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AN EMPIRICAL STUDY ON INCOME AND ENERGY CONSUMPTION IN BANGLADESH

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ABSTRACT

This study investigates the inter-temporal causal relationship between energy consumption and economic growth in Bangladesh during the period 1971-2007. This issue is of fundamental importance for the developing economy of Bangladesh. We use the Autoregressive Distributive Lag (ARDL) bounds testing approach to cointegration tests to explore the dynamic relationship between energy consumption and economic growth in Bangladesh. We apply newly developed methods based on simulations that are robust to the violation of statistical assumptions especially when the sample size is small as is the case in this paper. The interesting results of the paper are that unidirectional causality runs from energy consumption to economic growth in Bangladesh and then restrictions on the use of energy could lead to a reduction in economic growth. There is a convergence process in the long-run dynamics of energy use to real GDP so that any shock in energy adjusts with real GDP by 2-2.5 year. The growth hypothesis suggests that energy consumption plays an important role in economic growth in Bangladesh.

Key words:
income, energy consumption, Granger causality, co-integration, error-correction model.

JEL Classification: Q43; Q53; Q56

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INTRODUCTION

Economic development is inclined by the amount of energy as well as primary inputs (Beaudreau 2005) in the production function. In the last two decades, a number of academic papers explored the relationship between economic growth and energy consumption (Yu and Hwang 1984, Yu and Choi 1985, Yu and Jin 1992, Cheng 1995, Yang 2000, Akarca and Long 1980). There are several studies that examined the causal relationship between energy consumption and economic growth using a production function framework for some developed and developing countries, but there are no conclusive findings. Although a strong interdependence exists between economic growth and energy consumption, the direction of causality is of question and thus exploration of such causality needs to be examined on a country-specific basis.

The directions and policy implications for the causal relationship between electricity consumption and economic growth can be categorized primarily into two. If it is found that unidirectional causality runs from electricity consumption to economic growth, then restrictions on the use of electricity could lead to a reduction in economic growth. Many countries worry about this negative effect on economic growth caused by the restricted use of energy, as there is pressure to mitigate CO_2 emissions in order to slow down the rate of climate change. On the other hand, if unidirectional causality runs from GDP to electricity consumption, electricity conservation measures may be implemented with little or no adverse impacts on economic growth. A bi-directional causal relationship thus implies that electricity use and economic growth are jointly determined and they affect one other at the same time. If no causal relationship between the two variables is found, then the "neutrality hypothesis" holds.

In this study, we investigate the relationship between energy consumption and economic growth in Bangladesh from a long run granger causality perspective in bivariate framework. To the best of our knowledge, there are only a few studies that examined the Granger causality link between economic growth and energy consumption for some developing and least developing countries, especially for Bangladesh. The lack of consensus may largely be due to the differences in the development stages of the various countries. The analysis relies on recent time series techniques that offer potential solutions to the methodological problems listed in Stern (2004). The most striking result may be that the long run Granger causality is running from energy consumption to economic growth in Bangladesh.

1. LITERATURE REVIEW

An earlier study by Kraft and Kraft (1978) examined the Granger causality link between energy and income with mixed results (Akarca and Long 1980, Yu and Hwang 1984, Yu and Choi 1985, Erol and Yu 1987, Hwang and Gum 1992, Bentzen and Engsted 1993, Glasure and lee 1997). The multivariate studies, following Stern (1993), employed recent and powerful time series techniques (Stern 2000, Glasure 2002, Soytas and Sari 2003, Lee 2006). Stern (2000) examined the relationship between income, energy use, labour, capital stock in the US for the period 1948-1994 using cointegration and vector error correction (VEC) modeling. He concluded that there is mutual causality between energy consumption and GDP in the USA. A consensus conclusion of these studies is that employment is found to Granger cause electricity consumption in the long run. While in the short run the causal effect is neutral between employment and electricity consumption, except Chang and Wong (2001) for the case of Taiwan. In addition to that, a country's population growth plays an important role in electricity consumption via the residential and commercial usage. Previous empirical studies have focused on the relationship between electricity consumption, income and employment, and among them are Narayan and Smyth (2005), and Narayan and Singh (2007).

Wolde-Rufael (2005) found conflicting evidence with the neutrality hypothesis supported in a substantial number of countries, with little support for the hypothesis that energy consumption causes economic growth. Lee (2006), in a panel cointegration and causality study for a group of 18 developing countries, found causality running from energy consumption to economic growth but not vice versa. Al-Iriani (2006) found a unidirectional causality running from economic growth to energy consumption for a group of six Gulf Cooperation countries. Richmond and Kaufmann (2006) included energy consumption into their analyses in order to overcome the omitted variables problem and to find a relation between income and energy consumption and emission. Soytas and Sari (2006c) failed to identify a significant Granger causality link between any of the variables in a tri-variate model with energy, carbon emission and income. There are a few studies that investigated the relationship between economic indicators and energy consumption in Turkey, using different methods and approaches (Say and Yucel (2006). The relationship between carbon emissions and income in Turkey is linear rather than EKC path (Lise, 2006).

Soytas and Sari (2007) found energy to be an important factor of production in a study of six developing countries. In a bivariate relationship between energy consumption and economic growth in African countries, Ricci (2007), in his survey of theoretical work, points out transmission mechanisms through which environmental policy and economic growth may interact. He stated that general environmental policies are deemed to have negative effects on growth. Soytas et al. (2007) investigated the long run Granger causality between carbon emission, energy use, and income in the US. They found no evidence of a causal link between income and carbon emission, and income and energy consumption. Mahadeven and Asafu-Adjaye (2007) found bi-directional causality for some countries while for others they found unidirectional causality running from energy consumption to economic growth.

In a study of over more than one hundred countries, Chontanawat et al. (2008) found that the causal relationship between energy consumption and economic growth is more pronounced in developed countries than in developing countries. Causality running from energy consumption to economic growth was found in only 35% of the poorest nations and in 42% of the middle-income nations, while it was found in 69% of the high-income countries. Similarly, Huang et al. (2008) found no causality between energy consumption and economic growth in low-income countries, while in middle-income and high-income countries they found that economic growth leads in energy consumption. Lee and Chiang (2008) found a long-run causality running from energy consumption to economic growth. Further, for a group of 22 OECD countries, Lee et al. (2008) found a bi-directional relationship among energy consumption, the capital stock and economic growth. In a panel of G7 countries, Narayan and Smyth (2008) found that capital formation and energy consumption Granger-cause real GDP positively in the long run.

Apergis and Payne (2009) found both short-run and long-run causality from energy consumption to economic growth in a panel cointegration test for a group of some Latin American countries. In his study on the G7 countries, Sadorsky (2009) found that real income and carbon dioxide emissions are both important drivers of renewable energy consumption.

2. DATA, EMPIRICAL MODEL AND METHODOLOGY

This paper utilized annual data on energy use (kg of oil equivalent) per capita and real GDP (both in constant 2000 US$) per capita for Bangladesh. We collected the data from the world Development Indicators (WDI) published by the World Bank in 2010. We found 36 observations on each series ranging from 1971 to 2007. All the data used in the paper are expressed in logarithmic form. This transformation can reduce the problem of heteroskedasticity as log transformation compresses the scale in which the variables are measured.

The main objective of this study is to examine the long-run relationship between energy consumption and economic growth for Bangladesh in an ARDL bounds testing approach to cointegration. The studies that sequentially developed this approach include Pesaran and Pesaran (1997), Pesaran and Shin (1999), and Pesaran et al. (2001). There are a number of comparative advantages in the ARDL method which makes it more useful than others. With a small sample size, as is the case with ours, this method is more efficient than other techniques. In contrast, the Johansen cointegration technique, which is due to Johansen and Juselius (1990), requires larger samples for the results to be valid (Ghatak and Siddiki 2001). The simplicity of this ARDL bounds testing method is appealing. As opposed to other multivariate cointegration techniques, it allows the cointegrating relationship to be estimated by the OLS method once the lag order of the model is identified. Johansen's technique requires the variables be integrated of the same order. The ARDL approach does not require the pretesting variables for unit roots. It is applicable irrespective of whether the regressors in the model are purely *I(0)*, purely *I(1)*, or mutually cointegrated.

Thus, a long-run relationship can be established with this technique irrespective of the time series properties of the variables in the model. Even when some of the model regressors are endogenous, the bounds testing approach generally provides unbiased long-run estimates and valid *t*-statistics (Narayan 2005, Odhiambo 2008). Moreover this approach provides a method of assessing the short-run and the long-run effects of one variable on the other simultaneously. At the same time, the ARDL has an appealing separation of short and long-run effects (Bentzen and Ergsted 2001). The long-run relationship can be estimated in the following forms:

$$1) \quad GDP_t = \alpha_1 + \beta_1 ENG_t + \varepsilon_{1t}$$

Where ENG_t denotes energy consumptions, α_1 represents the intercepts and β_1 is representing the coefficient on energy consumptions respectively, and finally ε_t is the error term. In this study, we have used the recently developed ARDL-bounds testing approach in order to examine the long-run cointegration relationship between energy consumptions and output variables. The ARDL modeling approach was originally introduced by Pesaran and Shin (1999) and later extended by Pesaran et al. (2001). To implement the bounds testing procedure, we start by modeling equations (1) as conditional ARDL model:

$$2)\quad \Delta GDP_t = c_1 + \delta_1 trend + \pi_1 GDP_{t-1} + \pi_2 ENG_{t-1} + \sum_{i=1}^{p}\theta_i \Delta GDP_{t-i} + \sum_{i=1}^{p}\phi_i \Delta ENG_{t-i} + u_{1t}$$

Here Δ denotes the first difference operator. c_1 is constant, δ_1 is coefficient on the trend term, and π_1 and π_2 are the coefficients on the lagged levels of the dependent and independent variables, respectively. θ_i and ϕ_i are the coefficients on the lagged dependent and independent variables, respectively. u_1 denotes the error terms, and *p* signifies the maximum lag length, which is decided by the researchers. The researchers usually depend on literature and convention to determine the maximum lag length. As Pesaran et al. (2001) caution, there is a delicate balance between choosing *p* sufficiently large to mitigate the residual serial correlation problem and, at the same time, sufficiently small so that the conditional ECM is not unduly over-parameterized, particularly in view of the limited time series data which are available.

The bounds testing approach involves two stages. In the first step, a long-run relationship between variables under investigation is tested. If cointegration was established, the coefficients of long-run relations were then estimated in the second stage. Following Pesaran et al. (2001), two separate statistics were employed to 'bounds test' for determining the existence of a long-run relationship: an *F*-test for the joint significance of the coefficients of the lagged levels in equation (2) (so that $H_0: \pi_1 = \pi_2 = 0$).

Pesaran et al. (2001) provide lower and upper bound critical values where the lower bound critical values assume all variables are *I(0)* while the upper bound critical values assume all variables are *I(1)*. If the calculated *F*-statistic exceeds the upper bound, the null hypothesis of no cointegration can be rejected. If the calculated *F*-statistic falls below the lower bound, the null hypothesis of no long-term relationship cannot be rejected. However, if the *F*-statistic falls within their respective bounds, inference would be inconclusive. At this stage, it becomes necessary to learn about the time-series properties of the variables before reaching any conclusion. Once *F*-statistic exceeds the upper bound, we verify the *t*-statistic whose distribution is nonstandard. Pesaran et al. (2001) have provided the table with upper and lower bounds of *t*-statistics. The coefficient on the lagged level, π_1, should exceed the upper bound to confirm the long-term relationship of the variables in question.

The next step involves determining the ARDL model with optimal lags. The selection criteria such as Schwarz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) are mainly used to determine the order of the ARDL model. Once the ARDL model with optimal lags has been selected by either the SBC or the AIC, we need to estimate long-run coefficients. The coefficient on the forcing variable must be significant to prove the long-run relationship between the variables under investigation.

Once the long-run relationships have been identified, then the next step is to examine the short-run and long-run Granger-causality using the following models (see Odhiambo 2009a, 2009b, Narayan and Smyth 2008):

$$3)\quad \Delta GDP_t = c_1 + \delta_1 trend + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \phi_i \Delta ENG_{t-i} + ECM_{t-1} + u_{1t}$$

Although the existence of a long-run relationship between GDP and ENG suggests that there must be Granger-causality in at least one direction, it does not indicate the direction of temporal causality between the variables. The direction of the causality in this case can only be determined by the F-statistic and the lagged error-correction term. While the t-statistic on the coefficient of the lagged error-correction term represents the long-run causal relationship, the F-statistic on the explanatory variables represents the short-run causal effect (Odhiambo, 2009a, Narayan and Smyth 2006). It should, however, be noted that even though the error-correction term has been incorporated in the equation (3), only the equation where the null hypothesis of no-cointegration is rejected will be estimated with an error-correction term (Narayan and Smyth 2006, Morley 2006, Odhiambo 2009a). Next we estimate the ECM along with the short-run parameters. The sign of the error correction (EC) coefficient must be negative and significant to ensure convergence of the dynamics to the long-run equilibrium. The value of the EC coefficient, which signifies the speed of convergence to the equilibrium process, usually ranges between negative one and zero: negative one signifies perfect and instantaneous convergence while zero means no convergence after a shock in the process.

3. RESULTS AND DISCUSSION

Table 1 presents the *F*-statistics estimations from equation (2). After deciding on lag length and trend, the issue on the selection of critical values (CVs) becomes imperative. The CVs of the *F*-test depend on sample sizes. The critical value bounds are computed by stochastic simulations using 20000 replications. With 35 observations in our sample, we report 95 percent critical bounds in Table 1 from stochastic simulations using 20000 replications. The test results are clear and robust. While the long-term relationship between energy use and real output does exist indeed and the causality runs from energy consumption to real GDP to be significant, that is also found by the study (Table 2).

Table 1:
Bounds F-test for Cointegration with Energy Consumption and Real GDP.

LHS Variable	Forcing variable	F-statistic	95% Critical Bounds		90% Critical Bounds		Cointegration
			I(0)	I(1)	I(0)	I(1)	
ΔGDP	ENG	12.76*	7.203	8.002	5.946	6.629	Present

* denotes the value that rejects the null of no cointegration at 5% level of significance.
Δ denotes the first order difference operator.

Table 2:
Granger-Causality Tests with Energy Consumption and Real GDP.

Null Hypotheses	*F*-Statistics	p-Values
LE does not Granger Cause LY	30.28*	0.00
LY does not Granger Cause LE	1.54	0.22

* denotes significant at 5% level.

Based on the results in Table 1, we need to proceed only with the ARDL model. Now we need to determine the ARDL model with optimal lags before estimating long-run coefficients on regressors and the EC term. Most studies used either the SBC or the AIC to select their models. Pesaran and Shin (1999) insist on using the SBC for the sake of parsimony. Given our sample size, we also prefer the SBC to the AIC. The long-run coefficients of the selected ARDL models are presented in Table 3.

Table 3:
Long Run Coefficients of ARDL Models.

Lag Selection Criteria	Model	Constant	Trend	ENG(t)
SBC	ARDL(1,0)	13.289* (0.004)	-.004 (0.820)	1.167** (0.026)
AIC	ARDL(1,1)	7.993 (0.114)	-.030 (0.204)	1.786* (0.004)

* and ** indicate significant at the 1% and 5% levels, respectively.
Note: Standard errors are shown in parentheses.

Both cases of the SBC and AIC, ARDL (1, 0) and ARDL (1, 1) model for real GDP equation is robust. The energy coefficients are significant at the 1 and 5 percent level. The coefficient on ENG is about 1.16 (SBC) and 1.78 (AIC), suggesting a long-run response of energy consumption to real output in a positive direction.

Table 4:
Error Correction Representation for the Selected ARDL Models.

Lag Selection Criteria	Model	Δ ENG(t)	ECM(t-1)	Adjusted R^2
SBC	ARDL(1,0)	0.521*	-0.446**	0.56
AIC	ARDL(1,1)	0.469*	-0.488**	0.60

*, and ** indicate significant at the 1% and 5% levels, respectively.
Note: Error Correction Model (ECM) estimation with ΔGDP(t) as dependent variable
ECM [ARDL(1,0):SBC] = GDP - 1.1670*ENG - 13.2897*INPT + .0047687*TREND
ECM [ARDL (1,1):AIC] = GDP - 1.7865*ENG - 7.9934*INPT + .030753*TREND

Table 4 provides the error correction representation of the selected ARDL models. It shows ECM estimations having change in the real GDP as the dependent variable. However, the short-run effects of energy on real GDP are significant. The negative sign on the ECM term confirms the expected convergence process in the long-run dynamics of energy use to real GDP. The coefficient shows 44% or 48% of the last year's disequilibria are corrected in the current year, suggesting a good speed of adjustment in the relationship process following a shock. That means once a shock has occurred, it takes energy the period from 2 to 2.5 years to adjust with real GDP to restore its long-run relation with this variable.

Table 5:
Diagnostic Tests for Serial Correlation.

Test	Statistics	*P*- Value
F-version	F(1, 31) = 0.66	0.42
LM-version	$\chi 2$ (1) = 0.752	0.386

Table 5 presents diagnostic tests associated with the estimations in the Lagrange multiplier test of residual serial correlation. The diagnostic tests suggest that the estimations of the long-run coefficients and the ECM are free from serial correlation. The value of the adjusted R-squared in the vicinity of 50 percent signifies a good fit of the models (Table 4).

Conclusion

The relationship between energy consumption and output is still inconclusive in literature; most studies find that energy has a positive effect on output in the long run. Bangladesh is registering spectacular output growth in the last two decades. As a result, the question as to whether energy use and output maintain a long-term relation has become interesting and important. This study answers to this question by using the ARDL bounds testing approach to cointegration.

Our study finds that energy consumption alone determined long-run movements in output growth in a positive direction in the Bangladesh economy over the last 36 years from 1971 to 2007. Surprisingly, unidirectional causality runs from energy consumption to economic growth in Bangladesh and then restrictions on the use of energy could lead to a reduction in economic growth. The growth hypothesis suggests that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to labour and capital. Consequently, we may conclude that energy is a limiting factor to economic growth and, hence, shocks to energy supply will have a negative impact on economic growth in Bangladesh.

However, there is a convergence process in the long-run dynamics of energy use to real GDP. About 44% to 48% of the last year's disequilibria are corrected in the current year, suggesting a good speed of adjustment in the relationship process following a shock. Here, any shock in energy adjusts with real GDP by 2-2.5 year. But in overall, Bangladesh needs more energy for its growth. The current rate of energy consumption is not enough to meet the demand. Still, a huge power shortage restricts the investment, industrial growth, and socio economic development. A large portion of energy is supplied from wood, animal wastes and crop residues. Government has already stopped to supply gas connection for any new establishments, especially industry. The current reserve of natural gas is also not adequate to provide household necessities. Moreover, it is expected that if new gas field is not explored, the current reserve will be finished by 2016. So, to continue a progressive economic growth, Bangladesh needs to ensure all required energy uses and find alternative sources of energy.

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