# Natural Gas Consumption and Economic Growth: Cointegration, Causality and Forecast Error Variance Decomposition Tests for Pakistan

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26 November 2011

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**Abstract:** This paper examines the relationship between natural gas consumption and economic growth in Pakistan using a multivariate model by including capital and labor as the control variables for the periods of 1972-2009. The results of the ARDL bounds testing indicate the presence of cointegration among the variables. The estimated long-run impact of gas consumption (0.49) on economic growth is greater than other factor inputs suggesting that energy is a critical driver of production and growth in Pakistan. Furthermore, the results of causality test and variance decomposition analysis suggest a unidirectional causality running from natural gas consumption to economic growth. Gas being the primary source of energy in Pakistan, the implications of this study is that natural gas conservation policies could harm growth and, therefore, requires the policy makers to improve the energy supply efficiency as well as formulate appropriate policy to attract investment and establish public-private partnership initiatives.

**Keywords: Natural Gas Consumption, Growth, Pakistan, Cointegration, Causality.**

## 1. Introduction

The issue of energy consumption and growth nexus is examined extensively by scholars due to its potential policy implications[1] (Ozturk et al., 2010). Of recent, growing interest emerged on the issues of the use of natural gas and its relationship to economic growth. In order to meet the Kyoto targets and since natural gas produce less $CO_2$ emissions than other fossil fuels, countries around the world are exploring the policy options to encourage the use of gas as an alternative source (Apergis and Payne, 2010). In average, the world natural gas consumption as a percentage of total energy is around 21% and 23 % in 1990 and 2007 respectively[2]. Likewise, between 2007 and 2035, the total natural gas consumption is expected to grow at 1.8%, in average (EIA, 2010). Similarly, higher demand for electricity also increases the need for natural gas due to the fact that natural gas is an important source of electricity generation[3] (EIA, 2010). Natural gas becomes attractive option since it is more fuel efficient, provides better operational flexibility and lower emission and capital costs. Developing countries that are not likely to attract enough investment[4], including foreign direct investments, for other fuel mix strategies especially nuclear energy resolves to use natural gas as an alternative. The growing need for natural gas as well as its implication for growth requires one to understand the link between them to better inform the policy makers on the available policy options. This is more acute in the case of Pakistan for two main reasons. First, there is a lack of studies examining the long-run relationship as well as the causal link between natural gas consumption and growth to provide sound policy lessons for Pakistan. Second, natural gas has been

[1] If natural gas consumption impacts economic growth directly or accompanied with complement to capital and labor, than energy conservation policy could adversely impact the growth. Investigating both the long run relationship and the causal link provides lesson for future policy direction.
[2] Authors calculation based on the data obtained from EIA (2010)
[3] Based on a projection, electricity generation from natural gas is expected to increase by 2.1% over the year 2007 to 2035 (EIA, 2010).
[4] Pakistan had development plans for hydropower but was discontinued due to difficulties in acquiring foreign investment (EIA, 2010). Pakistan's nuclear power contribution to total energy production is small supplying only 2.34% of the country's electricity (World Nuclear Association, http://www.world-nuclear.org/info/inf108.html).

a dominant fuel[5] in Pakistan accounting for almost 47 percent of primary energy demand in 2007. Since 2000, natural gas and petroleum were considered the main sources of energy that was, in average, 50 percent and 29 percent of total energy consumption in Pakistan (Pakistan Energy Yearbook, 2005). The consumption of petroleum products had decreased due to hike in petroleum prices while the nature of transportation is increasingly been converted to the use of compressed gas. This has resulted in rise in natural gas consumption in the country. Furthermore, government had also made efforts to encourage the local compressed gas (CNG) and liquefied petroleum gas (LPG) for the consumption in the transport, agriculture, and power sectors due to high costs of imported oil. Transport and the power sectors account for nearly 51% and 40% of the overall gas consumption (GoP[6], 2008-09). It also offers the cheapest and relatively cleaner alternative source of energy for the sectors. In this aspects diversifying fuel mix is not only the priorities at country level but also at sectoral level especially among power consuming firms. The above description provides a rational to investigate the impact of natural gas consumption on economic growth and the direction of causal relationship between natural gas consumption and economic growth.

Furthermore, existing studies on natural gas consumption and growth is limited (Apergis and Payne, 2010) and consensus on the potential links are still mixed (Lee and Chang, 2005; Zamani, 2007; Sari et al., 2008). Indeed, Karanfil, (2009) argued on the need for consistent results for policy makers to make sense of the future policy directions for their respective countries. It was further recommended that novel methods using the recent econometric tools that are appropriate to examine the energy-growth nexus be implemented to provide consistent results for policy makers.

In the case of Pakistan, to our best of knowledge, only four studies (Zahid, 2008; Aqeel and Butt, 2001; Siddiqui, 2004; Khan and Ahmed, 2009) are available and they ignored investigating the

[5] In last 20 years, energy consumption has been tripled from 0.6 Btu (quadrillion British thermal units) in 1980 to 1.9 quadrillion Btu in 2001 due to rising demand which was the result of consistent rise in per capita income.
[6] Government of Pakistan

dynamic relationship between gas consumption and economic growth. In addition, most of these studies relied on bivariate models to establish the causality between gas consumption and economic growth. The investigation is still limited by the model specification issues as well as the use of inappropriate estimation techniques. Lütkepohl (1982) indicated that exclusion of other relevant variables contributes to biasness and inconsistent results. Inclusion of the control variables of growth such as capital and labor and estimating a multivariate model helps provide more reliable evidence about the causal relation among the variables (Loizides and Vamvoukas, 2005). Likewise, most studies also uses unit root test such as Augmented Dicky-Fuller (ADF) that is perceived less reliable (Shahbaz et al. 2010c). For instance, Dejong et al, (1992) and, Harris and Sollis (2003) contended that due to their poor size and power properties, ADF test is unreliable for small sample data set. Moreover, ADF test seems to over-reject the null hypotheses when it is true and accepts it when it is false. In this paper, we used three different unit-root tests. In addition, although it is acknowlegde that determing series as $I(0)$ and $I(1)$ is difficult due to power deficiency inherented in classical unit root test, the use of ARDL model[7] will be able to mitigate this problem as the approach does not require pre-testing for unit root. According to Rahbek and Mosconi (1999), although Johansen's approach allows a mixture of I(0) and I(1) variables, the procedure for the cointegration rank can be sensitive to the presence of stationary variables.

This paper intends to overcome the limitations[8] discussed above by offering a more robust specification with the inclusion of control variables using multivariate framework as well as a country specific evidence. The use of recent estimation technique known as Auto Regressive Distributed Lag (ARDL) bounds testing as well as vector error correction method, variance decomposition and impulse response function allows us to check the robustness of the results. The

[7] Although Johansen's approach can deal with the issue, the cointegration rank can still be sensitive to the presence of stationary series (Rahbek and Mosconi, 1999)
[8] Details of limitation are offered by Jinke et al. (2008) and Wolde-Rufael, (2010).

ARDL approach is known to offer the following advantages. It yields consistent long-run estimates even when the right hand side variables are endogenous (Inder, 1993). Using appropriate order of the ARDL model, it is possible to simultaneously correct for (i) serial correlation in residuals and (ii) the problem of endogenous regressors (Pesaran and Shin, 1999). Indeed, it is a preferred cointegration technique due to its robustness for studies using small sample size[9] and it allows the variables to have different optimal lags. The approach is also valid regardless of whether a series is $I(0)$ or $I(1)$. Similarly, Vector Error Correction Model (VECM) Granger causality allows the examination of long and short-run causality while innovative accounting technique (forecast error variance decomposition and impulse response function) allows reinforcing and confirming the direction of causality of the VECM. In addition, country specific evidence of this study allows us to mitigate the shortcomings of cross country analysis (see Sari and Soytas, 2009; Chang et al., 2001; Stern, 2000). Chandran et al. (2010) indicates that country specific studies allow one to take into account the institutional, structural and policy reform more specifically. Indeed, it offers more room to discuss the policy implication for the country under study. The present paper fills this gap in energy literature by examining nature of direction of causality between natural gas consumption and economic growth in case of Pakistan over the period of 1971-2009 by including capital and employment.

## 2. Literature Review

A number of recent time series studies have examined the direction of causality between both the variables in different countries (both developed and developing countries) using various cointegration and causality approaches. For example, Yu and Choi (1985) for UK, US and Poland,

[9] In the energy literature, a large number of studies involving relatively small sample size have utilised ARDL-bounds testing procedure.

Yang (2000b) and Lee and Chang (2005) for Taiwan, Ewing et al. (2007), Sari et al. (2008) and Hu and Lin (2008) for US, Zamani (2007) and Amadeh et al. (2009) for Iran, Reynolds and Kolodziej (2008) for Soviet Union, Adeniran (2009) and Clement (2010) for Nigeria, Fatai et al. (2004) for New Zealand and Australia, and Apergis and Payne (2010) for 67 countries. Table 1 summarizes the main findings of these empirical works. Review of relevant literature highlights two important issues. First, evidence is mixed and is less country specific. Likewise, estimation techniques are less appropriate in some of the studies that used small sample size. Indeed, examining the link using bivariate models is subjected to omitted variable biasness. As Lütkepohl (1982) indicated that exclusion of relevant variables makes the results inconsistent and more often no causal relationship can be found between natural gas consumption and economic growth. Second, the estimation periods are not current leading to lack of knowledge on the links between the two variables in the presents of new developments in energy outlooks. Inclusion of this time periods is crucial so that appropriate policy can be suggested. For instance, due to global crisis and the recent development in climate change agendas, fuel mix policy has drastically change and, therefore, without the inclusion of this time periods, results of the previous studies might be invalid, if not less accurate.

## Table 1: Summary on the relationship between Gas Consumption and Economic Growth[10]

| Authors | Countries | Sample Period | Methodology | Variables | Cointegration | Causation |
|---|---|---|---|---|---|---|
| **Single-Country Studies** | | | | | | |
| Yang (2000b) | Taiwan | 1954-1997 | GC | Real GDP, Natural Gas Consumption | No | G → Y |
| Aqeel and Butt (2001) | Pakistan | 1955-1996 | GC by Hsiao | Real GDP, Natural Gas Consumption | No | Y × G |
| Siddiqui (2004) | Pakistan | 1970-2003 | ADL, GC by Hsiao | Real GDP, Natural Gas Consumption | N.A | Y × G |
| Lee and Chang (2005) | Taiwan | 1954-2003 | JML, WE, | Real GDP per Capita, Natural Gas Consumption | Yes | G → Y |
| Ewing et al. (2007) | US | 2001:1–2005:6 | VARGFEVD | Industrial Production, Natural Gas Consumption | N.A | G → Y |
| Zamani (2007) | Iran | 1967-2003 | JML, VECM | Real GDP, Natural Gas Consumption | Yes | G ↔ Y |
| Sari et al. (2008) | US | 2001:1–2005:6 | ARDL, VECM | Industrial Production, Natural Gas Consumption | Yes | G ← Y |
| Hu and Lin (2008) | Taiwan | 1982:1 to 2006:4 | Hansen and Seo, VECM | Real GDP, Natural Gas Consumption | Yes | G ↔ Y |
| Reynolds and Kolodziej (2008) | Soviet Union | 1928–1987, 1988–1991, 1992–2003 | GC | Real GNP, Natural Gas Consumption | N.A | G → Y |
| Adeniran (2009) | Nigeria | 1980-2006 | GC by Sims | Rea GDP, Natural Gas Consumption | Yes | G ← Y |
| Amadeh et al (2009) | Iran | 1973-2003 | ARDL, VECM | Real GDP, Natural Gas Consumption | Yes | G ← Y |
| Clement (2010) | Nigeria | 1970-2005 | JML, VECM | Real GDP, Natural Gas Consumption | Yes | G → Y |
| **Multi-Country Studies** | | | | | | |
| Yu and Choi (1985) | UK | N.A | GC by Sims | Real GNP, Natural Gas Consumption | N. A | G ← Y |
| | US | | | | N. A | Y × G |
| | Poland | | | | N. A | Y × G |
| Fatai et al. (2004) | New Zealand | 1960-1999 | ARDL, JML, TY | Real GDP, Natural Gas Consumption | No | Y × G |
| | Australia | | | | Yes | Y × G |
| Zahid (2008) | Pakistan | 1971-2003 | TY | Real GDP per Capita, Gas Consumption | Yes | Y × G |
| | Bangladesh | | | | No | G → Y |
| | India | | | | No | Y × G |
| | Nepal | | | | No | Y × G |
| | Sri Lanka | | | | No | Y × G |
| Apergis and Payne (2010) | 67 Countries | 1992-2005 | Pedroni's (1999, 2000)[11] | Real GDP, Natural Gas Consumption, Labor, Real capital | Yes | G ↔ Y |

Notes: Y and G represent economic growth and natural gas consumption. Y→ G indicates a unidirectional causality running from economic growth to natural gas consumption and G → Y is from natural gas consumption to economic growth. G ↔ Y indicates bidirectional causality and Y × G indicates no causal relationship. N. A means not applied. GC, VARGFEVD, JML, WE, VECM, ARDL and TY means Granger causality, Vector Autoregression Generalized Forecast Error Variance Decomposition, Johansen's Maximum Likelihood, weak exogeneity test, Vector Error Correction Method, Autoregressive Distributed Lag Model to Cointegration and Toda and Yamamoto (1995) causality test.

[10] Extracted from Saten and Shahbaz (2010)
[11] Panel cointegration

Search of literature indicates that large number of studies in the context of Pakistan examines the link between total energy consumption and growth12 with limited studies concentrating on natural gas consumption. Therefore, despite its importance to the economic development, the empirical evidence on the causality between natural gas consumption and economic growth in Pakistan is less explored and limited. Recently, Khan and Ahmed (2009) examined the demand for gas, electricity and coal consumption using Johansen and Juselius (1990) cointegration methodology in a multivariate framework by including per capital income and price level. The results suggest the existence of a long-run relationship between gas consumption, income per capita and price. In the long-run, income and price exerts positive and negative impact on gas consumption in Pakistan respectively. However, the price level is found to be insignificant. They concluded that gas consumption is more responsive to income change in the long-run. However, except for electricity and coal consumption, the study did not examine the causality between gas consumption, income and price level.

Aqeel and Butt (2001) also examined causality between energy consumption (petroleum, electricity and gas), energy price and economic growth for Pakistan. They fail to find any causality between natural gas consumption and economic growth. Their empirical exercise only showed unidirectional causality from economic growth to petroleum consumption and electricity consumption to economic growth. Likewise, Zahid (2008) using the Toda and Yamamoto (1995) examined the causal relationship between natural gas consumption and economic growth in Pakistan, India, Sri Lanka, Bangladesh and Nepal over the period of 1971-2003. In the case of Pakistan, there is no

[12] Masih and Masih (1996), Hye and Riaz (2008) and Saten and Shahbaz (2010) reported bidirectional causality between energy consumption and economic growth in Pakistan, while Khan and Qayyum (2007) and Imran and Siddiqui (2010) found unidirectional causality running from energy consumption to economic growth in SAARC including Pakistan. Finally Noor and Siddiqui (2010) concluded that rise in income per capita Granger caused energy consumption in South Asian countries namely Pakistan, Bangladesh, India, Nepal and Sri Lanka.

causal relation between natural gas consumption and economic growth. Siddiqui (2004) also reported the absence of causal relationship between natural gas consumption and economic growth. They concluded that gas consumption is less important for both economic and productivity growth in Pakistan. We can conclude, on the basis of previous studies regarding Pakistan, that most of empirical evidence on the direction of causality between natural gas consumption and economic growth is based on bivariate analysis and the results may not be robust enough. In addition, the dynamic relationship between gas consumption and economic growth is ignored. In this study, we intend to revisit the link between natural gas consumption and economic growth using a more recent cointegration methodology and explore the dynamics relationships between the variables.

## 3. Methodology

### 3.1 Model Specification and Data

Recent empirical studies such as Stern, (2000); Ghali and El-Sakka, (2004); Beaudreau, (2005); Sari and Soytas, (2007); Lee and Chang, (2008); Yuan et al. (2008) and Wolde-Rufael, (2006) used the production function framework to examine the causal relationship between energy consumption and economic growth. Following existing literature, conventional neo-classical production model was used where gas consumption, capital and labor are treated as separate factor inputs as given below:

$$Y_t = f(K_t, L_t, G_t) \qquad (1)$$

Where $Y$ is real GDP, $K$ is real capital stock, $L$ is labor and $G$ is natural gas consumption. Following Lean and Smyth (2010), all variables were divided by population and expressed in per capita terms. Therefore, $L_t$ represents labor force participation rate. We used log-linear specification of Equation

1. The log-linear specification provides superior results than simple linear specification. Bowers and Pierce (1975) have criticized the findings of Ehrlich's (1975) based on functional form of empirical model. Furthermore, Ehrlich (1977) and Layson (1983) have argued on basis of the theory and empirical evidence that log-linear functional form provides better results as compared to linear specification[13]. In case of Pakistan, Shahbaz (2010) has proved that log-linear specification provides superior results than simple linear specification. This study covers the period of 1972 to 2009. The data on gas consumption, real GDP, real capital and employment were obtained from GoP (2009-10)[14].

### 3.2 Estimation Techniques

#### 3.2.1 ARDL Bounds Testing Approach to Co integration and Granger Causality

This paper follows the ARDL bounds testing approach to cointegration developed by Pesaran et al. (2001) to examine the long-run relationship between economic growth, natural gas consumption, real capital and employment in the case of Pakistan. There are certain advantages of this approach. First, the short and long-run parameters are estimated simultaneously. Secondly, it can be applied irrespective of whether the variable are integrated of order zero *I(0)* or integrated of order one *I(1)*. Thirdly, it has better small sample properties (Smyth and Narayan, 2004). ARDL approach involves estimating the following unrestricted error correction model as follows:

[13] See for more details (Shahbaz, 2010)
[14] CPI was used to convert the series into real term.

$$\Delta Y_t = \varphi_{y0} + \varsigma_y T + \pi_{y1} Y_{t-1} + \pi_{y2} K_{t-1} + \pi_{y3} L_{t-1} + \pi_{y4} G_{t-1} + \sum_{i=1}^{p} \lambda_{iy} \Delta Y_{t-i} + \sum_{j=0}^{p} \gamma_{iy} \Delta K_{t-j} + \sum_{i=0}^{p} \alpha_{iy} \Delta L_{t-i} + \sum_{i=0}^{p} \beta_{iy} \Delta G_{t-i} + \varepsilon_{1t} \tag{1.1}$$

$$\Delta K_t = \varphi_{k0} + \varsigma_k T + \pi_{k1} K_{t-1} + \pi_{k2} Y_{t-1} + \pi_{k3} L_{t-1} + \pi_{k4} G_{t-1} + \sum_{i=1}^{p} \lambda_{ik} \Delta K_{t-i} + \sum_{j=0}^{p} \gamma_{ik} \Delta Y_{t-j} + \sum_{i=0}^{p} \alpha_{ik} \Delta L_{t-i} + \sum_{i=0}^{p} \beta_{ik} \Delta G_{t-i} + \varepsilon_{2t} \tag{1.2}$$

$$\Delta L_t = \varphi_{l0} + \varsigma_l T + \pi_{l1} L_{t-1} + \pi_{l2} Y_{t-1} + \pi_{l3} K_{t-1} + \pi_{l4} G_{t-1} + \sum_{i=1}^{p} \lambda_{il} \Delta L_{t-i} + \sum_{j=0}^{p} \gamma_{il} \Delta Y_{t-j} + \sum_{i=0}^{p} \alpha_{il} \Delta K_{t-i} + \sum_{i=0}^{p} \beta_{il} \Delta G_{t-i} + \varepsilon_{3t} \tag{1.3}$$

$$\Delta G_t = \varphi_{g0} + \varsigma_g T + \pi_{g1} G_{t-1} + \pi_{g2} Y_{t-1} + \pi_{g3} K_{t-1} + \pi_{g4} L_{t-1} + \sum_{i=1}^{p} \lambda_{ig} \Delta G_{t-i} + \sum_{j=0}^{p} \gamma_{ig} \Delta Y_{t-j} + \sum_{i=0}^{p} \alpha_{ig} \Delta K_{t-i} + \sum_{i=0}^{p} \beta_{ig} \Delta L_{t-i} + \varepsilon_{4t} \tag{1.4}$$

Where, $\Delta$ is the first difference operator; $\varphi_{j0}$ is the constant; $\pi_s$ are the long-run coefficients; $\lambda, \gamma, \alpha, \beta$ represent short-run dynamics and $\varepsilon_t$ is the random variable which is assumed to be white noise. *T* represents the time trend. The optimal lag structure under ARDL approach is determined by estimating $(p+1)^k$ regressions for each equation, where *p* is the maximum number of lags and $k$ is the number of variables in the equation. The optimal lag structure is determined by making use of Schwartz-Bayesian Criteria (SBC) or Akaike Information Criteria (AIC). We used AIC to ensure that the residuals do not suffer from the problem of significant serial correlation.

The asymptotic distributions of the test statistics are non-standard regardless of whether the variables are *I(0)* or *I(1)*. Two separate bounds test are available to examine the presence of long-run relationship among the variables of interest: a Wald or *F*-test for the joint null hypothesis $\pi_1 = \pi_2 = \pi_3 = \pi_4 = 0$, (referred to as $F_Y(Y/G, K, L)$ for Equation 1.1) and a *t*-test on the lagged level dependent variable (so that $H_0$: $\pi_1 = 0$). Since the asymptotic distribution of Wald or *F* statistics is non-standard, one can use the critical bounds values provided by Pesaran et al. (2001). Pesaran et al. (2001) have computed two asymptotic critical values - one when the variables are assumed to be *I(0)* and the other when the variables are assumed to be *I(1).* These are respectively known as the lower critical bound (LCB) and the upper critical bound (UCB). Following Pesaran et al. (2001), if the test statistic exceeds the corresponding UCB then there is evidence of a significant long-run relationship. Alternatively, if the test statistic is below the LCB then the null hypothesis cannot be rejected. In addition, if the sample test statistic falls between these two bounds then the result is inconclusive. In such case, error correction method is appropriate method to investigate the cointegration (Bannerjee et al. 1998). This indicates that error correction term will be a useful way of establishing cointegration. However, critical values of Pesaran et al. (2001) may not be suitable for small sample studies like ours that have only 37 observations. We, therefore, computed critical values using surface response procedure proposed by Turner (2006). To examine the stability of the ARDL bounds testing approach to cointegration, stability tests namely CUSUM and CUSUMSQ have been applied (Brown et al. 1975).

The long-run relationship can be estimated using the selected ARDL model. For example, if variables are cointegrated in equation (1.1), where *Y* is used as the dependent variable then there is a stable long-run level relationship among the variables, which can be described as follows:

$$Y_t = \Phi_0 + \Phi_1 K_t + \Phi_2 L_t + \Phi_3 G_t + \mu_t \qquad (1.5)$$

where $\Phi_0 = -\varphi_{y0} / \pi_{y1}, \Phi_1 = -\pi_{y2} / \pi_{y1}, \Phi_2 = -\pi_{y3} / \pi_{y1}, \Phi_3 = -\pi_{y4} / \pi_{y1}$ and $\mu_t$ is the usual error term. These long-run coefficients are estimated by the ARDL approach to cointegration. The same process can be used when other variables are used as a dependent variable. Given the existence of long-run relationship among variables, an error correction representation can be developed as follows:[15]

$$(1-L)\begin{bmatrix} Y \\ K \\ L \\ G \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11i} b_{12i} b_{13i} b_{14i} \\ b_{21i} b_{22i} b_{23i} b_{24i} \\ b_{31i} b_{32i} b_{33i} b_{34i} \\ b_{41i} b_{42i} b_{43i} b_{44i} \end{bmatrix} + \begin{bmatrix} \theta \\ \vartheta \\ \varphi \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \tag{1.6}$$

where $(1-L)$ is the difference operator; $ECT_{t-1}$ is the lagged error-correction term derived from the long-run cointegrating relationship; and $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}$ and $\varepsilon_{4t}$ are serially independent random errors with mean zero and finite covariance matrix. The presence of a significant relationship in first differences of the variables provides evidence on the direction of the short-run causation while a significant *t*-statistic pertaining to the error correction term (*ECT*) suggests the presence significant long-run causation. However, it should be kept in mind that the results of the statistical testing can only be interpreted in a predictive rather than in the deterministic sense. In other words, the causality has to be interpreted in the Granger sense. In addition, to unveil the nature of the feedback effects among the variables, we further applied the variance decomposition method and response function to check for the robustness of the results and to gain more insights on the complexity of the relationships.

## 4. Empirical Results

Although pre-testing for non-stationarity of the series is not necessary for the ARDL bounds test, we still conducted the test to check that none of series is *I*(2) or higher in which case it can complicate the *F*-test (Ouattara, 2004). In doing so, we used three unit root tests i.e. Augmented Dicky-Fuller (ADF), Phillip-Perron (PP) and Augmented Dickey-Fuller Generalized Least Squares (ADF-GLS). Additionally, it also serves as a robustness check on the stationarity of the series. For instance, DF-GLS unit root test is preferred as the results tend to be more reliable and consistent as compared to the ADF and PP unit root tests (Elliot et al. 1996). The results are reported in Table 2. The results show that GDP (*Y*), natural gas consumption (*G*), real capital (*K*) and employment (*L*)

[15] If cointegration is not detected, the causality test is performed without an error correction term (*ECT*).

are nonstationary at their levels. The empirical evidence confirmed that all the four macroeconomic variables are integrated of order $I(1)$.

**Table 2: The Results of Unit Root Tests**

| Variables | ADF (with trend) | PP (with trend) | DF-GLS (with trend) |
|---|---|---|---|
| $\ln Y_t$ | –1.4110(1) | –1.5787(4) | –1.4571(1) |
| $\Delta \ln Y_t$ | –4.3216(0)*** | –4.4607(3)*** | –4.4120(0)*** |
| $\ln G_t$ | –2.7303(0) | –2.6125(1) | –2.5631(0) |
| $\Delta \ln G_t$ | –8.2814(0)*** | –8.1571(2)*** | –8.1757(0)*** |
| $\ln K_t$ | –1.6737(1) | –1.5122(3) | –1.8960(1) |
| $\Delta \ln K_t$ | –3.9841(0)** | –3.9804(2)** | –4.1042(0)*** |
| $\ln L_t$ | –0.7263 (1) | –1.3083 (1) | –1.8161 (0) |
| $\Delta \ln L_t$ | –8.1053 (0)*** | –8.1053 (0)*** | –8.3321 (0)*** |

Note: The asterisks *** and ** denote the significant at %1 and 5% levels, respectively. The figure in the parenthesis is the optimal lag structure for ADF and DF-GLS tests, bandwidth for the PP unit root test is determined by the Schwert (1989) formula.

The long-run relationship between the variables is investigated through the ARDL bound testing approach to cointegration using Equations (1.1 – 1.4). The results are reported in Table 3. The calculated $F$-statistics (6.771) is greater than UCB at 5% level of significance when $Y$ serves as the dependent variable. It suggests that $G$, $K$ and $L$ are long-run forcing variables in equation 1.1. Therefore, we can reject the null hypothesis of no cointegration when Y serves as the dependent variable. In contrast, the computed $F$-statistic (6.159) is lower than UCB when natural gas consumption is considered as the dependent variable. Similarly, the computed $F$-statistics (3.590 and 5.302) are less than UCB when $K$ and $L$ are considered as endogenous variables respectively.

**Table 3: Results of Cointegration Test**

| Panel I: Bounds Testing to Cointegration | | | | |
|---|---|---|---|---|
| Estimated Model | $F_Y(Y/G,K,L)$ | $F_G(G/Y,K,L)$ | $F_K(K/Y,G,L)$ | $F_L(L/Y,G,K)$ |
| Optimal Lag Length | [2, 2, 1, 2] | [2, 2, 2, 2] | [2, 1, 2, 2] | [2, 2, 2, 2] |
| *F*-Statistics | 6.771** | 6.159*** | 3.590 | 5.302 |
| | Critical values ($T = 37$)# | | | |
| | Lower bounds $I(0)$ | Upper bounds $I(1)$ | | |
| 1 per cent level | 7.397 | 8.926 | | |
| 5 per cent level | 5.296 | 6.504 | | |
| Panel II: Diagnostic tests | | | | |
| $R^2$ | 0.8273 | 0.8421 | 0.8149 | 0.7716 |
| Adjusted- $R^2$ | 0.6648 | 0.6744 | 0.6408 | 0.5289 |
| F-statistics | 5.0917*** | 5.0218*** | 4.6800*** | 3.1800*** |
| J-B Normality test | 0.4760 (0.7881) | 0.3240 (0.8504) | 0.5033 (0.7774) | 4.1068 (0.1282) |
| Breusch-Godfrey LM test | 1.7735 (0.2016) | 1.9600 (0.1776) | 1.0465 (0.3754) | 1.4906 (0.2589) |
| ARCH LM test | 0.9063 (0.3485) | 2.8042 (0.1041) | 0.0689 (0.7947) | 1.8497 (0.1836) |
| White Heteroscedisticity test | 1.8197 (0.1156) | 1.7908 (0.1253) | 0.5668 (0.8685) | 1.6451 (0.1628) |
| Ramsey RESET | 0.5449 (0.4711) | 0.9351 (0.3489) | 3.4270 (0.0468) | 5.1031 (0.0120) |
| CUSUM | Stable | Stable | Stable | Stable |
| CUSUMSQ | Stable | Stable | Stable | Stable |

Note: The asterisks ** and ***denotes the significant at 5% and 10% level respectively. The optimal lag structure is determined by AIC. The parenthesis ( ) is the prob-values of diagnostic tests. # Critical values were computed by surface response procedure developed by Turner (2006).

Since there is evidence of cointegration when *Y* serves as the dependent variable, it is possible to estimate the long-run impact of *G* on *Y*. The long-run coefficients derived from the ARDL model are reported in Table 4. The results reveal that *G* has positive impact on *Y* and it is significant at 1 percent significance level. These findings are consistent with Apergis and Payne (2010), in the case of 67 economies including Pakistan, but contradict with the views of other studies using Pakistan as a case[16]. The results posit that a 1 percent increase in *G* increases *Y* by 0.4913 percent. Similarly, an increase in *K* is linked positively to *Y* and it is significant at 1 percent significance level. This empirical evidence is consistent with the argument by Arby and Batool (2007) that *K* also plays an important role in economic growth. Therefore, ignoring the influence of *K* and estimating the model

[16] It should be noted that other studies use bivariate model to check the impact of natural gas consumption on economic growth.

in a bivariate framework may lead to biasness. A 1 percent increase in *K* increases *Y* by 0.406 percent. However, the result seems to suggest that among the input factors the influence of *G* is greater than *K* and *L*. This confirms that Pakistan is an energy-dependent country and any distortion to its natural gas supply would definitely impact the economic growth significantly. With the growing demand for gas, which is expected to outpace its gas production, new initiatives in terms of new exploration as well as import options is needed. More importantly, any attempt by the government in introducing conversation policy would harm the economic progress. Unless if there is a substitution effects[17] (Smyth et al, 2011) between energy and capital or labor, any shortage in energy supply or price increase would definitely impact the economic growth in Pakistan.

**Table 4: The Long Run Results**

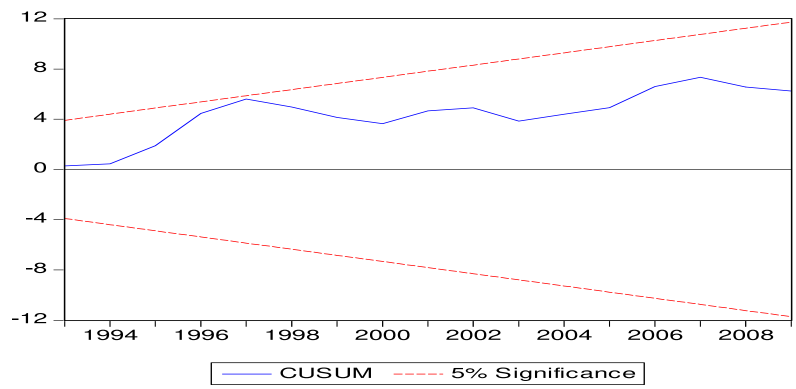
| Variable | Coefficient | *t*-Statistic |
|---|---|---|
| Constant | -50.2465 | -3.0066* |
| $\ln G_t$ | 0.4913 | 21.9474* |
| $\ln K_t$ | 0.4063 | 8.5839* |
| $\ln L_t$ | 0.1329 | 3.6720* |
| J-B Normality Test | 2.3306 (0.3118) | |
| Breusch-Godfrey LM Test | 0.5283 (0.5948) | |
| ARCH LM Test | 1.3418 (0.2548) | |
| White Heteroskedasticity | 1.2772 (0.2983) | |
| Ramsey RESET | 0.8309 (0.3688) | |

The diagnostic tests imply that error term is normally distributed and there is no serial correlation in the model. There is no sign of existence of autoregressive conditional heteroskedasticity. The

[17] It is possible that certain types of capital investment may reduce the need for energy use e.g. investment in energy efficient machinery. In the case of Pakistan we did not extend the study to examine the substitution effects. However, to be certain that the independent variables do not exhibit any problems of multicollinearity, we examined the correlation matrices and the variance inflation factors (VIF). The value of VIF is less than 10 suggesting that there is no problem of multicollinearity. Since our estimates are at aggregate level and does not use any particular types of capital or sectoral analysis, it is possible not to detect high correlations between capital and energy use. Consequently, the problem of serious multicollinearity involving gas consumption, capital and labor can be mitigated as ARDL is known to yield consistent long-run estimates even when the right hand side variables are endogenous (Inder, 1993). Pesaran and Shin (1999) proved that it is possible to correct for serial correlation in residuals and the problem of endogenous regressors using appropriate order of the ARDL model.

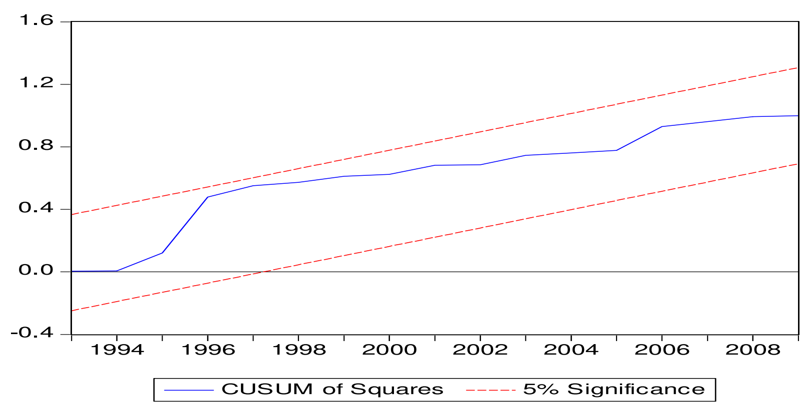
Ramsey RESET estimates show that functional form of the model is well specified. Furthermore, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) revealed that our selected ARDL model is stable (see Figures 1 and 2).

**Figure 1: Plot of Cumulative Sum of Recursive Residuals**




The straight lines represent critical bounds at 5% significance level.

**Figure 2: Plot of Cumulative Sum of Squares of Recursive Residuals**




The straight lines represent critical bounds at 5% significance level.

Although *K*, *L* and *G* appear to be the long-run forcing variables based on cointegration test in equation 1.1, the direction of causality is less clear. In this aspect, the evidence of cointegration is only a necessary but not sufficient condition for rejecting Granger non-causality. The presence of cointegrating among the variables leads us to perform the Granger causality test to provide more insights on the direction of causality. It is important to select the appropriate lag length in order to avoid spurious regression. We employed a combination of AIC, SBC, and likehood ratio (LR) test in order to select appropriate lag length for the VAR. In addition, we checked to see that the selected lags pass the usual diagnostic tests to ensure that the classical regression assumptions are not violated. We find no serious violation of the autocorrelation, normality and heteroscedasticity assumptions. Table 5 shows the results of the optimum lag length selection. Since the lag length orders are different between AIC and SBC, we relied on LR test to choose the appropriate lag length (Pesaran and Pesaran, 1997). The optimum lag length chosen is 2 based on the LR test.

**Table 5: Test Statistics and Choice Criteria for Selecting the Order of the VAR Model**

| Lag | Log-likelihood | AIC | SBC | LR test | Adjusted LR test |
|---|---|---|---|---|---|
| 3 | 354.94 | 298.94 | 255.39 | - | - |
| 2 | 328.33 | 288.33 | 257.23 | CHSQ( 16)= 53.219 [.000] | CHSQ( 16)= 31.93[.010] |
| 1 | 308.10 | 284.10 | 265.43 | CHSQ( 32)= 93.691 [.000] | CHSQ( 32)= 56.21[.005] |

The results of Granger causality is reported in Table 6. The causality can be performed for the short-run and long-run. The long-run causality can be tested by examining the significance of coefficient of the one period lagged error-correction term ( $ECT_{t-1}$ ) using *t*-test. Similarly, the short-run causality can be detected by examining the joint significance of the lagged explanatory variables in the equations. Our empirical results suggest that the $ECT_{t-1}$ is negative and statistically significant when *Y* serves as a dependent variable. The coefficient of $ECT_{t-1}$ implies that deviations from short-run to long-run equilibrium in the current to future period are corrected by about 38% per year. The results indicated uni-directional causal relationship running from *G* to *Y* in the long-run and short-run. These findings are consistent with Yang (2000b) and Lee and Chang (2005) for Taiwan, Ewing et al. (2007) for US, Reynolds and Kolodziej (2008) for Former Soviet Union and Clement (2010) for Nigeria while contradict with the empirical evidence by Apergis and Payne

(2010)[18], Khan and Ahmed (2009), Zahid (2008), Siddiqui (2004) and Aqeel and Butt (2001) in the case of Pakistan. *K* also Granger caused *Y* in both long-run and short-run. The unidirectional causality was also found running from *L* to *Y* in long-run but not in the short-run. In contrast, *Y*, *K* and *L* did not Granger cause *G* in the short-run. Our major focus was to detect causality between *G* and *Y* that is unidirectional running from *G* to *Y*. This confirms that energy (natural gas) conservation policies may retard the rate of economic growth in the country.

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[18] They found bidirectional causal relationship between gas consumption and economic growth while Khan and Ahmed (2009), Zahid (2008), Siddiqui (2004) and Aqeel and Butt (2001) reported absence of any causality between the said variables.

**Table 6: Results of Granger Causality**

| Dependent variable | Type of Granger causality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Short-run | | | | Long-run | Joint (short and long-run) | | |
| | $\Delta \ln Y_t$ | $\Delta \ln G_t$ | $\Delta \ln K_t$ | $\Delta \ln L_t$ | $ECT_{t-1}$ | $\Delta \ln G_t, ECT_{t-1}$ | $\Delta \ln K_t, ECT_{t-1}$ | $\Delta \ln L_t, ECT_{t-1}$ |
| | *F*-statistics [p-values] | | | | (*t*-statistics) | *F*-statistics [p-values] | | |
| $\Delta \ln Y_t$ | – | 4.9192** [0.0151] | 3.4328** [0.0470] | 1.3247 [0.2826] | –0.3856*** (–5.1722) | 10.1160*** [0.0001] | 10.8388*** [0.0001] | 11.9457*** [0.0000] |
| $\Delta \ln G_t$ | 2.4530 [0.1049] | – | 0.0935 [0.9109] | 1.4751 [0.2465] | | | | |
| $\Delta \ln K_t$ | 2.1573 [0.1345] | 0.7134 [0.4986] | – | 0.5947 [0.5585] | | | | |
| $\Delta \ln L_t$ | 0.0119 [0.9881] | 0.8821 [0.4251] | 1.1236 [0.3393] | – | | | | |

Note: The asterisks ***, and ** denote the significant level at the 1 and 5 per cent respectively.

The Granger causality tests do not determine the relative strength of causality effects beyond the selected time span (Wolde-Rufael, 2009). It implies that causality tests are inappropriate because these tests are unable to indicate on how much feedback exist from one variable to the other. For this reason, we employed the generalized forecast error variance decomposition approaches proposed by Pesaran and Shin (1999). Contrasting the orthogonalized approach of Sims (1980), this approach are not sensitive to the order of the variables in the vector autoregressive and allows for more reliable estimates of the variance of a variable due to shocks of another variable in the same system of simultaneous equation. Generalized forecast error variance decompositions are based on the estimation of the moving-average representation of the original VAR (Pesaran and Pesaran, 1997).

The generalized forecast error variance decomposition indicates the influence of a shock in one variable that is explained by the shocks of the other variable. As the study's main motive is to investigate the interrelationship between natural gas consumption and economic growth, we only decompose the forecast-error variance of economic growth and natural gas consumption. Table 7 reports the results of the generalized forecast error variance decomposition. The results confirm that there is a uni-directional causality running from natural gas consumption to economic growth. The forecast variance of natural gas consumption explains more than 34% in horizon 1 and increases to around 60-70% in the long-run. Likewise, economic growth is also predominantly explained by its own variance. However, the influence seems to decline over a longer time horizon. In contrast, forecast-error variance of natural gas consumption economic growth is mainly explained by itself. The forecast-error variance of economic growth explains 16% of the forecast-error variance of natural gas consumption.

**Table 7: Generalized Forecast Error Variance Decomposition**

| | Variance Decomposition of $\ln Y_t$ | | | | Variance Decomposition of $\ln G_t$ | | | |
|---|---|---|---|---|---|---|---|---|
| Horizon | $\ln Y_t$ | $\ln K_t$ | $\ln L_t$ | $\ln G_t$ | $\ln Y_t$ | $\ln K_t$ | $\ln L_t$ | $\ln G_t$ |
| 1 | 88.6 | 5.72 | 6.48 | 34.5 | 16.4 | 2.12 | 10.3 | 92.7 |
| 5 | 54.5 | 13.1 | 2.27 | 68.1 | 12.3 | 1.75 | 8.00 | 83.4 |
| 10 | 39.1 | 13.1 | 2.96 | 69.5 | 15.6 | 1.52 | 7.49 | 81.1 |
| 15 | 43.1 | 12.1 | 3.05 | 67.4 | 15.8 | 2.24 | 7.09 | 81.0 |
| 20 | 39.1 | 12.0 | 2.81 | 70.1 | 16.6 | 1.98 | 7.14 | 79.9 |

The row values for the generalized variance decomposition do not add up to 100 unlike the case of orthogonalized approach (Sari and Soytas, 2007).

## 5. Conclusion and Policy Implications

This study has investigated the relationship between natural gas consumption and economic growth by including real capital and employment using the production functional form within the framework of a multivariate model over the period of 1972–2009 in the case of Pakistan. The ARDL bound testing approach confirms that there exists a long-run relationship between real GDP, natural gas consumption, real capital and employment. The long-run elasticity estimates indicate a positive and significant impact of natural gas consumption, real capital and employment on economic growth. In comparison to the long-run elasticity (0.652) estimates of Apergis and Payne (2010) utilizing almost the same model using panel data for 67 countries, our elasticity estimate with respect to natural gas consumption is 0.4913. This might indicate the requirement for a country specific study, like ours, so that more accurate magnitude of effects can be established for policy purpose. Furthermore, the results of Granger causality and variance decomposition analysis reveal unidirectional causality running from natural gas consumption to economic growth supporting the natural gas consumption-led-economic growth hypothesis.

This suggests that energy (natural gas consumption) conservation policies may retard the rate of economic growth in Pakistan. With gas being the primary energy source accounting for 48% of total energy in 2008, that is almost indigenously produced, Pakistan need to ensure that this source of energy is able to meet the demand. The appropriate energy policies regarding natural gas should be tailored towards improving the energy efficiency consistent with the pace of economic growth in the country. Pakistan being one of the largest users of CNG should also increase the investment in gas production infrastructure including technology development[19]. Alternatively, intensifying the private-public partnership efforts would also ensure reliable supply of gas, operational efficiency, better distribution as well as allows in achieving import substitutions targets which otherwise will have an adverse effects on balance of payments. Commitment to increase local gas exploration and investment incentives as well as initiatives to attract investment in the gas production would ensure sustainable supply of gas to propel the economic. This will also ensures that local gas price are keep

[19] Although Pakistan has fairly a well developed gas infrastructure, with the growing demand for gas the efforts need be intensified.

at affordable rate which otherwise would reduce the need for gas that in turn effects the economic growth. Since gas serves as an important factor input of growth, policy makers planning for the future economic development in Pakistan should synchronize the progress and development of the energy sector in particular the gas industry.

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