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Renewable and Non-renewable Energy Consumption and Economic Growth in Pakistan: A Disaggregated Analysis

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ABSTRACT

This study addresses the research question of how renewable and non-renewable energy consumption (EC) affects economic growth (GDP) in Pakistan over a period of 1972-2015. The study extends the basic production function having labor and capital as the mainstream variables by adding major energy sources of Pakistan. The results of Toda-Yamamoto Granger causality test confirm that no causality exists between GDP and labor force and bidirectional causality exists between GDP and gross capital formation. Moreover, the results confirm a unidirectional relationship (growth hypothesis) between hydroelectricity consumption (HEC) and nuclear energy consumption (NEC) and a bidirectional relationship (feedback hypothesis) between fossil fuel consumption (FFC) and GDP, respectively. The findings suggest for an efficient utilization of existing energy resources along with diversification and expansion of the renewable energy resources. The study recommends for the government policy to avoid energy conservation as it can hamper GDP growth in Pakistan.

Keywords

Energy Consumption, Economic Growth, Casual Relationship, Disaggregated Analysis, Government Policy

JEL Classification

Q13, Q42, Q48

1. Introduction

The mainstream economic theory of production considers labor and capital as the main factors of production. Nevertheless, the neo-classical aggregate production function complements energy as an additional and necessary input factor in the production model (Shahbaz et al., 2014; Chiou-Wei et al., 2016). In a broader sense, energy is a vital input for all production processes (Azam et al., 2015). It is required for domestic, agricultural, industrial, and transportation purposes (Kahouli, 2017). Thus, a secure, adequate, and accessible energy supply is important for socioeconomic development of a country (Jan et al., 2017; Rafindadi & Ozturk, 2017; Durrani et al., 2021; Li et al., 2022; Wang et al., 2022).

Pakistan is an energy deficient country (Jan, 2012; Javed et al., 2016; Jan & Lohano, 2021). Over the last two decades, Pakistan is trapped in the worst crisis of energy (Javid et al., 2013; Jan et al., 2017) which has severely affected economic growth (GDP) in the country (Jan & Akram, 2018). Fossil fuels, renewable energy (hydroelectricity), and nuclear energy are the major sources constituting Pakistan's total energy mix. In Pakistan, energy consumption (EC) and GDP growth are highly correlated (Jan & Akram, 2018). Figure 1 illustrates the historical trend in total EC and GDP in Pakistan. The figure shows that increase in GDP is accompanied by increased EC. During 1972-2015, Pakistan's fossil fuels consumption has increased from 7.039 to 68.870 million tons of oil equivalent (MTOE) whereas hydroelectricity consumption (HEC) has increased from 4 to 34.6 Terawatt-hour (TWh). Until 1999, there was no considerable change in nuclear energy consumption (NEC). However, after 1999 the consumption of nuclear energy started to grow and reached to 4.7 TWh by 2015 (BPS, 2017).

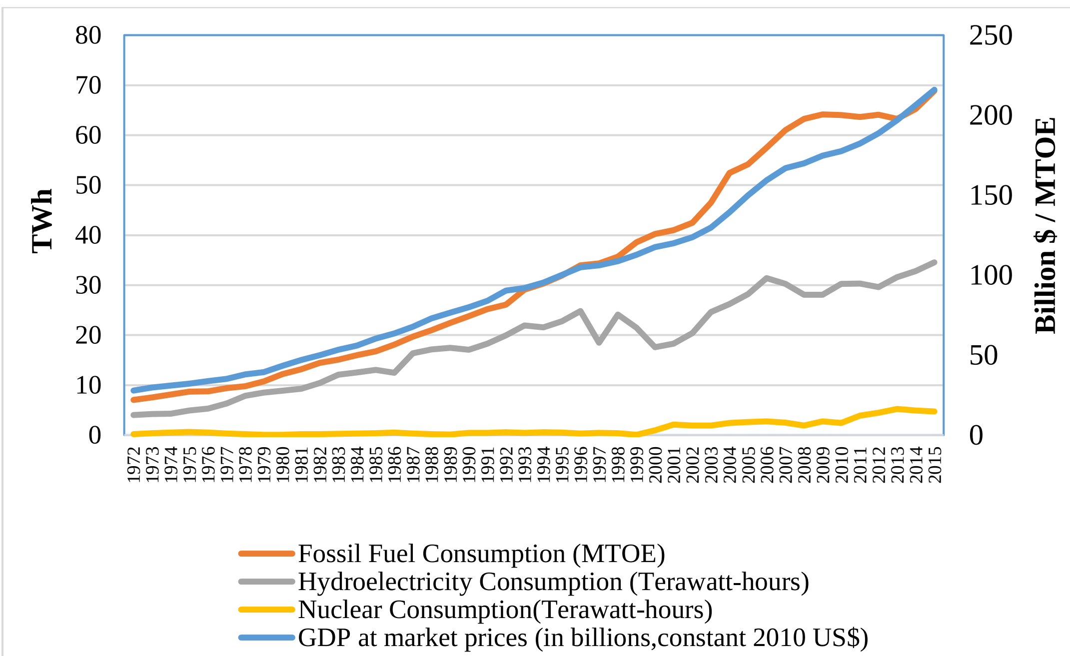

Figure 1: Disaggregated EC and GDP growth in Pakistan, 1972-2015 (BPS, 2016; World Bank, 2017)

This study is motivated by the fact that EC is an important determinant of GDP growth. In countries like Pakistan, high rates of EC are highly correlated with high GDP growth (Jan & Akram, 2018). Considering this scenario, this paper attempts to address the research question that what is the causal link between energy consumption and economic growth in Pakistan?

A number of studies have examined the EC-GDP nexus (Jan et al., 2020; Durrani et al., 2021; Husaini & Lean, 2022; Oryani et al., 2022; Wang et al., 2022; Zhang et al., 2022). However, this study is different from other studies in several aspects. Firstly, we determine the EC-GDP relationship by taking labor and capital as additional variables, and thereby, evade the problem of specification error that could possibly arise by the omission of relevant variables from the model. Secondly, we carry out a disaggregated analysis which gives us source specific results regarding different types of energy sources in Pakistan. To our knowledge, none or very few studies investigate the energy-growth relationship by employing fossil fuel consumption (FFC), HEC, and NEC altogether in a single study. Thirdly, we used Toda-Yamamoto (T-Y) causality test for detecting the direction of causal relationship. The T-Y causality approach allows us to test for cointegration even if the variables are integrated of order I(0) or I(1) or the combination of both orders i.e. I(0) and I(1). The approach can also be used disregarding either the variables are cointegrated or not. Fourthly and most importantly, the previous studies have explored the EC and GDP relationship without considering structural break in the analysis. We use Break Point test to determine the break point while estimating the energy-growth nexus. The combination of these different methodological approaches, different data period, and country specific outcomes and inferences make the paper novel and an original contribution to literature.

This paper is organized in various sections in the following manner. After introduction, we present a literature review. In section three, we provide details of the methodology used during this research. In this section, we provide relevant information on the data, variables, and econometric technique used in this study. Section four is related to the empirical results of unit roots test and T-Y Granger causality test. In the last section, we provide conclusion and policy implications.

2. Literature Review

Literature on energy-growth nexus provides evidence of mixed and conflicting results (Yuan et al., 2008; Jan et al., 2020; Oryani et al., 2022). The conflicting nature of results is because of the heterogeneity of data sets and temporal and methodological variations in various studies. Based on the causality between EC and GDP, four types of hypotheses have been identified in literature (Apergis et al., 2010; Ikhide & Adjasi, 2015; Marques et al., 2016; Thao & Chon, 2016; Zaidi & Ferhi, 2019; Durrani et al., 2021; Filippidis et al., 2021; Husaini & Lean, 2022; Zhang et al., 2022). In the first case, the results exhibit a causality that runs from GDP to EC (Kraft & Kraft, 1978; Al-Iriani, 2006; Li et al., 2011; Ouedraogo, 2013; Dudzevičiūtė & Šimelytė, 2017; Furouka, 2017). This kind of hypothesis is referred to as conservation hypothesis. The conservation hypothesis confirms that GDP is the major driver of EC (Oryani et al., 2022). This hypothesis recommends for energy conservation policies having little or no effects on GDP. In the second case, EC leads to GDP, and is referred to as growth hypothesis (Siddiqui, 2004; Kakar & Khilji, 2011; Arouri et al., 2014; Mutascu, 2016; Gozgor et al., 2018; Husaini & Lean, 2022). In this case, energy conservation policies are not recommended as they may negatively affect GDP. The growth hypothesis suggests for increased energy production and consumption which flourishes GDP. In the third case, a bidirectional relationship is asserted between EC and GDP. This type of relationship is summed up in the feedback hypothesis (Omri & Chaibi, 2014; Alper & Oguz, 2016; Kahia et al., 2016; Rodríguez-Caballero & Ventosa-Santaulària, 2016; Tiba & Omri, 2017; Durrani et al., 2021;). According to this hypothesis, EC and GDP are complementary to each other and a change in one causes a change in the other. This is the reason why feedback hypothesis emphasizes on energy exploration and efficiency policies. The fourth case, the neutrality hypothesis, confirms no causality between EC and GDP (Zhang & Cheng, 2009; Jalil & Feridun, 2014; Yildirim et al., 2014).The neutrality hypothesis calls for energy efficiency policies. A recap of literature on causality between EC and GDP is provided in Table 1.

Table 1: Literature on EC-GDP Nexus

Study	Period	Country	Methods	Relationship
Omri & Chaibi (2014)	1990- 2011	Developed and developing countries	DSEMs and GMM	EC↔GDP for Pakistan
Pin (2014)	1982-2011	OECD countries	ARDL bounds test, VECM Granger causality	Mixed results
Ahmed & Azam (2015)	30 years, varying	119 countries	Granger causality test	Mixed results
Alper & Oguz (2016)	1990–2009	New EU member countries	Asymmetric causality test and ARDL bounds test	EC←GDP (Czech Republic)
Destek (2016)	1971-2011	Newly	Asymmetric	EC– GDP

		industrialized countries	causality approach	(Brazil and Malaysia)
Luke (2016)	1990-2011	Sub-Sahara African countries	Panel cointegration, Granger causality test	EC←GDP
Marques et al., (2016)	1965-2013	Global	ARDL bound test and T-Y causality test	EC↔GDP
Nadeem & Munir (2016)	1972-2014	Pakistan	ARDL bound test, Granger causality test	Mixed results
Narayan (2016)	1984-2010	135 countries	Panel data predictive regression model	EC– GDP
Tang et al., (2016)	1971-2011	Vietnam	Cointegration and Granger causality	EC→GDP
Thao & Chon (2016)	1990-2012	OECD countries	Stochastic distance function	EC→GDP
Carmona et al., (2017)	1980-2013	Oil exporting countries	Cointegration and Granger causality	EC↔GDP
Koçak & Şarkgüneşi (2017)	1990–2012	Black Sea and Balkan countries	Panel cointegration, Heterogeneous panel causality approach	EC–GDP (Turkey)
Gozgor et al., 2018	1990-2013	OECD countries	Panel ARDL and PQR	EC→GDP
Jan et al., 2020	1972–2015	Pakistan	ARDL bound test	EC→GDP
Durrani et al., 2021	1972-2015	Pakistan	T-Y causality test	EC↔GDP
Husaini & Lean, 2022	1980-2017	Asia	Threshold estimation	EC→GDP
Oryani et al., 2022	1976-2017	Iran	ARDL, cointegration test, causality	EC←GDP

Note: EC→GDP shows the direction of causality running from EC to GDP. EG←GDP signifies the direction of causality running from GDP to EC. EC↔GDP symbolizes bidirectional causality between GDP and EC. EC–GDP means no causality between EC and GDP. ARDL means autoregressive distributed lag, VECM means vector error correction model, T-Y means Toda-Yamamoto causality test, DSEMs means dynamic simultaneous-equation models and GMM means generalized method of moments.

3. Methodology

3.1. Data Sources and Variables

In this study, we employed the basic production function containing only two variables, i.e. capital and labor and extended this basic function by adding FFC, HEC, and NEC in it. Annual time series data on GDP, gross capital formation (K), labor (L), FFC, HEC and NEC for Pakistan for the period 1972-2015 has been used in this study. Data on gross domestic product (GDP) and gross capital formation was obtained from the World Development Indicators (WDI) database (WB, 2017). Data on labor force was taken from various issues of the Economic Survey of Pakistan (published by the Ministry of Finance, Government of Pakistan). Data on fossil fuels consumption, HEC, and NEC was retrieved from British Petroleum's (BPs) Statistical Review of World Energy 2016 (BPS, 2017).

We use GDP in constant US$ 2010 as a dependent variable (Li et al., 2011). Explanatory variables include labor, gross capital formation, FFC, HEC, and NEC. Labor is measured in million whereas gross capital formation is measured in constant US$ 2010. Fossil fuels consumption is measured in Million Tons of Oil Equivalent (MTOE) whereas HEC and NEC are measured in Terawatt-Hour (TWh) (Jan et al., 2020; Durrani et al., 2021). All the variables were measured in natural logarithms. E-Views v.10 was used for data analysis.

3.2. Model Specification

We examined the direction of causality between Pakistan's major sources of EC (at disaggregated level) and GDP using the following basic model:

$$Y_t = f(L_t, K_t, FFC_t, HEC_t, NEC_t) \quad (1)$$

Where Y denotes GDP, L denotes labor, K denotes gross capital formation, FFC means fossil fuel consumption, HEC means hydroelectricity consumption, and NEC means nuclear energy consumption.

All of the study variables are converted into log form. The econometric model to be estimated is:

$$LNY_t = \beta_o + \beta_1 LNL_t + \beta_2 LNK_t + \beta_3 LNFFC_t + \beta_4 LNHEC_t + \beta_5 LNNEC_t + \varepsilon_t \quad (2)$$

Where β_0 = intercept, β_1 to β_5= coefficients that are interpreted as elasticity in logarithmic models, ε_t = error term in time t.

3.3. Unit Root Tests

It is essential to check time series data for the unit root. In the presence of a unit root, the model will generate spurious, biased and meaningless results (Gujarati & Porter, 2009). We used the Augmented Dickey-Fuller (ADF) (Chiou-Wei, 2008) and Break Point (BP) (Lee, 2006) unit root tests to avoid unit root problem. We conducted unit root tests both with (Eq. 3) and without allowing for a time trend (Eq. 4) (Oh & Lee, 2004).

$$\Delta Y_t = \alpha + \beta_t + \delta Y_{t-1} + \sum\nolimits_{i=1}^{p} \beta_1 Y_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum\nolimits_{i=1}^{p} \beta_1 Y_{t-1} + \varepsilon_t \quad (4)$$

Where, ΔY_t means 1st differenced value of variable to be tested in time t; α means intercept; β_t means time trend; Y_{t-1} means the first lag of variable; δ means parameter to be estimated; p means number of lags; and ε_t means error term in time t.

Our null and alternative hypotheses are: $H_0: \delta = 0$ (depicting nonstationarity) and $H_A: \delta < 0$ (depicting stationarity). The null hypothesis of unit root tests is compared with the significance levels of 1%, 5%, and 10%. In order to reject the null hypothesis, the probability value of ADF or BP statistics should be less than the specified significance level. Besides, if the probability of trend is found significant at 1%, 5%, and 10% level, then the results of model with intercept and trend are accepted (i.e. Eq. 3). Nonetheless, if the trend is found insignificant, then the decision about stationarity of a variable is made on the basis of model with intercept only (i.e. Eq. 4).

3.4.Optimum Lag Selection

In this study, the Akaike's Information Criterion (AIC) has been used for selecting optimum number of lags for the model. The AIC is significant over other criteria if the number of observations is small (Liew & Khimm, 2004). For 60 observations or below, AIC is a more reliable and accurate criterion.

3.5.Toda-Yamamoto Causality Test

The direction of causality was determined by using Toda-Yamamoto causality test (Toda & Yamamoto, 1995; Leiva & Liu, 2018). T-Y test is preferred for determining causality because this test can be applied without considering the integration order of the selected variables. It means that we can use this test if all variables are integrated at levels or at difference or both. This test can also be applied regardless of the presence or absence of cointegration (Soytas & Sari, 2009). The following general form of the equations has to be estimated:

$$Y_t = \alpha + \sum_{i=1}^{h+d} \beta_i Y_{t-i} + \sum_{j=1}^{k+d} \beta_j X_{t-j} + \varepsilon_t \quad (5)$$

$$X_t = \alpha + \sum_{i=1}^{h+d} \gamma_i X_{t-i} + \sum_{j=1}^{k+d} \gamma_j Y_{t-j} + \varepsilon_t \qquad (6)$$

Where, d is the maximum order of integration of the variables; h and k are optimum lags of Y and X, and ε_t is the error term.

4. Analysis and Discussion

4.1. Unit Root Tests

The results of ADF and BP unit root tests for GDP (Y), L, K, FFC, HEC, and NEC along with their order of integration are illustrated in Table 2. The table confirms that the unit root tests produce mixed results about the variables being I(0) and I(1). Integration order of each variable is decided following ADF test that does not consider structural break in the data series and a Break Point unit root test that considers a single structural break when testing for unit root.

Table 2: Unit Root Tests Results

	Variable	ADF	Decision	BP	Decision
Level					
I	LNY	-1.858222		-0.2666 (1992)	
	LNL	-0.696935		-3.862556 (1996)	
	LNK	-3.382422**	I(*0*)	-4.532775 (2004)	I(*0*)
	LNFFC	-3.268340**	I(*0*)	-4.407659 (1978)	
	LNHEC	-2.267476		-3.713505(2003)	
	LNNEC	-1.403973		-4.306537**(1999)	
I & Γ	LNY	-1.020664		-1.013616 (2009)	
	LNL	-1.681005		-0.719640 (1996)	
	LNK	-2.316333		-5.130789** (1991)	
	LNFFC	0.396322		-2.726607 (2005)	
	LNHEC	-1.966210		-4.169948(1986)	
	LNNEC	-2.900759		-5.606595**(2002)	
First difference					
I	LNY	-4.359346***		-5.162705** (1992)	
	LNL	-6.962707***		-7.16885*** (2010)	
	LNK	-5.752976		-4.84811*** (1993)	
	LNFFC	-4.214846***		-5.82469*** (2004)	
	LNHEC	6.966780***		-7.29408***(1988)	
	LNNEC	-6.905983***		-8.06017***(1999)	
I & Γ	LNY	-4.781955***	I(*1*)	-5.161639 (2003)	I(*1*)
	LNL	-6.909658***	I(*1*)	-8.75798*** (1996)	I(*1*)

LNK	-5.952431***		-6.34264*** (2005)	
LNFFC	-4.988945***		-5.519503** (2003)	I(*1*)
LNHEC	-7.432628***	I(*1*)	-7.57556***(1979)	I(*1*)
LNNEC	-6.881003***	I(*1*)	-10.2694***(1999)	I(*1*)

Note: ***, **, * represents significance at 1%, 5%, and 10% respectively. The years in the parentheses indicates break year. *I* shows intercept and *I & Γ* show intercept and trend.

Table 2 shows that the two unit root tests provide mixed and somewhat contradicting results. Both tests concur that GDP, labor, HEC and NEC are stationary at first difference and are integrated of order I(1). However, the results are contradicting for FFC. For FFC, the results of ADF test indicate stationarity at level, i.e. I(0), whereas the results of the BP test show startionarity and first difference, i.e. I(1). For labor, both ADF and BP unit root tests are showing the same order, i.e. I(0). Comparing the results of two unit root tests, the results of BP test are preferred due to incorporation of structural break in it, and hence, are used to decide integration order of variables. According to BP unit root test, it is concluded that except for labor, all other variables failed to reject the null hypothesis at level. Hence, the unit roots results indicate that the dependent variable and all explanatory variable except labor are stationary at first difference and are I(1).

4.2.Optimum Lag Selection

We use VAR lag order selection criteria to select the appropriate number of lags (Razzaqi et al., 2011). We used different lag order selection criteria to decide the lag length (Zhang & Cheng, 2009). The results of VAR lag order selection criteria for VAR model are provided in Table 3. The table confirms that the number of lags selected by AIC is two. In our study, three among five criteria are selecting one as optimal lag. However, we select two lag as optimum because the model run with two lags perform better and pass all the diagnostic tests. In contrast, model with one lag exhibits the problem of serial correlation and dynamic instability. The auto-regressive (AR) root graph and other relevant tests applications confirm that the model is dynamically stable at two lags (see Figure 2) and is free from non-normality, serial correlation, and heteroskedasticity issues.

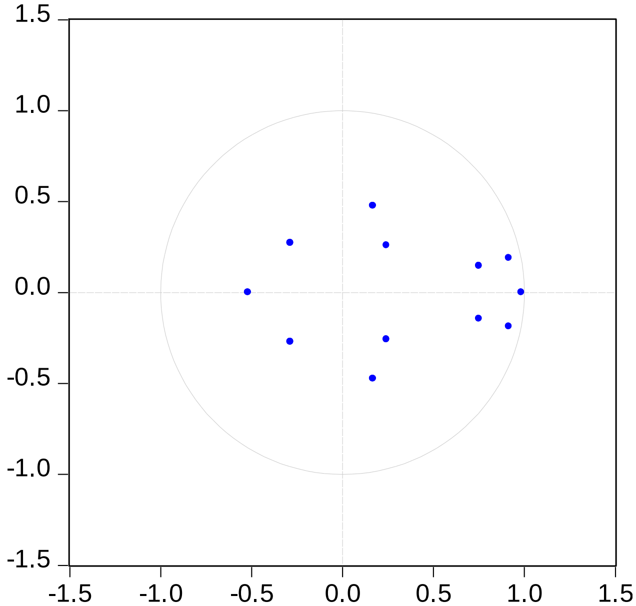

Figure 2: Inverse Roots of Auto-regressive Characteristic Polynomial

Table 3: VAR Lag Order Selection Criteria

Lag	LogL	LR[a]	FPE[b]	AIC[c]	SC[d]	HQ[e]
0	148.5196	NA	4.00e-06	-6.757055	-6.339111	-6.604863
1	230.7338	36.3552*	8.84e-08	-10.57238	-9.987257*	-10.35931*
2	235.5195	7.470385	8.57e-08*	-10.61071*	-9.858407	-10.33676
3	238.3091	4.082382	9.21e-08	-10.55166	-9.632187	-10.21684

* indicates optimum lags selected by the criterion (at 5% level).
[a]Sequential modified LR test statistic (LR), [b]Final prediction error (FPE), [c]Akaike information criterion (AIC), [d]Schwarz information criterion (SC), and [e]Hannan-Quinn information criterion (HQ)

4.3.Results of T-Y Granger Causality Test

The T-Y Granger causality test was carried out by using modified WALD (MWALD) test to investigate the direction of causality between EC and GDP (Alper & Oguz, 2016). In our model, the maximum integration order is I(1) and maximum lag length is 2 lags. Table 4 shows results of the T-Y Granger causality test. The results confirm that in panel A, all variables except labor reject the null of non-Granger causality at 10%, 1%, and 5% levels respectively. These results suggest that labor does not cause GDP. However, the remaining variables such as gross capital formation, FFC, HEC, and NEC are significantly Granger causing GDP of Pakistan. The results are in consensus with those of Gozgor et al., (2018) who found that both renewable and non-renewable energy consumption are positively associated with economic growth in 29 OECD countries. In panel B, gross capital formation, FFC, and NEC are significantly Granger causing labor at 5% level and the rest of the variables fail to reject the non-causality null in case of GDP and labor, and HEC and labor. In case of panel C, however, the results are opposite to panel B. In panel C, the GDP and HEC are Granger causing the gross capital formation at 5% and 1% level respectively. Contrary to that, labor, FFC, and NEC fail to cause the gross capital formation, as none of them reject the null of non-causality at any prescribed significance level. In case of panel D, with FFC as dependent variable, only GDP is significantly causing the FFC at 10% level. All other variables including labor, gross capital formation, HEC, and NEC are failed to reject the null of non-causality. In panel E, no other variable other than NEC is significantly Granger causing the HEC. In penal F, where NEC is taken as a dependent variable in MWALD test, only FFC was causing NEC. The remaining four variables failed to reject the null of non-causality. Similar results were reported by Husaini & Lean (2022) and Oryani et al., (2022).

Table 4: Results of T-Y Granger Causality Test

	Dependent variable	Excluded variables	Chi-square	Probability
Panel A	LNY	LNL	2.287107	0.3187
		LNK	4.808387*	0.0903
		LNFFC	5.721649*	0.0572
		LNHEC	10.28256***	0.0059
		LNNEC	6.577388**	0.0373
Panel B	LNL	LNY	0.229032	0.8918
		LNK	6.280045**	0.0433
		LNFFC	8.934992**	0.0115
		LNHEC	3.461423	0.1772
		LNNEC	8.002591**	0.0183
Panel C	LNK	LNY	7.021431**	0.0299
		LNL	1.738061	0.4194
		LNFFC	3.949095	0.1388
		LNHEC	11.32432***	0.0035
		LNNEC	3.507478	0.1731
Panel D	LNFFC	LNY	5.678164*	0.0585

		LNL	0.604023	0.7393
		LNK	2.020159	0.3642
		LNHEC	0.754212	0.6858
		LNNEC	1.918292	0.3832
Panel E	LNHEC	LNY	0.108051	0.9474
		LNL	3.515819	0.1724
		LNK	0.556998	0.7569
		LNFFC	2.811650	0.2452
		LNNEC	6.832299**	0.0328
Panel F	LNNEC	LNY	0.781551	0.6765
		LNL	3.379927	0.1845
		LNK	2.911404	0.2332
		LNFFC	6.330418**	0.0422
		LNHEC	4.471844	0.1069

Note: ***, **, * represents respective significance at 1%, 5%, and 10% levels.

We provide an overview of the above results and the associated direction of causality in Table 5. The table shows that no causality exists between GDP and labor force. However, a bidirectional causal relationship between GDP and gross capital formation occurs. The results further validate a growth hypothesis for HEC and GDP and NEC and GDP. The findings are in consensus with those of Aqeel & Butt (2001) and Wolde-Rufael (2004) who confirmed growth hypothesis between electricity use and GDP growth for Pakistan and Shanghai, respectively. Likewise, the study by Omri & Chaibi (2014) supported growth hypothesis between NEC and GDP for Belgium and Spain. In case of FFC and GDP, a feedback hypothesis is confirmed for Pakistan. Similar findings were reported by Bildirici & Bakirtas (2014) who found bidirectional causality between coal consumption and GDP for China.

Table 5: Direction of Causality between Variables

No Granger Causality	Unidirectional Granger Causality	Bidirectional Granger Causality
LNY – LNL	**LNHEC → LNY**	LNY ↔ LNK
LNHEC − LNL	**LNNEC → LNY**	**LNY ↔ LNFFC**
LNFFC − LNK	LNK → LNL	
LNNEC − LNK	LNFFC → LNL	
LNHEC − LNFFC	LNNEC → LNL	
	LNHEC → LNK	
	LNFFC → LNNEC	
	LNNEC → LNHEC	

Note: −, →, ↔ indicate no, unidirectional, and bidirectional Granger causality at1%, 5%, and 10% levels, respectively.

5. Conclusion

This study probes causality between major sources of EC and GDP of Pakistan over the period 1972 to 2015. ADF and BP unit root tests were used for testing stationarity of the data series. Only gross capital formation was found stationary at level. The rest of all variables became stationary after differencing and were integrated of order I(1). Given the mixed integration order, T-Y Granger causality test was employed for investigating the direction of causality among the variables of interest. Results of the Granger causality tests confirm the existence of feedback hypothesis for GDP and FFC. Besides, the findings also confirm the growth hypothesis for hydroelectricity and NEC and GDP. Based on the findings of this study, it is recommended that government should focus on expanding the supply of energy along with the diversification of energy mix. The focus of the government policy should be on increasing the renewable energy sources in the total energy mix. This will promote economic growth as well as global environmental sustainability which are hampered by carbon emission from non-renewable energy consumption.

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