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Factors Affecting Energy Demand in Developing Countries: A Dynamic Panel Analysis

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ABSTRACT: This work presents an empirical study of energy demand, in which demand for energy is expressed as a function of various factors, such as income, price, economic structure, and CO_2 emission. Parameter values are estimated econometrically, using a panel data approach of 16 developing countries over 30-years period. In general, the empirical results of this study confirm the majority of the findings in energy demand analysis where income and price have shown to be important determinants in energy demand. Moreover, economic structure and also CO_2 emission appear to exert significant impact on energy demand. Short- and long-run elasticities of demand are estimated and some policy suggestions are given to improve energy saving and green energy consumption in developing countries.

Keywords: Energy demand; panel data
JEL Classifications: C23; Q31; Q41

1. Introduction

Energy plays a vital role in the functioning of the world economy. Spurred by the oil price shocks in late 1973 and during the period 1979 to 1980 until the recent oil prices increased in 1999 and 2000, a lot of attention was devoted to the analysis of energy demand. As a consequence of the dramatic events in energy markets and the increasing importance of this sector in national economies, great effort was made to estimate the relationship between energy demand and its determinants such as income and price. Empirical studies have focusing on energy demand have used cross-section data (eg. Petersen, 2002) or through the use of time series data (eg. Masih and Masih, 1996) and also through the use of panel data (eg. Pesaran et al., 1998; Liu, 2004; Chaudry, 2010). In most of these papers the purpose has been to measure the impact of economic activity and energy prices on energy demand that is to estimate income and own-price elasticities.

Pesaran et al. (1998) highlighted that the empirical investigation of energy demand has been one of the most researched areas in energy economics. The energy demand specification is crucial input to any analysis of future energy usage and the impact of policy responses. According to Barker et al. (1995), one of the main reasons for the popularity of energy demand investigation is its application to a wide range of importance energy policy issues. These issues include the growing concern over the global environmental problem. For example, global warming, which resulting from the emissions of carbon dioxide currently originates in the energy sector, where the principal source of greenhouse gas is the emissions of CO_2 from the burning of fossil fuels, has highlighted focused attention on the pattern and the trend of energy demand. Therefore, accurately estimating and

analyzing the determinants of energy demand 8can provide some information for governments as a basis of setting up appropriate policies related to environment such as pollution and energy taxes.

Another major concern in modelling energy demand study is the price volatility in international energy markets. Generally, the developing countries suffer more than the developed countries from energy price increases. The impact on growth in developing countries is thought to be significantly higher, because energy-intensive manufacturing generally accounts for a larger share of their GDP and energy is used less efficiently. The volatile energy markets can distort the mid- and long-term development path of the industry and even countries' economy as a whole.

The paper aims to make the following contributions to the energy demand literature. First, it attempts to estimate energy demand by including not only income and price as the determinants, but also attempts to identify how significant are the structural variation in economy and carbon dioxide emission on energy demand. It is important to know how structural variation and carbon dioxide emission impact energy demand because any changes in energy demand with respect to these variables will provide important information as a basis of energy policy formulation regarding climate change and energy security issues. Then, this paper applied a dynamic heterogenous panel estimation technique to model the impact of income, price, structural variation and carbon dioxide emissions on energy demand. Dynamic models have more advantages compared to the traditional panel data analysis and static model because both long-run and short-run impacts (elasticities) are identified. In this paper, panel regression models are estimated using the mean group (MG) Pesaran and Smith (1995) and pooled mean group (PMG) estimator of Pesaran et al. (1999).

The structure of the paper is organized as follows. The next section briefly discusses the literature review. Section 3 specifies the general framework that usually underlies the empirical formulation in estimating the demand for energy, the method applied and the data used in the study. Section 4 provides the results and their interpretations. Section 5 provides a summary of the key results of the study and policy implications.

2. Literature Review

In the early study of energy demand, Pindyck (1979) focus on the structure of demand for energy on a pooled time-series cross-section data for a group of OECD countries and a few less developed countries. He reports that for both developed and developing countries, the price of energy and income has a significant effect on demand in the long run for residential, industrial and transport sectors. He also shows that the income elasticity of demand for energy is about unitary.

Chan and Lee (1996) examine the energy consumption behaviour of China over the period 1953 to 1993. They analysed four important variables in the energy demand study. The first is the energy consumption in year t as a dependent variable where the total energy consumption comprises four major energy inputs consumed in China, namely coal, electricity, natural gas and petroleum. The second is the national income, which measures the level of economic activity in China. The third variable is the price of energy and the fourth is an indicator of structural variation. The latter variable is represented by the share of heavy industry in the national income. This variable has been included because of its importance as the major energy consumers of the country. Using the co-integration and vector error-correction model, they find that not only the conventional variables (price and income) are important, but the share of heavy industry's output in the national income is also a significant demand determinant. They also reveal that China has relatively high price elasticity but low income elasticity.

Al-Azzam and Hawdon (1999) estimate the demand for energy in Jordan over the period 1968 to 1997. In addition to income and relative prices, they also include a construction activity as an indicator of the development process. Controlling for changes in the political climate facing by Jordan, they incorporate dummy variables to represent the level of conflict in the region. Using a log-linear specification and the dynamic OLS method, they find that income; construction activity and political instability have a positive statistically significant relationship with energy consumption. However, real price has only a neutral or weak effect. They conclude that "economic growth is likely to be accompanied by proportional increases in energy demand and hence environmental degradation". They also conclude that " the lack of responsiveness of demand to price changes suggest that taxes on

their own are unlikely to achieve government goals for energy conservation or environmental improvement, although they may well be efficient for revenue raising".

Recently, the growing concern of the environmental problems has focused attention on the relationship between energy consumption and the carbon dioxide (CO_2) emissions. Examples include Bhattacharyya and Ussanarassamee (2004) and Liu (2005). The origin issue of the relationship between energy consumption and CO_2 emissions was arise in the Earth Summit held in June 1992 at Rio de Janeiro in Brazil. The convention recognizes that climate is changing as a result of the increase in greenhouse gases arising from the burning of fossil fuels (Barker et al. 1995).

Bhattacharyya and Ussanarassamee (2004) investigate the changes in industrial energy intensities and CO_2 intensities from use of energy over a period of 1981 to 2000 in Thailand. The relationship is examined in four phases, namely, 1981-1986, 1986-1996, 1996-1998 and 1998 –2000 where the last two periods are chosen to reflect the significant changes in the Thai economy during and after the economic crisis. They demonstrate that the developing countries with high demand growth are contributing significantly to increase in CO_2 emissions, and use of energy is a major source of CO_2 emissions in most of these countries.

Liu (2005) examine the role of energy consumption in analysing the relationship between CO_2 emissions and national income for 24 OECD countries over the period 1975 to 1990. His estimation results based on panel data indicate that CO_2 emissions have a positive statistically significant relationship with energy consumption. Generally, these empirical study shows that the higher the CO_2 emissions, the higher the energy consumption.

Chaudry (2010) estimated energy demand at the economy-wide and the firm level in Pakistan during 1998–2008. Based on a panel dataset, the author finds that an increase in income will lead to an increase in the demand for electricity. Moreover, he also found that an increase in electricity price will lead to a decrease in electricity demand for energy.

3. Methodology and Research Design

The model specification to identify determinants for energy demand is formulated on the basis of pooled cross-country time series data and is shown as below:

$$LECP_{it} = \alpha_0 + \alpha_1 LRYP_{it} + \alpha_2 LRPR_{it} + \alpha_3 LIND_{it} + LCOE_{it} + \varepsilon_{it} \quad (1)$$

where $LECP_{it}$, $LRYP_{it}$, $LRPR_{it}$, $LIND_{it}$ and $LCOE_{it}$ represents per capita energy consumption by population in country *i* at time *t*; real GDP, real price of energy, share of industry in GDP and carbon dioxide emissions, respectively and ε_t is an error term and is assumed to be identically and independently distributed with zero mean and constant variance, i.e., $\varepsilon_t \sim IID\,(0,\sigma^2)$.

The estimates of the parameters in equation (1) are obtained by using the pooled mean group (PMG) estimation. It is an intermediate estimator which allows the intercepts, short-run coefficients and error variances to be different across group, but the long-run coefficient are constrained to be the same. For comparison purposes, this equation is also estimated by the mean group (MG) estimation. These estimations are able to accommodate both the long run equilibrium and the possibly heterogenous dynamic adjustment process, which is unlikely be obtained if using the traditional procedures such as fixed and random effects.

Although the MG estimator proposed by Pesaran and Smith (1995) provides consistent estimates of the mean of the long-run coefficients, these will be inefficient if the homogenenity of error variances or the equality of short- and long-run slope coefficients across countries holds. On the other hand, under long-run slope homogeneity, the pooled estimators are consistent and efficient. Therefore, the hypothesis of homogeneity of the long-run parameters is tested in order to determine the effect of both long-run and short-run heterogeneity on the means of the coefficients. For this purpose, the Hausman test (Hausman, 1978) is applied to examine the extent of panel heterogeneity. Under the null hypothesis there is no different between the MG and PMG estimates. PMG is more efficient when the difference in the estimated coefficients between the MG and PMG are not significantly different. In other words, in the presence of long-run homogeneity, the use of the PMG estimator is preferred because it offers efficiency gains over the MG estimator.

The data set used in this study represents a panel of observations for 16 countries over the periods from 1978 to 2003. All the series are obtained from the World Development Indicators (WDI) online database (www.worldbank.org), except for energy price, the data is collected from the Energy

Prices and Taxes, Third Quarter 2004, International Energy Agency (IEA) CD-ROM. Energy consumption is represented by energy use in kilograms of oil equivalent (kgoe) and then divided by population to give a per capita series. The data on real GDP per capita is used as the measure of income, and is denominated in constant 1995 US dollars. To avoid the country specific heterogeneity the real GDP measurement is estimated in international prices, which is comparable across countries. An annual energy price is obtained from the compilation of energy prices at all market levels, namely import prices, industry prices and consumer prices. The share of industry in GDP and CO_2 is used to proxy the structural changes in the economy and the level of pollutant, respectively.

4. Discussion of Findings

Table 1 presents the estimation of the long- and short-run coefficients, the adjustment coefficients (the error correction coefficients), Hausman test statistic and the corresponding p-values for the coefficients on each of the explanatory variables and for all of them jointly. The order of lag is chosen by the Schwarz Bayesian Criterion (SBC), subject to a maximum lag of 1. The null hypothesis of the long-run parameters is the same across countries can be conducted through Hausman test. In all cases, the Hausman test statistic fails to reject the null hypothesis for both individual and jointly parameters. This explains that the data do not reject the restriction of the equality of the long-run restriction and implies that the PMG method is efficient estimates. However, for comparison purposes, the mean group and statistic fixed effect estimator's results are also reported. The PMG results reveal that the signs of the coefficients are consistent with the theory. The real GDP per capita (economic growth), the economic structure and emission of CO_2 have positive sign whereas the real price of energy has negative sign. In model 1, the estimate of the long-run income is 0.93, which is about unity and the long-run price elasticity is –0.07. This result is consistent with Al-Azzam and Hawdon (1999) and Gately and Huntington (2002) where they find that income is significantly positive to the energy consumption in the long-run and is about unity whereas the long-run price elasticities tend to be very inelastic.

Table 1. Alternative pooled estimators for ARDL-SBC specification of developing countries

Dependent variable: real energy consumption per capita (1978-2003)

	PMG Estimators	MG Estimators	Hausman Tests	SFE Estimators
Model 1				
Long-Run Coefficients				
RYP	0.93(27.40)***	2.19(1.54)	0.78(0.38)	0.52(18.84)***
RPI	-0.07(-5.54)***	-0.55(-1.00)	0.76(0.38)	-0.06(-3.85)***
	Joint Hausman Test: 0.79 (0.68)			
Error Correction Coefficients				
Phi	-0.24(-3.62)***	-0.40(-6.26)***		
Short-Run Coefficients				
RYP	0.22(3.62)***	0.24(5.32)***		
ΔRYP	0.12(1.67)*	0.08(1.46)		
RPI	-0.02(-3.62)***	-0.02(-0.92)		
ΔRPI	-0.02(-1.60)	-0.02(-1.74)**		
Intercept	0.15(1.61)	1.15(2.11)		
N x T	416	416		416
Model 2				
Long-Run Coefficients				
RYP	0.17(13.25)***	0.21(1.20)	0.06(0.81)	0.13(8.40)***
RPI	-0.03(-5.09)***	-0.08(-1.89)*	1.68(0.20)	-0.02(-3.24)***
IND	0.10(5.60)***	0.16(1.01)	0.16(0.69)	0.12(6.21)***
COE	0.64(66.41)***	0.50(4.27)***	1.32(0.25)	0.58(34.83)***
	Joint Hausman Test: 4.46 (0.35)			

Error Correction Coefficients				
Phi	-0.60(-5.52)***	-0.70(-7.54)***		
Short-Run Coefficients				
RYP	0.10(5.52)***	0.21(4.37) ***		
ΔRYP	-0.07(-0.72)	0.03(0.66)		
RPI	-0.02(-5.00) ***	-0.02(-1.37)		
ΔRPI	-0.02(-0.54)	0.01(0.44)		
IND	0.06(5.45) ***	0.08(1.18)		
ΔIND	-0.03(-0.86)	-0.07(-1.78) *		
COE	0.38(5.48) ***	0.33(3.68)***		
ΔCOE	0.08(0.77)	0.05(0.65)		
Intercept	3.04(5.45)	2.90(4.58)		
N x T	416	416		416

Notes: Figures in parentheses are t-statistic except for Hausman test (H), which is p-value. Significance at the 1%, 5% and 10% levels are denoted by *** ,** and * respectively.

The introduction of the degree of industrialization and carbon dioxide emissions in Model 2 reduces the income and price elasticities, though it remains statistically significant at 1% level. The share of industry in GDP has the expected positive sign, which reflect the higher the levels of industrialization, the higher the levels of energy consumption. This finding is accordance with Chan and Lee (1996) and Adams and Shachmurove (2000) who found an importance of degree of industrialization in explaining energy use. The result also indicates that the carbon dioxide emissions variable has the strongest impact on energy consumption, as reflected in its larger coefficient compared to other explanatory variables. This demonstrate that the higher the emissions of carbon dioxide, the higher the use of energy. The importance relationship of the carbon dioxide emissions with energy consumption is in line with Bhattacharyya and Ussanarassamee (2004) and Liu (2005). This finding implies that the environmental taxes, which aim to reduce the use of scarce resources is not as effective as it would be.

On the other hand, the short-run coefficients for the above four regressors are statistically significant to determine energy consumption. However, the effects of a change in energy elasticities are smaller in the short-run than in the long-run. This is in line with the various interpretations that have been discussed for the response in the short-run is smaller than in the long-run. For instance, in the household level the response to a price change is smaller in the short-run, when the demand is limited by the given stock of installations, than in the long-run, when the appliance has been optimally adapted to new conditions (Vaage, 2000). Thus, comparing the long-run and short-run estimates, we can conclude that income, energy price, structural change and the emissions of carbon dioxide are important in determining energy consumption in the long-run.

5. Conclusion

This study examines the determinants of energy consumption using the panel data framework for 16 developing nations. The results of this study indicate that not only income and price are important determinant for energy demand, but the degree of industrialization and the emissions of carbon dioxide are also statistically significant to determine energy demand in developing nations. Nevertheless, the carbon dioxide emissions indicator demonstrates more powerful impact on energy consumption compared to other explanatory variables.

These findings seem to suggest that the low-income elasticities for developing countries reflect the tendency for the developing economies to become less energy intensive and move towards more efficient processes. Hence, it should be reasonable to expect that in the future every percentage increase in GDP will be associated with a less than equal percentage in energy. This study also indicates that the price elasticity of energy consumption in developing countries is quite low, indicating that energy conservation measures based on the price mechanism are less. The statistically significant share of industry in GDP for developing countries seems to suggest the importance of industrial sector in energy consumption. This result also suggests that the emission of carbon dioxide

shows a powerful impact for developing countries, indicating that ineffectiveness environmental taxes as a tool to reduce the use of energy as a scarcity resource are greater in these nations.

Given fairly large geographically differences with varying level of economic development, the empirical results seems to suggest that a tidy, uniform international or national policy designed to apply to energy use as an exhaustible resources may not prove to be as effective as one would expect. If its demand is income-elastic, energy policies of changing income directly or indirectly via, e.g., higher taxes on energy consumption, may be effective. If it is price-elastic, the control of the limited energy source could be achieved by the policy of price changes. Following this principle, the empirical results suggest that it is hard to achieve efficiency in the designed policy such as energy conservation or environmental improvement because the lack of responsiveness of demand to income and price changes.

In conclusion, not only the traditional factors such as income and price are important to determine energy consumption, but it does appear to be the case that the structural change and environmental indicator, variables that have been neglected in majority of previous studies, are very important to determine energy consumption. The results suggest that energy consumption follows the level of economic activity in the long-run. Given that energy is such an important part of daily life, we would expect the price elasticity to be rather low.

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