NUST JOURNAL OF SOCIAL SCIENCES AND HUMANITIES
Vol. 6 No. 1 (January-June 2020) pp. 1-16

Energy-Economy Nexus in Emerging Economies: A Dynamic Panel Data Analysis

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Abstract

Keeping in view the strong link between energy use and economic growth along with associated environmental costs and contradictory findings, this study re-investigates the energy-economy nexus for a group of 45 emerging economies. Empirical estimation of the modified Solow growth equation is carried out through pooled mean group estimator, impulse response functions and forecast error variance decomposition for the period 1991-2015. Our empirical results show that energy use and economic growth are interdependent (feedback hypothesis) in case of emerging economies. Overall, the analysis demonstrates that energy is the mainstay of emerging economies. Therefore, to maintain the ongoing pace of economic growth the discussed countries must ensure uninterrupted energy supply.

Key Words: Energy Use, Economic Growth, Pedroni Cointegration Test, Heterogeneity, Emerging Economies.

1. INTRODUCTION

The importance of energy and exploitation of its resources for economic development can never be denied[1]. Nonetheless, the environmental costs that are associated with the use of energy resources cannot be disregarded, either. Owing to the sensitivity of the issue, there has been an ever-evolving debate in economic literature on energy-economy nexus, since the 1970s. Certainly, in production process, energy not only contributes as a basic factor but it also improves the productivity of other input factors. Thus, the comparative abundance of available energy resources (of any country as compared to other countries) and their appropriate utilization lead to more rapid economic development. However, utilization of more energy resources, in the process of production, results in emission of greenhouse-gases that are responsible for global warming.

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[1] For details, see Siddiqui (2004) and Alam and Butt (2002).

In this backdrop, based on the direction of causal co-movements and policy prescription, on energy-economy nexus there are four strands of studies in economic literature, [Ozturk (2010)]. The first strand is based on the growth hypothesis (a type of unidirectional relationship in which use of energy stimulates economic growth only), that connotes utilization of energy as an important determinant of economic growth and energy conservational policies as an impediment to economic growth[2]. The second strand of literature is based on the conservation hypothesis (a unidirectional relationship in which economic growth stimulates the use of energy), that considers economic growth as a determinant of use of energy[3]. The third strand of literature is based on feedback hypothesis (a bidirectional relationship between use of energy and economic growth)[4]. Finally, the forth strand of literature is based on the neutrality hypothesis, that implies lack of causal relationship between use of energy and economic growth. Hence, in view of these four strands of economic literature, the direction of causal relationship between energy use and economic growth is not lucid, so far, even for countries that are similar in many aspects.

However, based on an extensive survey of existing literature, and complexity of relationship between energy use and economic growth the findings are mostly contradictory and need re-examination. The current study is an attempt to reinvestigate the dynamic relationship between energy use and economic activities. To serve the purpose, current study takes into account the case of emerging economies. Since last two decades, the emerging economies are growing fast and striving hard to catch-up with their developed counterparts. Consequently, their growing demand for energy resources is putting undue pressure on energy prices. Besides this fact, the IEO[5] (2017), published by EIA[6] and BPEO[7] (2018) projects that, to a large extent, the future growth in world energy consumption will occur in the emerging economies.

The distribution of remaining sections of the present study is as follows: section 2 provides an overview of relevant economic literature; section 3 explains methodological issues; section 4 provides a detailed discussion on empirical findings, finally, section 5 provides conclusions and important policy implications.

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[2] For details, see Lee and Chang (2005); Lee and Chang (2008); Ho and Joo, *et al.* (2015), Pao and Fu (2013) and Jamil and Ahmad (2010).
[3] Ziramba (2009) and Menegaki and Tugcu (2016).
[4] Soares, *et al.* (2014) and Halicioglu (2009).
[5] International Energy Outlook (2017).
[6] U.S. Energy Information Administration.
[7] British Petroleum: Energy Outlook (2018).

2. LITERATURE REVIEW

The role of energy resources in the development of an economy is well established in economic literature. However, due to lack of agreement and conflicting evidences concerning direction of causality between energy and economy, plethora of studies have been devoted to explore this topic. The existing literature on the topic can be divided into two categories. One strand of studies has been conducted for individual countries, using time series techniques while the other studies are carried out for more than one country and uses panel data analysis.

Kraft and Kraft (1978) making a pioneering attempt, confirmed causal relationship between energy use and economic growth for US economy. They used data set for the period 1947 to 1974 and found unidirectional causality running from economic growth to energy consumption (the Conservation hypothesis). These findings imply that energy conservation policies can be adopted to minimize the extravagant use of energy resources, without any adverse impact on economic growth. Thereon, a large number of studies have been conducted for many developed and developing countries to investigate the energy-economy nexus. Other studies that support the conservation hypothesis are; Cheng (1995) for the US, Cheng (1998) for Japan, Cheng and Lai (1997) for Taiwan, Jobert and Karanfi (2007) for Turkey, Yildirim *et al*. (2014) for Malaysia; Aqeel and Butt (2001) for Pakistan, Hwang and Yoo (2014) for Indonesia, Pao and Fu (2013) for Brazil, Cheng (1999) for India, and Zamani (2007) for Iran.

Other studies conducted for the same countries (mentioned above) report unidirectional causality, running form energy use to economic growth (the Growth hypothesis). The policy implications in this case are different. The growth hypothesis implies that any intervention in the supply of energy will cause the economic growth directly. These studies include; Stern (1993; 2000) for the US economy, Menegaki and Tugcu (2016) for Brazil, Chiou-Wei *et al.* (2008) for Indonesia, Aslan and Kum (2010) for Malaysia, Soytas *et al.* (2001) for Turkey, Hwang and Gum (1991) for Taiwan, and Paul and Bhattacharya (2004) for India. In view of above mentioned two strands of studies, their findings are conflicting and hence provide different policy implications. In other words, the inconsistent conclusions could not be relied upon for prescription of any appropriate policy measures.

Various reasons may be responsible for the conflicting results; one being the use of time series data, that involve issues such as; selection of different time periods, quality of data, and limited number of observations. To overcome this issue, researchers usually prefer panel data. The panel data analysis takes into account heterogeneous countries, to improve the statistical accuracy.

Therefore, a large number of studies have been conducted for different regions or group of countries using panel data techniques. For instance, Chen *et al.* (2007) considered energy-economy nexus using vector error correction mechanism for the period 1971–2007 for ten Asian countries. The empirical results validate the feedback hypothesis for Indonesia, South Korea, and Philippines. For OPEC countries, Squalli (2007) employed Toda-Yamamoto procedure. The results of the study confirm the growth hypothesis for Indonesia and feedback hypothesis for Iran. Similarly, Narayan and Prasad (2008) examined a panel of thirty OECD countries using Bootstrapped Toda-Yamamoto procedure. They confirmed the feedback hypothesis for South Korea and neutrality hypothesis for Mexico and Turkey. Ozturk, *et al.* (2010) examined the energy-economy nexus, using panel co-integration and causality tests for a sample of 51 countries, covering the period from 1971 to 2005. Their results reveal the existence of unidirectional causality, which runs from energy use to economic growth. Where in case of eleven African countries, Eggoh *et al*. (2011) used the co-integration procedure for the period from 1981 to 2007. Their findings are consistent with the feedback hypothesis. Similarly, Fuinhas and Marques (2011) for the period from 1965 to 2009, employed the autoregressive distributed lag (ARDL) model for a panel of 5 countries, namely; Greece, Italy, Portugal, Spain, and Turkey. They also vali-dated the feedback hypothesis. Another important study is conducted by Omay *et al.* (2015) for eight Central Asian and European countries. They confirmed conservation hypothesis for all selected countries. Asafu-Adjaye (2000) considered four developing Asian economies, using annual data for the period 1971-1995. He found unidirectional causality that runs from energy use to economic growth, for India and Indonesia and bidirectional causality for Thailand and Philippine. Razzaqi and Sherbaz (2011) studied the energy-economy nexus for D8 countries using Johansen's counteraction test. Their findings confirm the existence of short-run and long-run relationship between energy use and GDP of all D8 countries.

From an extensive survey of literature.[8], it may be concluded that a large number of studies are carried out for developed economies and that the case of emerging countries has been overlooked for various reasons. Thus, the current study contributes to the existing literature by considering the role of 45 (maximum possible) emerging economies. To serve the purpose, the study utilizes the appropriate dynamic panel data techniques that are; IPS, Pedroni

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[8] Including Ozturk (2010) and Tiba and Omri (2016) among many others.

Co-integration test, Pooled mean Group estimator, Impulse response functions and variance decomposition analysis.

3. METHODOLOGY

In case of developing and many emerging economies, non-availability of data always remained a binding constraint. Therefore, we found time series analysis only for some selected developing countries but with inadequate degree of freedom. For this reason, the panel data technique is an appropriate solution to handle this problem. As discussed above, for various reasons, panel data analysis is a popular methodology and many recent studies, focus on panel data estimation techniques. This study attempts to address the issue of energy-economy nexus for 45 emerging economies. The behavioural equation estimated in this study is basically a modified version of Solow-type neoclassical growth equation, where output is assumed to be determined by capital, labour force, and energy use. In recent times energy is considered as lifeline for the modern economies and serves as a basic input in the production process of goods and services. Therefore, our behavioural equation becomes:

$$Y = F(K, L, E)$$

The augmented Solow-growth equation is estimated for the period 1991-2015 for 45. The multivariate framework includes real GDP (Y) in constant 2005 US dollars, real gross fixed capital formation (K) in constant 2005 US dollars, labour force (L) in millions and energy use (E) in kt of oil equivilant. All the variables are in natural logarithms. For estimation of the model, data is retrieved from World Development indicators, World Bank database. The choice of data span depends on the availability of time series. Our long-run model is as follows.

$$y_{it} = \alpha_0 + \alpha_1 k_{it} + \alpha_2 l_{it} + \alpha_3 en_{it} + u_{it} \qquad \dots (1)$$

Equation (1) represents the long-run relationship between real economic activity and its major determinants. Since capital stock, employed labour force, and availability of energy resources are believed to be the basic ingredients to the growth process; hence, theoretically, the signs of all the coefficients should be positive $\alpha_1, \alpha_2, \alpha_3$. The PMG approach requires that to evaluate the extent of long-run association and the speed of adjustment to its long-run path, we must allow the short-run dynamics to be data determined for each country. This can be achieved by reformulating equation (1) as an ARDL ($p, q, \dots, q$) model;

$$Y_{it} = \sum_{j=1}^{p} \lambda_{ij} (Y_i)_{t-j} + \sum_{j=0}^{q} \delta_{ij} (X_i)_{t-j} + \mu_i + \varepsilon_{it}$$

where, the number of groups i = 1, 2, ..., N; the number of periods t = 1, 2, …, T; X_{it} is a 3 × 1 vector of explanatory variables; δ_{it} are the k × 1 coefficient vectors; λ_{ij} are scalars; and μ_i is the group-specific effect. This model can be re-parameterized as a Vector Error Correction Model (VECM) system:

$$\Delta Y_{it} = \phi_i [(Y_i)_{t-1} - \theta_i X_{it}] + \sum_{j=1}^{p-1} \lambda_{ij} (\Delta Y_i)_{t-1} + \sum_{j=0}^{q-1} \delta_{ij} (\Delta X_i)_{t-j} + \mu_i + \varepsilon_{it}$$

where the θ_i are the long-run parameters and ϕ_i; is the equilibrium (or error-correction) parameter. If $\phi_i = 0$, then there would be no evidence of long-run relationship. This parameter is expected to be significantly negative under the assumption that the variables show a return to a long run equilibrium. The pooled mean group restriction is that the elements of θ are common across countries.

4. EMPIRICAL RESULTS

This section discusses the empirical results of the study. First of all, as a pre-requisite to core analysis, non-stationarity has been checked using IPS unit root test. The IPS unit root test results show that null hypothesis of unit root cannot be rejected for the variables in levels. We further applied the unit root test in the first differences of the variables and the results reject the null hypothesis, implying that all variables are non-stationary at level, but become stationary at first differences (see, Table 1).

Table 1. Im, Pesaran and Shin W-stat (Null Hypothesis: There is unit root)

Variable	Level		1st Difference	
	Statistic	Prob.	Statistic	Prob
Y	-1.7191	0.04	-11.7808*	0.00
E	-0.6467	0.74	-19.1455*	0.00
L	-0.1652	0.43	-10.8092*	0.00
K	-2.0579	0.26	-27.0673*	0.00

Note: To ensure that the residuals are white noise we have chosen lag length based on the Akaike Info Criterion (0 to 4). Probabilities are computed assuming asympotic normality. * denotes the rejection of null hypothesis of unit root at 1 percent level of significance. The order of variables is (Y) real GDP, (E) energy use, (L) labour force and (K) gross fixed capital formation. We have taken annual data of emerging economies from 1991–2015.

Source: Authors' calculation using Eviews-8 software.

Next, our estimation proceeds with verifying the existence of long-run relationship between the variables of interest, if any. The empirical results are reported in Table 2, the test-statistics Panel PP, group PP, Panel ADF and group ADF strongly reject the null hypothesis of no cointegration, four out of seven test-statistics show the rejection of null hypothesis. Hence, our results provide strong evidence of cointegration among variables considered. Thus, it can be predicted that energy use and GDP move together in the long-run.

Table 2. Pedroni Cointegration Test (Null Hypothesis: No cointegration)

Test	Statistic	Prob.
Within dimension (common AR coefs)		
Panel v-Statistic	-0.746018	0.7722
Panel rho-Statistic	-0.585834	0.7211
Panel PP-Statistic	-4.262081	0.000*
Panel ADF-Statistic	-5.442284	0.000*
Between dimension (individual AR coefs)		
Group rho-Statistic	-3.267142	0.9995
Group PP-Statistic	-2.613359	0.004*
Group ADF-Statistic	-4.928611	0.000*

Note: We have chosen lag length based on the Akaike Info Criterion (0 to 4). * denotes the rejection of null hypothesis of no cointegration at 1 percent level of significance. Pedroni proposes two types of cointegration tests. First, the panel tests based on the within dimension approach, these statistics essentially pool the autoregressive coefficients across different countries for the unit root tests on the estimated residuals. These statistics take into account common time factors and heterogeneity across countries. Second, the group tests are based on the between dimension approach, these statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals for each country in the panel.
Source: Authors' own calculation.

4.1. Pooled Mean Group Regression (long run estimates)

After confirming that energy use and economic growth are cointegrated we need to look at the direction and magnitude of the relationship. Thus, we proceed with PMG test to estimate the appropriate sign and size of the energy coefficient in the long run as well as short-run. Our empirical results reveal that the impact of energy consumption on output growth is positive and statistically significant implying that energy plays crucial role in the economic development of emerging countries. Thus, our findings suggest that energy use is an indispensable component in growth process, directly or indirectly as a complement to capital and labour as an input in the production process. An increase of 1% in the energy use increases the economic growth by 0.463%. On the other hand, equation shows that 1% change in output energy demand rises by 0.66%. Thus, our findings support the feedback hypothesis for the emerging economies.

Table 3. Pooled Mean Group Estimates (Long-run Analysis)

Dependent variable: Y			
Variable	Coef.	z.stat	Prob.
E	0.46	11.54	0.00*
K	0.16	06.68	0.00*
L	0.23	04.45	0.00*
Dependent variable: E			
K	0.11	03.44	0.01
L	1.30	25.74	0.00

Note: * denotes the significance of the variables at 1 percent level by taking into account the probability value of Z statistics. The order of variables is (E) energy use, (K) gross fixed capital formation and (L) labour force. Y is real GDP which is dependent variable. We have taken annual data of emerging economies from 1991–2015.

Source: Authors' own calculation.

Theoretically, an increase in the physical capital stock (plant, machinery, and infrastructure investment) leads to expansion in productive capacity which in turn lead to increase in output growth by increasing productivity, and employment opportunities, getting the benefits of economies of scale and by raising the overall welfare of country. Our empirical results show that a 1% increase in the capital stock increases the economic growth by 0.165%. Increase in labour force means the increase in the work age population of an economy that increases the output growth by participating in economic activities. A 1% increase in the employment opportunities increases the economic growth by 0.23%. Similarly, from our results depicted by the energy equation show that due to increase in the capital stock as well as employment, the demand for energy rises. Another important implication of our results is that capital stock, employment, and energy resources are complementary to each other.

4.2. Pooled Mean Group Regression (Short run estimates)

Given that the variables are cointegrated, a panel vector error correction model [Pesaran, *et al*. (1999)] is estimated to perform causality tests. The short-run VECM model reveals that there is bidirectional causality between energy use and economic growth in the long run. While in the short run, there is no evidence of causality between the two variables [Yusma and Waliha (2010), Islam (2011) and Joyex and Ripple (2007)]. The bidirectional causality between energy use and economic growth implies that a high level of economic growth leads to high level of energy demand and vice versa. This means that they are interrelated and may very well serve as complements to each other [Apergis and Payne (2009)].

Table 4. Pooled Mean Group Estimates (short-run Analysis)

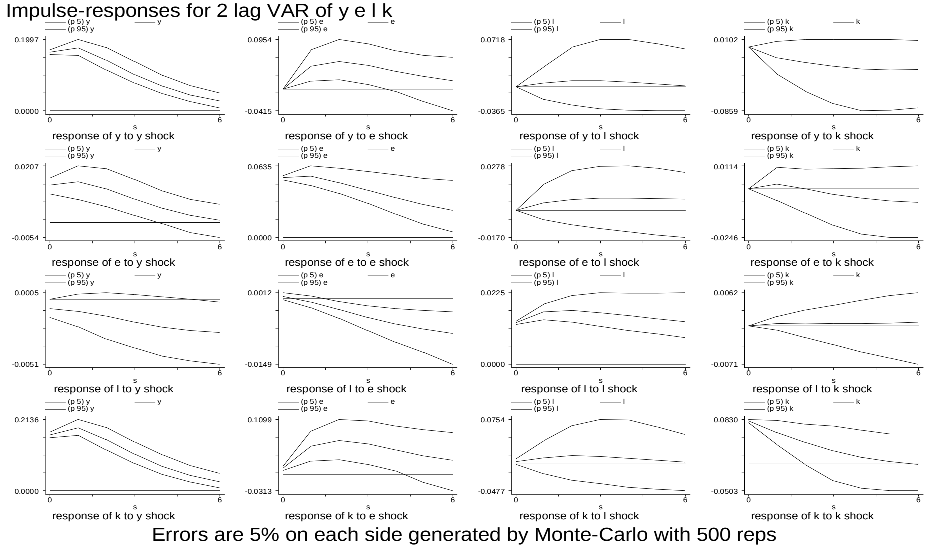
	dY	dE	dK	dL	ECT
dY		.0697001	.3818621	.5053764	-0.1220429
		(0.339)	(0.000)*	(0.354)	(0.000)*
dE	.0298203		.0556494	-.4396881	-0.1320845
	(0.649)		(0.087)	(0.088)	(0.001)*
dK	1.084216	.2923253		.4446729	-0.228818
	(0.000)*	(0.001)*		(0.392)	(0.000)*
dL	-.0146819	-.0059119	.0126215		-.0080631
	(0.381)	(0.593)	(0.268)		(0.222)

Note: d stands for the first difference of each variable where (Y) real GDP, (E) energy use, (K) gross fixed capital formation and (L) labour force. ECT represents the coefficient of the error correction term which represents the long run causality between variables. While the short run causality is represented by the coefficients of first differenced variables in each equation. Probability values of z-statistic are in brackets and * denote the significance at the 1% level of significance.
Source: Authors' calculation using Stata software.

4.3. Impulse Response Functions

In order to measure the dynamic behaviour of endogenous variables that are real GDP, energy use, capital formation and labour force, we compute impulse-response functions for the panel VAR model. IRFs are useful tools that describe the reaction of each endogenous variable to innovations in any other variable of the system, while holding all other shocks equal to zero. Figure 1 plots impulse-response functions together with 5 percent errors bands generated through Monte Carlo simulations with 500 repetitions.

Figure 1. Impulse Response Function.



The main interest in this paper is to check the intertemporal interconnectedness between economic growth and energy use. Our estimated IRFs show that in response to one standard deviation shock to energy use, income responds positively and starts to rise immediately, reaches its maximum level in the second period. The increase in income sustains for three periods; before falling slowly and taking six periods to attain its initial level. The shock of labour force on real GDP is also positive and reaches its initial level in six periods. Similarly, an unexpected shock to capital formation boosts output but the impact is statistically insignificant.

In addition, due to an unexpected one standard deviation shock to real GDP, energy use instantaneously rises. It is evident from figure that the impact of growth on energy demand dies out in six periods. Furthermore, due to positive shock to output growth, employment opportunities and hence demand for workers shows positive trend that lasts for almost five periods. Demand for investment goods also rises. Keeping in view the objective of the study other graphs and their explanation seem to be irrelevant, hence we stick to the most relevant discussion only. Overall, we can conclude that in emerging countries, demand for energy and economic activity are strongly related and any increase in economic activity will require more energy resources and vice versa a positive supply shock to energy resources will boost the economy.

4.4. Variance Decompositions Analysis

Having confirmed the feedback hypothesis form our long-run estimates and impulse response functions we further extend our analysis to forecast error variance decomposition analysis. FEVD analysis describes the relative importance of various shocks causing variation in endogenous variables. Restricting our analysis to the objective of the study we will discuss the FEVD analysis for output growth and energy use only. Our empirical findings show that shock to energy use contributes four percent variation in economic growth at any horizon. A shock to capital formation seems to be the most prominent source of variation in economic growth. Similarly, if we look at the sources of variation in energy use it is pertinent to note that most of the variation in energy use is due to shocks to energy sector. However, shock to economic growth is an important source, contributing eight percent variation in energy demand at any horizon. Other sources such as shock to investment and employment also contributes by twelve percent and sixteen percent variation in energy use.

Hence, based on our findings from FEVD analysis we can safely conclude that energy use and economic activity are strongly related and shock to any of these variables can forecast fluctuations in other variables. Our findings again support the feedback hypothesis. Overall, our findings from

PMG estimation, IRFs, and FEVD analysis are in-line with each other, which depicting the robustness of our estimation procedure and results.

Table 5. Forecast Error Variance Decomposition Analysis

	S	Y	E	L	K
Y	10	0.86295046	0.08065423	0.002397	0.053998
E	10	0.04572992	0.90688921	0.028932	0.018449
L	10	0.01732975	0.16738834	0.812893	0.002389
K	10	0.77990964	0.12675041	0.003579	0.089760
Y	20	0.85150910	0.07963143	0.002466	0.066393
E	20	0.04432451	0.87885712	0.046481	0.030338
L	20	0.01917556	0.30073155	0.667102	0.012991
K	20	0.77578774	0.12944218	0.003771	0.090999
Y	30	0.85100774	0.07962537	0.002468	0.066899
E	30	0.04406662	0.87326756	0.052188	0.030478
L	30	0.01884083	0.33456507	0.625169	0.021426
K	30	0.77542134	0.12959717	0.003779	0.091203

Source: Author's calculations.

5. CONCLUSION AND POLICY IMPLICATIONS

The understanding of causal relationship between energy use and economic growth is very important and helpful for policy makers in planning strategic energy investment. Thus, this study is designed to investigate the relationship between energy use and economic growth in a panel of 45 emerging economies for the period 1991-2015. Various advanced econo-metric techniques have been utilized to achieve the basic objective of the study. Keeping in view, longer time span and heterogeneous panel, appropriate estimation techniques have been employed. For this purpose, Pedroni's cointegration test is employed to validate the existence of long-run relationship. Next, PMG estimator is used to measure the direction and size of causal relationship between the two variables in short-run and long-run. Furthermore, forecast error variance decompositions analysis and impulse response functions are estimated to designate the dynamic relationship between the variables concerned.

For basic analysis, the Solow growth equation is modified by incorporating energy use as an independent variable. Using IPS test we found that all variables are integrated of order I*(1)* and the variables are co-integrated implying, the existence of long run relationship between energy use and economic growth. Furthermore, the empirical results obtained from PMG estimator establishes a positive bidirectional link between energy use and economic growth in the long-run. Whereas, the short-run analysis carried out through error correction model also provides the evidence of long run bidirectional causality between the energy use and economic growth. However, no short run causality has been found between the two variables. IRFs and FEVD also confirm a strong positive co-movement among the two variables of interest. Hence, the overall empirical findings of this study support the feedback hypothesis that implies that there is no room for any intervention in energy markets. Furthermore, these results also validate the statement by international energy agencies that emerging economies will play a crucial role in the international energy markets in the near future.

Apart from energy use and economic growth, capital stock and energy use also have a strong link which implies that both components are complementary to each other, where in case of developed economies the link between capital stock and energy use is getting weaker due to technological innovations. Hence, there is need to look for energy efficient technology.

Since both variables are interconnected, the policy makers must strive to ensure uninterrupted energy supplies. As energy is an important component to retain economic activities in any economy, a suitable energy policy should be maintained to boost economic growth and maintain sustainable economic development.

There is a dire need to build new dams, investment in energy infrastructure and new energy projects to expand the energy productive capacity especially in the countries facing acute energy crises. Moreover, energy efficiency can be enhanced through the investment in the areas of research and development. Effective regulation in the energy sector may also be helpful to maintain equilibrium in energy supply and its demand. Specifically, the energy demand in urban areas is expected to grow rapidly in future, hence appropriate policies should be enacted not only to promote production of clean and green energy but also motivate pro-environmental attitude and practices among households. Finally, diversification of energy-mix, and minimizing the share fossil fuels in the primary energy production should be the ultimate goal for every emerging country.

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APPENDIX

List of Countries

1	Armenia	24	Korea, Rep.
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3	Belarus	26	Nicaragua
4	Bostwana	27	Senegal
5	Bulgaria	28	Sri Lanka
6	Cambod	29	Tanzania
7	China	30	Tunisia
8	Czech Republic	31	Turkey
9	Jordan	32	Ukraine
10	Kenya	33	Uruguay
11	Latvia	34	Vietnam
12	Macedonia, FYR	35	Egypt, Arab Rep.
13	Malta	36	Iran, Islamic Rep.
14	Morocco	37	Kazakhstan
15	Nepal	38	Mexico
16	Namibia	39	Bolivia
17	Panama	40	Cameroon
18	Philippines	41	Colombia
19	Pakistan	42	Ecuador
20	Cyprus	43	South Africa
21	El Salvador	44	Malaysia
22	Guatemala	45	Indonesia
23	India		