Is Renewable Energy Consumption Effective to Promote Economic Growth in Pakistan: Evidence from Bounds Testing and Rolling Window Approach

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Abstract: The aim of present study is to re-investigate the impact of renewable energy consumption on economic growth by incorporating capital and labor as potential determinants of production function in case of Pakistan. We have used the ARDL bounds testing and rolling window approach (RWA) for cointegration. The causality analysis is conducted by applying VECM Granger causality and innovative accounting approaches.

The results showed that all the variables are cointegrated for long run relationship. Renewable energy consumption, capital and labor boost economic growth. The causality analysis indicated bidirectional causality between economic growth, renewable energy consumption and capital over the period of 1972Q1-2011Q4. The study opens up new directions for policy makers to explore new sources of energy sustain economic growth.

Keywords: Renewable Energy, Economic Growth, Rolling Window Approach

Introduction

Over the past ten years, industrialized countries have attained stable energy consumption pattern. On the other hand in developing countries, on average, are making 5% annual growth in energy consumption. The surprising verity is that about 8% of energy consumption is gratified by fossil fuels. Like other developing countries in Pakistan, primary energy consumption has raised 80% in preceding two decades. It was 34 million toe in 1994-95 and reached to 61 million toe to just in 2009-10. Aboriginal natural gas, imported oil, hydel power generation, coal consumption, and finally nuclear power constitute 45%, 35%, 12%, 6%, and 2% respectively in energy. Conventional energy is consumed mostly to satiate the energy requirements in Pakistan. Sheikh [34] argues that it contributes up to 99% in the total energy consumption. As the market for the conventional energy is much broad and extensive as compared to renewable energy, that is why investors are lesser interested in this source of energy. It results in lesser share of renewable energy consumption in total energy blend and is a threat to the future level of production. Nonetheless; Pakistan Alternative Energy Board is doing a great jog in this regard, it aims that produce 5% of total energy through renewable energy in the next 20 years (Khalil et al. [15]).

Pakistan has abundant potential for renewable energy. Solar energy is a cheaper source of energy as compared to fossil fuels and Pakistan has comparative advantage of producing energy with it. It doesn’t necessitate any refining nor does it involve any transportation which sorts it a cheaper and striking substitute for fossil fuels. Nonetheless, it is utilized in a very limited way in Pakistan e.g. highways telephone exchanges, emergency telephones, hospital utilities etc. So far, a solar energy program for 100 home has been initiated in Baluchistan which can enlighten 26000 houses there. In addition to this, the coastline zones in Pakistan are very rich for production of wind energy. It is projected that it has likely to produce energy of 50,000 MW. The landscapes of Northern areas make it a suitable candidate for wind energy also. It is estimated that 5000 village can be electrified if this energy is made operational in Pakistan. It is more appropriate for micro hydro plants which can yield energy of 300 MW. Canal system in Pakistan arranges for a great prospect for renewable energy. Just Punjab has the potential to yield energy of 350 MW. Along with it, there are also the prospect for the micro plants which can provide energy of 3 MW to small households and business units. As Pakistan is an agrarian economy, it would be able to make available cheaper energy to its rural sector if it makes proper use of biogas. It can yield 17.25 million cubic meters energy in the form of biogas daily which is sufficient to meet the cooking obligation of fifty million folks[1]. Hence, it is not the deficiency of resources but mismanagement and laxity which is making our lives difficult.

Energy (renewable energy consumption) plays a vital role by expanding domestic production. This implies that energy consumption is also an important determinant of economic growth like other factors of production such as labour and capital. Existing energy literature provides four competing hypotheses between energy consumption (renewable) and economic growth in case of Pakistan. These competing hypotheses are very important for policy point of view. For instance, reductions in energy would not

[1] We took the help of various reports, available on the official website of Alternative Energy Development Board Government of Pakistan, for this study.

have adverse impact on economic growth if economic growth Granger causes energy consumption/ neutral hypothesis is found between both the variables. If bidirectional causality is found both the variables / energy consumption Granger causes economic growth then new sources of energy should be explored. Energy is an important stimulus of production process and energy must Granger cause economic growth. An expansion in production is linked with energy demand and economic growth might Granger cause energy consumption. The main objective of present study is to investigate the relationship between renewable energy consumption capital, labour and economic growth in case of Pakistan of using Cobb-Douglas production function over the period of 1972Q1-2011Q4. In case of Pakistan, this study contributed to energy literature by five folds applying: (i) the ARDL bound testing approach to cointegration for long run relationship; (ii) the rolling window approach (RWA) to examine robustness of the ARDL results; (iii) OLS and ECM for long run and short run impacts of renewable energy consumption on economic growth; (d) the VECM Granger causality approach is to examine causal relationship between the variables and (v) innovative accounting approach to (IAA) test the robustness of the VECM Granger causality results. Our findings reveal that cointegration between renewable energy consumption economic growth, capital and labor exists in case of Pakistan. Further, our empirical evidence reports that renewable energy consumption has positive impact on economic growth. Capital and labour also adds in economic growth. Furthermore, estimated results indicated bidirectional causality relationship between renewable energy consumption and economic growth.

II. Literature Review:

Contemporaneous research on energy consumption provides a stream of information regarding the direction of causality between renewable energy consumption and economic growth. All the countries have different effects of renewable energy consumption; some countries report renewable energy consumption fetches handsome contribution in economic growth while for some countries this source of energy is not sufficient. For example, Ewing et al. [12] asserted that renewable energy consumption has little impact on economic growth in case of United States. In contrast, Payne ([23], United States) and Tiwari ([35], India) affirmed that renewable energy contributes much in economic growth and suggest that the share of renewable energy in total energy blend must rise over time. In the same spirit but with panel data[2], Tiwari [35] finds positive response of GDP in response to renewable energy consumption innovative shock. In addition, Magnani and Vaona [19] also share the same views for Italy and advised to discourage renewable energy conservation policies. Arifin and Syahruddin [6] reported that adoption of energy conservation policies would affect economic growth in Indonesia because causality is running from renewable energy consumption to economic growth.

Table-1: The summary of studies on renewable energy consumption-growth nexus

No.	Feedback hypothesis	Conservation hypothesis	Growth hypothesis	Neutrality hypothesis
1.	Ewing et al. [12]	Sari et al. [28]	Payne [23]	Payne [24]
2.	Tiwari [34]	Sadorsky [28]	Bowden [8]	Menegaki [21]
3.	Apergis and Payne [1]		Magnani and Vaona [19]	Mahmoodi and Mahmoodi [20]
4.	Apergis and Payne [2]		Arifin and Syahruddin [6]	

[2] Austria, Belgium & Luxembourg, Bulgaria, Finland, France, Germany, Greece, Republic of Ireland, Italy, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and United Kingdom

5.	Apergis and Payne [3]			
6.	Apergis and Payne [4]			
7.	Tiwari [35]			
8.	Apergis and Payne [5]			
Note: Growth hypothesis represents uni-directional causality running from renewable energy consumption to economic growth; Conservation hypothesis represents uni-directional causality running from economic growth to renewable energy consumption; Feedback hypothesis represents bi-directional causality; Neutrality hypothesis represents no causality.				

Other than growth hypothesis, empirical studies also extract conservation hypothesis. For instance, Sari et al. [29] share this view for United States while Sadorsky [28] for a panel of countries[3], both of the studies find conservation policies are more suitable. On other hand, Apergis and Payne [1] worked with a panel of OECD countries[4] and found the bidirectional causality between renewable energy consumption and economic growth. These finding are consistent with Apergis and Payne [2]; who worked with a panel of 13 Eurasian countries[5], Apergis and Payne [1]; for 6 Central American countries[6], Apergis and Payne [4]; for a panel of 80 countries[7]. Recently, Apergis and Payne [5] investigated

[3]Argentina, Brazil, Chile, China, Colombia, Czech Republic, Hungary, India, Indonesia, Korea, Mexico, Peru, Philippines, Poland, Portugal, Russia, Thailand, Turkey.

[4]Australia, Austria, Belgium, Canada, Denmark, France, Germany, Iceland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

[5]Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Moldova, Russia, Tajikistan, Ukraine, Uzbekistan.

[6]Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama.

[7]Algeria, Argentina, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Bulgaria, Canada, Cameron, Chile, China, Comoros, Costa Rica, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Finland, France, Gabon, Germany, Ghana, Greece, Guatemala, Guinea, Honduras, Hungary, Iceland, India, Indonesia, Iran, Ireland, Italy, Japan, Jordan, Kenya, Korea, Luxembourg, Madagascar, Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Mozambique, Netherlands, New Zealand, Nicaragua, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Senegal, South Africa, Spain,

the causality between renewable electricity consumption and economic growth in case of Central American countries namely Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama. They applied panel cointegration developed by Larsson et al. [16] and panel VECM Granger causality approach. Their results indicated the cointegration between the variables. Renewable electricity consumption adds in economic growth and feedback hypothesis exists between renewable electricity consumption and economic growth in long run and renewable electricity consumption Granger causes economic growth in short run.

In contrast, some studies find no causal relationship between renewable energy consumption and economic growth. Payne [24] reports no causal relationship between renewable energy consumption and economic growth for United States. A same inference is drawn by Menegaki [21] for a panel of 27 European countries[8]. Table-1 represents the summary of empirical studies regarding relationship between renewable energy consumption and economic growth. Mahmoodi and Mahmoodi [20] tested the direction of causal relation between renewable energy consumption and economic growth in 7 Asian developing economies[9]. Their findings validated the feedback hypothesis for Bangladesh, conservation hypothesis for India, Iran, Pakistan, and Syrian Arab Republic and neutral hypothesis between both variables is confirmed for Sri Lanka.

Sri Lanka, Sudan, Swaziland, Sweden, Switzerland, Syria, Thailand, Tunisia, Turkey, Uganda, United Kingdom, United States, Uruguay, Venezuela, Zambia.

[8] Belgium, Bulgaria, Czech Rep., Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxemburg, Hungary, Netherland, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, UK, Norway.

[9] India, Iran, Pakistan, Syrian Arab Republic, Bangladesh, Jordan and Sri Lanka

III. Modeling Framework and Data Collection

The purpose of current investigation is to link the relationship among renewable energy consumption and economic growth in case of Pakistan using quarterly data over the period of 1971-2011. This study employ Cobb-Douglus production function to analysis the correlation between renewable energy consumption and economic growth including capital and labour as additional factors of production. Commonly, the equation of production function is as follows:

$$Y = AR^{\alpha_1} K^{\alpha_2} L^{\alpha_3} e^{u} \tag{1}$$

where Y is domestic output in real terms; R, K and L indicate renewable energy consumption, real capital and labor respectively. A shows level of technology to be utilized in the country and e is the error term supposed to be identically, independently and normally distributed. The returns to scale is associated with renewable energy consumption, capital and labour is shown by α_1, α_2 and α_3 respectively. We have converted all the series into logarithms in order to linearize the form of nonlinear Cobb-Douglus production. The main reason is that linear specification does not seem to provide consistent results and not helpful for policy making purpose (Shahbaz et al. [33]; Shahbaz and Feridun [30]). To cover this problem, we use log-linear specification to investigate relationship between renewable energy consumption and economic growth in case of Pakistan. Ehrlich [10, 11], Cameron [9] and Layson [17] recommended pertain log-linear modeling in attaining better, consistent and efficient empirical results[10]. The log-linear functional form of Cobb-Douglus production function is modeled as follows:

$$\log Y_t = \log A + \alpha_1 \log R_t + \alpha_2 \log K_t + \alpha_3 \log L_t + u_t \qquad (2)$$

The empirical equation to investigate the relationship between renewable energy consumption and economic growth is modeled keeping technology constant. The log-linear specification to assess the relationship between renewable energy consumption and economic growth is as follows:

$$\ln Y_t = \alpha_0 + \alpha_1 \ln R_t + \alpha_3 \ln K_t + \alpha_4 \ln L_t + u_t \qquad (3)$$

Where $\ln Y_t$, $\ln R_t$, $\ln K_t$ and $\ln L_t$ is the logarithm of per capita real GDP, renewable energy consumption (kg of oil equivalent per capita) per capita, capital use per capita and labor per capita respectively. The long run association among renewable energy consumption and economic growth in case of Pakistan is investigated by applying the ARDL bounds testing approach presents by Pesaran et al. [27]. The empirical literature indicates the various cointegration approaches in order to test cointegration. But, the ARDL bounds testing approach is preferable due to its advantages over other cointegration techniques. For instance, order of integration of the series does not matter for applying the ARDL bounds testing if no variable is found to be stationary at I(2). This approach is more appropriate as compared to conventional cointegration techniques for

[10] See Shahbaz et al. [32] for more details

small sample (Haug, [14]). Within the general-to-specific framework, unrestricted version of the ARDL chooses proper lag order to capture the data generating procedure (see Shahbaz and Lean, [31] for more details). Appropriate specification of the ARDL model is sufficient to simultaneously correct for residual serial correlation and endogeneity problems (Pesaran and Shin, [26]). The equation of unrestricted error correction model (UECM) to investigate the long-and-short runs relations between the series is following:

$$\begin{aligned}\Delta \ln Y_t &= \vartheta_1 + \vartheta_T T + \vartheta_Y \ln Y_{t-1} + \vartheta_R \ln R_{t-1} + \vartheta_K \ln K_{t-1} + \vartheta_L \ln L_{t-1} + \sum_{i=1}^{p} \vartheta_i \Delta \ln Y_{t-i} \\ &\quad + \sum_{j=0}^{q} \vartheta_j \Delta \ln R_{t-j} + \sum_{l=0}^{s} \vartheta_l \Delta \ln K_{t-l} + \sum_{m=0}^{t} \vartheta_m \Delta \ln L_{t-m} + \mu_t\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta \ln R_t &= \alpha_1 + \alpha_T T + \alpha_Y \ln Y_{t-1} + \alpha_R \ln R_{t-1} + \alpha_K \ln K_{t-1} + \alpha_L \ln L_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln R_{t-i} \\ &\quad + \sum_{j=0}^{q} \alpha_j \Delta \ln Y_{t-j} + \sum_{l=0}^{s} \alpha_l \Delta \ln K_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta \ln L_{t-m} + \mu_t\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \ln K_t &= \rho_1 + \rho_T T + \rho_Y \ln Y_{t-1} + \rho_R \ln R_{t-1} + \rho_K \ln K_{t-1} + \rho_L \ln L_{t-1} + \sum_{i=1}^{p} \rho_i \Delta \ln K_{t-i} \\ &\quad + \sum_{j=0}^{q} \rho_j \Delta \ln Y_{t-j} + \sum_{k=0}^{r} \rho_k \Delta \ln R_{t-k} + \sum_{m=0}^{t} \rho_m \Delta \ln L_{t-m} + \mu_t\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta \ln L_t &= \sigma_1 + \sigma_T T + \sigma_Y \ln Y_{t-1} + \sigma_R \ln R_{t-1} + \sigma_K \ln K_{t-1} + \sigma_L \ln L_{t-1} + \sum_{i=1}^{p} \sigma_i \Delta \ln L_{t-i} \\ &\quad + \sum_{j=0}^{q} \sigma_j \Delta \ln Y_{t-j} + \sum_{k=0}^{r} \sigma_k \Delta \ln R_{t-k} \sum_{m=0}^{t} \sigma_m \Delta \ln K_{t-m} + \mu_t\end{aligned} \tag{7}$$

Where Δ is the differenced operator and μ_t is residual term in period *t*. The akaike information criterion (AIC) is applied to decide suitable lag length of the first differenced variables following Lütkepohl [18]. The proper calculated F-statistic depends upon the appropriate lag order selection of the series to be included in the model[11]. The overall significance of the coefficients of lagged variables is investigated by applying an F-test advanced by Pesaran et al. [27]. The null hypothesis of no long run relationship between the variables in equation (3) is $H_0 : \vartheta_Y = \vartheta_R = \vartheta_K = \vartheta_L = 0$ against the alternate hypothesis of long run relationship i.e. $H_0 : \vartheta_Y \neq \vartheta_R \neq \vartheta_K \neq \vartheta_L \neq 0$. Two asymptotic critical values have been generated by Pesaran et al. [27]. These bounds are upper critical bound (UCB) and lower critical bound (LCB) are used to decide whether variables are cointegrated for long run relationship or not. If all the variables are stationary at I(0) then we use LCB to test cointegration between the series. We use UCB to examine long run relationship between the series if the variables are integrated at I(1) or I(0) or I(1)/I(0). We compute the value of F-test applying following models such as $F_Y(Y/R,K,L)$, $F_R(R/Y,K,L)$, $F_K(K/Y,R,L)$ and $F_L(L/Y,R,K)$ for equations (4) to (7) respectively. The decision of cointegration is taken with the help of following rules: if upper critical bound (UCB) is less than our computed F-statistic then we conclude cointegration. If computed F-statistic does not exceed lower critical bound then no cointegration among the variables. The decision about cointegration between the series is questionable if computed F-statistic is found between LCB and UCB[12]. Our decision regarding cointegration is inconclusive if calculated F-statistic falls between LCB and UCB. In such an environment, error

[11] For details see Shahbaz et al. [32]
[12] If the variables are integrated at I(0) then F-statistic should be greater than lower critical bound for the existence of cointegration between the series

correction method is an easy and suitable way to investigate cointegration between the variables.

After the confirmation of long run relationship among the variables then in next step we investigate the causal relation between the series. Granger, [13] stated that once the variables are integrated at I(1) then vector error correction method (VECM) is suitable approach to test the direction of causal link among the variables. Relatively, the VECM is restricted form of unrestricted VAR (vector autoregressive) and restriction is levied on the presence of long run relationship between the series. All the series are endogenously used in the system of error correction model (ECM). This shows that in such situation, response variable is explained both by its own lags and lags of independent variables as well as the error correction term and by residual term. The VECM in five variables case can be written as follows:

$$\Delta \ln Y_t = \alpha_{\circ 1} + \sum_{i=1}^{l} \alpha_{11} \Delta \ln Y_{t-i} + \sum_{j=1}^{m} \alpha_{22} \Delta \ln R_{t-j} + \sum_{r=1}^{o} \alpha_{44} \Delta \ln K_{t-r} + \sum_{s=1}^{p} \alpha_{55} \Delta \ln L_{t-s} + \eta_1 ECT_{t-1} + \mu_{1i} \quad (8)$$

$$\Delta \ln R_t = \beta_{\circ 1} + \sum_{i=1}^{l} \beta_{11} \Delta \ln R_{t-i} + \sum_{j=1}^{m} \beta_{22} \Delta \ln Y_{t-j} + \sum_{r=1}^{o} \beta_{44} \Delta \ln K_{t-r} + \sum_{s=1}^{p} \beta_{55} \Delta \ln K_{t-s} + \eta_2 ECT_{t-1} + \mu_{2i} \quad (9)$$

$$\Delta \ln K_t = \varphi_{\circ 1} + \sum_{i=1}^{l} \varphi_{11} \Delta \ln K_{t-i} + \sum_{j=1}^{m} \varphi_{22} \Delta \ln Y_{t-j} + \sum_{k=1}^{n} \varphi_{33} \Delta \ln R_{t-k} + \sum_{s=1}^{p} \varphi_{55} \Delta \ln L_{t-s} + \eta_4 ECT_{t-1} + \mu_{4i} \quad (10)$$

$$\Delta \ln L_t = \delta_{\circ 1} + \sum_{i=1}^{l} \delta_{11} \Delta \ln L_{t-i} + \sum_{j=1}^{m} \delta_{22} \Delta \ln Y_{t-j} + \sum_{k=1}^{n} \delta_{33} \Delta \ln R_{t-k} + \sum_{s=1}^{p} \delta_{55} \Delta \ln K_{t-s} + \eta_4 ECT_{t-1} + \mu_{4i} \quad (11)$$

Where Δ indicates differenced operator and u_{it} are residual terms and assumed to be identically, independently and normally distributed. The statistical significance of lagged error term i.e. ECT_{t-1} further validates the established long run relationship between the variables. The estimates of ECT_{t-1} also shows the speed of convergence from short run towards long run equilibrium path in all models. The VECM is superior to test the causal relation once series are cointegrated and causality must be found at least from one direction. Further, the VECM helps to distinguish between short-and-long runs causal relationships.

The statistical significance of estimate of lagged error term i.e. ECT_{t-1} with negative sign confirms the existence of long run causal relation using the t-statistic. Short run causality is indicated by the joint χ^2 statistical significance of the estimates of first difference lagged independent variables. For example, the significance of $\alpha_{22,i} \neq 0 \forall_i$ implies that renewable energy consumption Granger-causes economic growth and causality runs from economic growth to renewable energy consumption can be indicated by the significance of $\beta_{22,i} \neq 0 \forall_i$. The same inference can be drawn for rest of causality hypotheses. Finally, we use Wald or F-test to test the joint significance of estimates of lagged terms of independent variables and error correction term. This further confirms the existence of short-and-long run causality relations (Shahbaz et al. [32]) and known as measure of strong Granger-causality (Oh and Lee, [22]).

The data span of present study is 1972Q1-2011Q4. The data on renewable energy consumption is collected from SBP (2010-11). We have used world development indicators (CD-ROM, 2011) to collect on data on real GDP, real capital and labour respectively.

IV. Empirical Results and Discussions

This study applies Ng-Perron unit root test in order to test the order of integration. This test is superior and more powerful as compared to traditional unit root tests such ADF, DF-GLS, KPPS etc. Baum, [7] stated that it is necessary condition to test the integrating order of the variables before applying the ARDL bounds testing approach to cointegration relationship between the series. The assumption of the ARDL bounds testing is that the variables should be integrated at I(0) or I(1) or I(0)/I(1) and no series is stationary at I(2). If any variable is integrated at I(2) then the computation of the ARDL F-statistic becomes invalid. The results of Ng-Perron unit root test are shown in Table-2. The empirical results indicate that all the series are non-stationary at level and stationary at 1st difference. So, all the variables are indicated order one i.e. I(1).

Table-1: Results of Ng-Perron Unit Root Test

Level				
Variables	MZa	MZt	MSB	MPT
$\ln Y_t$	-2.4251	-1.0907	0.4497	37.1408
$\ln R_t$	-0.9137	-0.6512	0.7127	93.6113

$\ln K_t$	-0.6889	-0.5238	0.7603	108.301
$\ln L_t$	-1.0930	-0.7322	0.6699	82.0658
1st Difference				
$\ln Y_t$	-27.6202*	-3.7074	0.1342	3.3513
$\ln R_t$	-30.3374*	-3.8864	0.1281	3.0519
$\ln K_t$	-29.1947*	-3.8123	0.1305	3.1704
$\ln L_t$	-26.5620	-3.6354	0.1368	3.4840
Note: * indicates the significance at the 1% level.				

The ARDL approach to cointegration checks the presence of long run link among variables. The lag selection is very important in case of the ARDL approach to cointegration. Hence this study uses akaike information criterion (AIC) to choose suitable lag length that helps us in capturing the dynamic relationship to select the best ARDL model to estimate. The results of lag length are reported in Table-3 which indicates that lag 5 is appropriate. The results of the ARDL bounds testing testing approach are reported in Table-4. The empirical evidence indicates that our computed F-statistics for $F_Y(Y/R,K,L)$, $F_R(R/Y,K,L)$ and $F_L(L/Y,R,K)$ are 8.776, 4.061 and 4.249 for economic growth, renewable energy consumption and labour equations respectively. These F-statistics are greater that upper critical bounds developed by Pesaran et al. [27] at 1 per cent, 10 per cent and 5 per cent levels of significance.

Table-3: Lag Selection Criteria

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	129.9537	NA	2.24e-06	-1.65728	-1.5777	-1.6249
1	905.2496	1499.585	1.03e-10	-11.6480	-11.2501	-11.4863
2	946.4360	77.49561	7.37e-11	-11.9794	-11.2632	-11.6884
3	1112.641	303.9806	1.02e-11	-13.9558	-12.9213	-13.5355
4	1575.482	822.1521	2.87e-14	-19.8353	-18.4825	-19.2855
5	1655.641	138.1672*	1.24e-14*	-20.6794*	-19.0083*	-20.0006*
6	1661.778	10.25650	1.41e-14	-20.5497	-18.5603	-19.7415
7	1672.323	17.06517	1.53e-14	-20.4779	-18.1702	-19.5404
8	1682.308	15.63497	1.67e-14	-20.3987	-17.7727	-19.3320

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table-4: Results of ARDL Cointegration Test

Variable	$\ln Y_t$	$\ln R_t$	$\ln K_t$	$\ln L_t$
F-statistics	8.776*	4.061***	1.949	4.249***
Critical values	1 per cent level	5 per cent level	10 percent level	
Lower bounds	5.23	3.12	2.75	
Upper bounds	3.93	4.25	3.79	
Diagnostic tests				
Durbin-Watson	2.0906	2.0009	2.0476	2.0907
Note: *, ** and *** show the significance at 5% and 10% level respectively.				

Table-4: Results of Johansen Cointegration Test

Hypothesis	Trace Statistic	Maximum Eigen Value
$R = 0$	142.0526*	89.6299*
$R \leq 1$	52.4226*	39.2551*
$R \leq 2$	13.1674	10.7930
$R \leq 3$	2.3744	2.3744
Note: * indicates significance at 1% level.		

This confirms the presence of cointegration between economic growth, renewable energy consumption, capital and labour in case of Pakistan. This implies that there is a long run relationship between the variables over the period of 1972Q1-2011Q4. The robustness of the ARDL bounds testing approach is examined by applying Johansen cointegration multivariate cointegration approach. The results are reported in Table-5. We can infer that there are two cointegrating vectors which validate the presence of long run relationship between the variables. This entails that the ARDL cointegration analysis is reliable and robust.

The investigation of long run relationship between the variables leads us to examine the marginal impacts of renewable energy consumption, capital and labor on economic growth in long run as well as in short run. Table-5 deals with long run marginal impact of determinants of economic growth. The results shown in Table-5 reveal that positive relationship found from renewable energy consumption to economic growth and statistically significance level is 1 per cent. All else is constant, 1 per cent rise in renewable energy consumption spurs economic growth by 0.6103 per cent. The impact of capital on economic growth is positive and is statistically significant at 5 per cent level of significant. Keeping the other things constant, 1 per cent increase in capital use enhances domestic production and hence economic growth by 0.1357 per cent. The relationship between labour and economic growth is positive and it is statistically significant at 1 per cent level of significance. A 0.4001 per cent of economic growth is stimulated by 1 per cent increase in labour, all else is same.

Table-5: Long-and-Short Run Analysis

Dependent Variable = $\ln Y_t$			
Long Run Results			
Variable	Coefficient	Std. Error	Prob. value
Constant	5.5906*	0.0602	0.0000

$\ln R_t$	0.6103*	0.0213	0.0000
$\ln K_t$	0.1357**	0.0068	0.0489
$\ln L_t$	0.4001*	0.0236	0.0000
Short Run Results			
Constant	0.0045*	0.0007	0.0000
$\ln R_t$	0.0738*	0.0234	0.0019
$\ln R_{t-1}$	0.0012**	0.0005	0.0348
$\ln K_t$	0.0873***	0.0500	0.0827
$\ln L_t$	0.0847*	0.0495	0.0000
ECM_{t-1}	-0.0341*	0.0093	0.0004
Diagnostic Tests			
Test	F-statistic	Prob. value	
$\chi^2 SERIAL$	1.5420	0.1686	
$\chi^2 ARCH$	1.3191	0.2525	
$\chi^2 WHITE$	4.0318	0.0001	
$\chi^2 REMSAY$	0.0046	0.9455	
Note: * and ** denote the significant at 1% and 5% level respectively.			

The lower segment of Table-5 reports the results of short dynamics of renewable energy consumption, capita and labour on economic growth. In short span of time, renewable energy consumption, lagged of renewable energy consumption, capital and labour contribute economic growth significantly. The negative and statistically significant estimate of ECM_{t-1} corroborates the established long run relationship between renewable energy consumption, capital, labour and economic growth in case of Pakistan. The results indicate that estimate of ECM_{t-1} -0.0341. It is statistically significant at 1 per cent level of significance. This implies that 3.41 per cent changes in economic growth are corrected by deviations in short run towards long run equilibrium path in each quarter. In this model, short run deviations in economic growth take 29 years and 6 month to converge to long run equilibrium path. The short run diagnostic tests show that no serial correlation is found and same interpretation can be drawn for ARCH test. Our empirical exercise indicates that there is no problem of heterogeneity and error term has homogenous variance. The Ramsey reset test shows that functional for model is well specified.

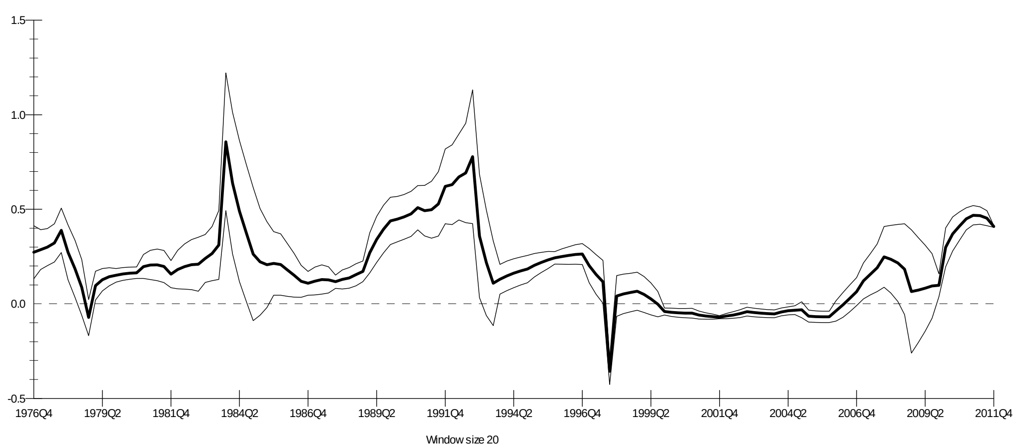
Results of Rolling Regression

The rolling regression model is used to evaluate the stability of the coefficient of the ARDL model in the sample size. Other estimation methods assume that the coefficients of the variables remain constant over the sample size. But in reality the economic condition cannot remains constant and as results the economic indicator are fluctuated over time, and their coefficients cannot remains same (Pesaran and Timmermann, [25]). With the help of rolling regression approach, we can estimate the coefficient of each observation of the sample by setting the rolling window size. If the economic indicators are changed overtime so this approach captures this instability.

Fig-1 Coefficient of INPT and its two*S.E. bands based on rolling OLS

The figure-1 to figure-4 shows the rolling window results. The black tick line represents the coefficients and light black upper and lower band represents the coefficients' statistical level of significance (at 5%) The fig-1 shows the graph of intercept that shows it remains positive over the sample size.

F-g-2 Coefficient of Ln R and its two*S.E. bands based on rolling OLS



The figure-2 shows the graph of lnR coefficients. It shows negative in $1978Q_4$ and $1999Q_3$ to $2006Q_2$. In the remaining sample it has positively related to economic growth.

Fig-3 Coefficient of Ln K and its two*S.E. bands based on rolling OLS

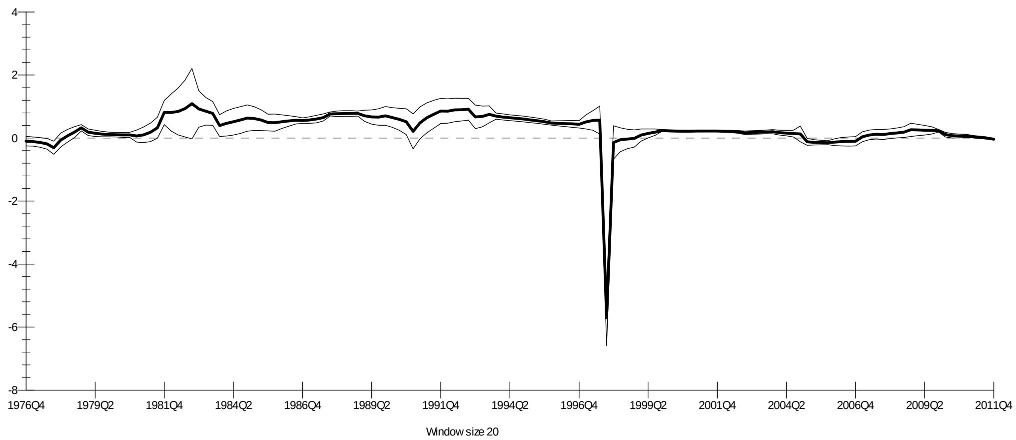


Fig-3 represents the capital coefficients. It shows that capital is negatively related to economic growth. In the sample of $1976Q_4$ to $1977Q_4$, 1997Q4 to $1998Q_4$, and $2005Q_1$ to $2006Q_4$.

Fig-4 Coefficient of Ln L and its two*S.E. bands based on rolling OLS

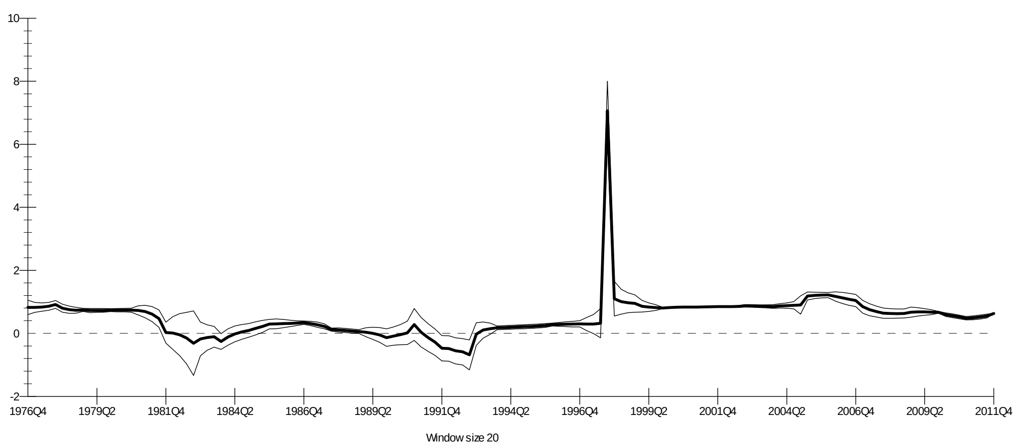


Fig-4 represents the labor force coefficients. It shows that capital is negatively related to economic growth, in the sample of $1982Q_2$-$1984Q_2$, $1989Q_3$-$1990Q_2$, and $1991Q_2$-$1993Q_1$. In the remaining sample it remains positive.

The VECM Granger Causality Analysis

After finding long-and-short runs affect of renewable energy consumption, capital and labour on economic growth in case of Pakistan over the period of 1972Q1-2011Q4. The direction of causal relationship between these variables is investigated by applying the VECM Granger causality approach. The appropriate environmental and energy policy to sustain economic growth is dependent upon the nature of causal relation between the series. In doing so, we applied the VECM Granger causality approach to detect the causality between renewable energy consumption, capital, labour and economic growth which would help policy makers in formulating comprehensive energy policy to accelerate economic growth for long run.

The Table-6 presents the empirical evidence of long run and short run causality relationships. The results suggest that feedback hypothesis between renewable energy consumption and economic growth, renewable energy consumption and labor, labor and economic growth, in case of Pakistan for long run. The results indicate that causality running from renewable energy consumption to economic growth is stronger compared to causal relationship from economic growth to renewable energy consumption. This shows that government must pay her attention to launch comprehensive energy policy in exploring new sources of renewable energy to sustain economic growth. The R & D activities should be encouraged in energy sector. To overcome energy crisis in the country, government must give incentive to foreign investors to investment in energy sector of Pakistan. The unidirectional causality exists from capital to renewable energy consumption, economic growth and labor. The feedback hypothesis is also found between economic growth and labor and, labor and renewable energy consumption.

In short run, bidirectional causal relationship is found between renewable energy consumption and economic growth. The feedback hypothesis also exists between capital and economic growth. Economic growth and labor Granger cause each other. The unidirectional causality is found running from labour to renewable energy consumption. The statistically significance of joint long-and-short run causality corroborates our long run and short run causal relationships between the series over the study period of 1972Q1-2011Q4.

Table-6: VECM Granger Causality Analysis

Dependent Variables	Direction of Causality								
	Short Run				Long Run	Joint Long-and-Short Run Causality			
	$\ln Y_t$	$\ln R_t$	$\ln K_t$	$\ln L_t$	ECT_{t-1}	$\ln Y_t, ECT_{t-1}$	$\ln R_t, ECT_{t-1}$	$\ln K_t, ECT_{t-1}$	$\ln L_t, ECT_{t-1}$
$\ln Y_t$	--	6.6272* [0.0003]	4.1369* [0.0075]	3.3038** [0.0400]	-0.0455* [-4.1305]	--	8.6325* [0.0000]	7.9252* [0.0000]	2.4920** [0.0500]
$\ln R_t$	8.3149* [0.0000]	--	1.0695 [0.3641]	3.0175** [0.0320]	-0.1614* [-3.5750]	7.3173* [0.0000]	--	3.7904* [0.0059]	3.9814** [0.0043]
$\ln K_t$	3.8681* [0.0107]	0.9990 [0.3949]	--	0.3270 [0.8058]	--	--	--	--	--
$\ln L_t$	3.1994* [0.0078]	1.8315 [0.1442]	0.6327 [0.5950]	--	-0.0379* [-3.8132]	2.4401** [0.0484]	4.5172* [0.0018]	6.6326* [0.0012]	3.6494* [0.0073]
Note: * and ** show significant at 1% and 5% percent respectively.									

Existing energy literature reveals that the Granger causality approaches such the VECM Granger causality test has some limitations. The causality test cannot capture the relative strength of causal relation between the variable beyond the selected time period. This weakens the reliability of causality results by the VECM Granger approach. To overcome this problem, we applied innovative accounting approach (IAA). The IAA is combination of variance decomposition method (VDM) and impulse response function (IRF). The variance decomposition approach (VDM) determines the response of the dependent actor to shocks stemming from independent actors. The IRF is an alternate of VDM. The Table-7 shows the results of VDM[13]. The variance decomposition approach indicates the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period.

Table-7 reports that economic growth is explained 40.61 per cent by innovative shocks of renewable energy consumption. The contribution of capital and labor contribute to economic growth is minimal i.e. 0.799 per cent and 4.90 per cent respectively. A 53.68 per cent of economic growth is contributed by factors outside the model such as technological advancements. Renewable energy consumption is contributed 70.98 per cent by its own shocks and 18.94 per cent by innovations stemming in economic growth. Capital and labour explain renewable energy consumption by 9.48 per cent and 0.59 per cent their innovative shocks. The contribution of renewable energy consumption is greater than economic growth to capital. A 61.67 per cent capital is contributed by its own innovations.

[13] The results of impulse response function are available from authors upon request

Table-7: Variance Decomposition Method

Period	Variance Decomposition of $\ln Y_t$				Variance Decomposition of $\ln R_t$				Variance Decomposition of $\ln K_t$				Variance Decomposition of $\ln L_t$			
	$\ln Y_t$	$\ln R_t$	$\ln K_t$	$\ln L_t$	$\ln Y_t$	$\ln R_t$	$\ln K_t$	$\ln L_t$	$\ln Y_t$	$\ln R_t$	$\ln K_t$	$\ln L_t$	$\ln Y_t$	$\ln R_t$	$\ln K_t$	$\ln L_t$
1	100.000	0.000	0.000	0.000	13.244	86.755	0.000	0.000	4.348	1.212	94.439	0.000	1.151	0.992	0.739	97.116
2	98.868	0.931	0.001	0.199	13.863	85.972	0.017	0.146	5.314	1.301	93.105	0.279	1.710	2.208	1.426	94.653
3	96.950	2.374	0.001	0.674	14.324	85.217	0.065	0.393	5.320	1.763	92.296	0.619	1.661	3.096	2.086	93.155
4	93.782	4.945	0.002	1.269	15.113	84.038	0.099	0.748	5.575	2.234	90.983	1.205	1.527	3.929	2.824	91.717
5	88.797	8.082	0.005	3.115	15.736	82.361	1.224	0.677	6.380	1.967	90.503	1.148	3.154	2.203	3.041	91.601
6	85.626	11.539	0.153	2.680	16.118	80.746	2.449	0.685	7.021	2.197	89.267	1.513	3.706	2.023	3.943	90.326
7	81.871	15.505	0.392	2.230	16.240	79.291	3.739	0.729	7.314	2.844	87.790	2.050	3.670	2.296	4.878	89.154
8	77.774	19.549	0.648	2.027	16.308	77.947	4.942	0.801	7.564	3.784	85.882	2.768	3.513	2.815	5.881	87.789
9	72.732	23.181	0.755	3.330	16.671	76.220	6.3734	0.734	8.318	4.929	83.895	2.857	3.912	2.249	5.691	88.147
10	69.819	25.951	0.988	3.240	16.982	74.804	7.505	0.707	8.913	6.420	81.450	3.215	4.090	2.473	6.278	87.157
11	67.293	28.640	1.161	2.903	17.171	73.711	8.402	0.714	9.225	8.224	78.850	3.699	3.987	2.984	6.987	86.040
12	64.960	31.195	1.263	2.580	17.306	72.893	9.056	0.743	9.371	10.164	76.205	4.258	3.833	3.660	7.769	84.736

13	62.002	32.962	1.219	3.816	17.606	72.106	9.585	0.702	9.754	12.290	73.715	4.239	4.023	3.346	7.529	85.101
14	60.337	34.471	1.214	3.976	17.875	71.575	9.878	0.671	9.954	14.308	71.407	4.329	4.113	3.674	7.932	84.278
15	58.964	36.036	1.175	3.823	18.064	71.264	10.016	0.656	9.980	16.228	69.312	4.481	4.025	4.233	8.473	83.268
16	57.751	37.557	1.114	3.576	18.205	71.110	10.034	0.649	9.928	17.972	67.420	4.678	3.902	4.911	9.089	82.096
17	55.999	38.231	1.001	4.767	18.452	70.946	9.956	0.644	10.056	19.735	65.653	4.554	4.040	4.682	8.864	82.412
18	55.086	38.918	0.922	5.072	18.671	70.885	9.817	0.626	10.129	21.214	64.163	4.491	4.113	4.999	9.172	81.714
19	54.341	39.748	0.854	5.055	18.828	70.910	9.653	0.6070	10.146	22.514	62.852	4.486	4.050	5.505	9.615	80.828
20	53.683	40.614	0.799	4.902	18.948	70.981	9.480	0.590	10.146	23.643	61.678	4.531	3.957	6.101	10.132	79.808

The share of labour is negligible. Finally, economic growth, renewable energy consumption and capital do not seem to contrite much to labour through their innovative shocks. Almost, 80 per cent of labour is explained by its own innovations. Overall, results indicate bidirectional causality between economic growth and renewable energy consumption. The causal relationship is stronger from renewable energy consumption to economic growth. These findings are consistent with the VECM Granger causality analysis. This entails that causality results are robust and reliable for policy making purpose.

V. Conclusion and Future Research

The present study investigated the relationship between renewable energy consumption and economic growth using Cobb-Douglus production function in case of Pakistan. The autoregressive distributed lag model or the ARDL bounds testing approach to cointegration applied to test the existence of long run relationship between renewable energy consumption, capital, labour and economic growth. The VECM Granger causality approach is used to examine the direction of causal relationship between these series and innovative accounting approach is used to test the robustness of the causality results.

Our empirical exercise confirmed that the variables are cointegrated for long run relationship over the study period of 1971Q1-2011Q4. The results indicated that renewable energy consumption raises economic growth. Capital and labor are also important factors of economic growth contributing to domestic production in the country. The rolling window results explain that renewable energy consumption, capital and labor positively impact on economic except few quarters. The causality analysis reveals that feedback hypothesis exists between renewable energy consumption and economic growth and same inference can be drawn for nonrenewable energy consumption.

The current study can be augmented to investigate the relationship between renewable energy consumption and economic growth at provincial level. Sectoral analysis also can be conducted in key sectors such as agriculture, industrial and services. This may help the policy makers to formulating comprehensive energy policy for sustainable economic growth at provincial as well as sectoral levels.

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