying the manufacturing and export base.

The "conservation hypothesis" is true for Egypt according to the long run investigation of the correlation between energy and economic growth for the selected years. Thus, it implies that in Egypt energy use does not determine pace of economic development and growth. The rationale of such result is that Egypt's main exports consist of non-petroleum products such as ready-made clothes, cotton textiles, medical and petrochemical products, citrus fruits, rice and dried onion, and more recently cement, steel, and ceramics along with natural gas. The exports of petroleum products are

minimal as compared to other exports. Egypt's main imports consist of pharmaceuticals and non-petroleum products such as wheat, maize, cars and car spare parts (Wikipedia). Therefore energy sector does not play the leading role in Egyptian economy and thus, energy conservation policies will not harm pace of economic development in Egypt.

The "feedback hypothesis" was established by the results of estimation of long run causality for Bangladesh, Indonesia, Iran, Malaysia, Pakistan and Turkey. This finding leads to the conclusion that energy sector is a major player in these economies and it has huge impact on the national income and development of the economies. Both of the variables have dynamic effect on each other. These findings are appropriate for these countries as Iran and Indonesia are major energy exporters and are prominent members of OPEC[1] while Malaysia and Turkey are among the fastest growing energy markets. The economies of these countries are, thus, massively dependent on their energy export revenues and thus there is a bi-directional causality between the real GDP and energy use as more energy production (i.e., a part of energy use) results in more national income with a feedback affect i.e., increased economic prosperity results in increased energy production and use. The economies of Pakistan and Bangladesh are facing energy shortages but are in developing phase where economies rely heavily on the energy use to ensure economic development. Both countries are net importers of energy. Therefore import payments have significant implications for the national income and any change in energy use will lead to a change in GDP and *vice versa.*

The evidence of "neutrality hypothesis" was not found in case of any of the D8 countries in the long-run. Thus the outcomes of estimation support the evidence that energy sector is an important part of the economies of the developing countries and it has dynamic affect on the economic standing of these countries. The energy sector thus needs proper attention of the governments of these countries as flawed, defective and misguided policies can injure the economy gravely for a long period of time.

IV. CONCLUDING REMARKS AND POLICY IMPLICATIONS

Energy plays a critical role in an economy on both demand and supply sides. On the demand side, energy is one of the products a consumer decides to buy to maximise his or her utility. On the supply side, energy is a key factor of production in addition to capital, labour and materials. This implies that there should be a causal relationship running from energy consumption to national income or GDP as well as vice versa. Consequently, governments as well as individuals and firms, motivated by financial or humanistic interests and who value access to energy as one of the basic human rights, are now making progress to provide energy to higher percentages of population throughout the world.

Keeping in mind the vital and critical role of energy in the process of development, this study aimed at developing the link between energy consumption and real output for the D8 countries including Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey in both short as well as the long-run. The study was based on annual data covering the period 1980- 2007 for all countries. VAR Granger causality test was applied for the investigation of short-run causality between energy use and economic

[1]For the sample period, i.e., 1980-2007. Indonesian membership of OPEC was suspended in 2008.

growth in all countries while to determine the long-run causal relationship, cointegration test based on Johansen technique and Vector Error Correction Model (VECM) were employed.

The short-run estimates of the VAR Granger causality provides support for 'growth hypothesis' in Iran and Nigeria, of the "conservation hypothesis" in Bangladesh, Egypt, Malaysia, Pakistan and Turkey, and of a "neutrality hypothesis" for Indonesia for the selected years. The 'evidence of a 'feedback affect' in the short-run, could not be found in any case.

The Cointegration tests supported the evidence of cointegration among the real output; measured by GDP and energy use in all the member countries. The VECM results confirmed that in the long-run, the "growth hypothesis" is true for the sample period in Nigeria while "conservation hypothesis" is true for Egypt. The "feedback hypothesis" was established by the results of estimation of long-run causality for Bangladesh, Indonesia, Iran, Malaysia, Pakistan and Turkey. The results based on the long-run analysis by VECM suggest that energy consumption plays an important role in enhancing productivity in all the countries except Egypt in long-run and energy use has important implications for these developing countries in the long-run. The results support the evidence of causality running in either one or both directions between energy consumption and GDP in all the countries in the long as well as in the short-run except Indonesia in the short-run. On the whole, results suggest that the economies of most countries are energy dependent and shortage of energy may negatively affect the economic growth which eventually results in a fall in income, employment and broadly, social welfare.

The important policy implications drawn from this study are that in order to achieve rapid economic growth, members of the D8 should adopt a policy of energy sector development on priority basis. The results of estimation reveal that there is energy sector has uni-directional or bi-directional long-run implications for the economic growth in these countries. These D8 countries are, as concluded by the situation analysis, rich in renewable resources of energy like tidal, air, solar, biomass etc. Therefore, there is need to build new dams, installation of wind power plant and tidal energy projects to expand the energy production capacity especially in the countries facing energy crunch such as Bangladesh, Pakistan and Turkey.

Bangladesh, Pakistan and Turkey should try to avoid or minimise the import of crude oil at massive costs which are resulting in depletion of foreign currency reserves. For the achievement of this objective, the masses in these countries should be educated about the use of renewable energy to decrease dependence on fossil and traditional sources of energy. Moreover, policy orientation needs a drastic modification to focus on utilisation of endogenous resources. There must be short-term and long-term planning regarding the energy demand and supply in the economy. Finally these countries should pursue energy conservation policies in such a way that is not detrimental to on economic growth.

As for the energy exporting countries, the results show that energy consumption plays an important role in these economies in short as well as long-run. These countries need to reduce their over dependence on the energy sector for the economic growth and development and diversify their economies. The analysis of the current situation exposes

the overdependence of these economies on the energy exports. The countries such as Iran and Nigeria need to broaden their industrial and export base from only natural resources to varying energy intensive industrial products. Furthermore, Nigeria should develop the domestic infrastructure and make sure of an environment conducive for foreign investment. Iranian and Malaysian governments have historically been giving huge amounts in respect of subsidies to the energy sector, as mentioned in the overview of the energy sector of the respective countries. These countries need to adjust their prices in accordance with the international market prices.

As for Malaysia and Indonesia, two of the fastest growing economies in East Asia, the demand of energy is growing at very fast pace in these countries. These countries, it is feared, will have to face energy crunch in near future. As it has been established by the outcomes of the estimation, energy has long-run insinuations in both economies therefore, the respective governments should plan ahead to avoid possible chaos due to energy crisis. For that purpose, there is a dire need of popularising the use of renewable energy, which might be the only solution to problems related to energy demand and supply.

While this analysis conclusively demonstrates dynamic causal linkages between energy consumption and economic growth, it should be stressed that the usual production function also includes capital and labour. Hence, in future work, the techniques employed in this study can be readily extended to other multivariate systems, where energy consumption and real income are exposed to other economic factors such as capital stock and employment to improve the model. The sample size of 28 years may also be increased for better inferences.

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