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Effect of Energy Utilization on Pakistan's Economic Development: A Time Series Analysis

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ABSTRACT

The present research has been conducted to study the causal relation among GDP, electricity utilization, exports, real capital and labor force for Pakistan. Time dependent data for the mentioned parameters have been used for the time period of 1980 to 2022. Inter-relations among the above-mentioned variables have been studied in this work by the method of cointegration using bounds test. The results illustrate that there is an existence of long run relation among the parameters where GDP has been taken into consideration as the dependent variable. Granger causation analysis has also been performed for the variables. Results show that Granger causality between GDP and electricity utilization runs in both directions. Moreover, the study discloses that Electricity utilization granger cause exports and per capita real capital. Exports granger cause per capita real capital. Per capita real capital granger cause GDP. Labor force granger cause GDP and exports. The long run relation equation of GDP, Electricity utilization, exports, real capital and labor force has also been examined for parameter stability. The parameters are found to be stable with the significance level of 5%. The research also suggests some significant strategy recommendations.

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1. Introduction

The implication of energy utilization in nurturing the economic progress is vital. In the first research done by (Kraft & Kraft, 1978)many econometric techniques were used to discover the time series relation among economic progress and energy. Since the 1970s, there has been increased focus on the course of causation among energy utilization and economic progress (Magazzino et al., 2021). Although many of the earlier researches accredits the initial effort to (Kraft & Kraft, 1978), research conducted by (Carter, 1974), predated it (Mutumba et al., 2021). But the utmost significant discussion is regarding the dynamic causal affiliation among energy utilization and economic development, which is extremely beneficial to energy and macroeconomists for policy formulation (Shahbaz et al., 2013).

Economic theories imply the presence of an affiliation amongst energy utilization and economic development. Nonetheless, this does not essentially infer that they are causally related. The course, intensity, and steadiness of the association among energy utilization and GDP (gross domestic product) have a noteworthy effect on the making of energy policies. For instance, if causality is unidirectional between electricity use and economic development, decreasing energy utilization might result in a decline in economic progress. Alternatively, if causality is unidirectional from economic progress to electricity utilization, then a decrease in power consumption may have slight to no negative effect on economic progress (Halicioglu, 2011).

The most illuminating argument in the energy-GDP debate is that energy is an obligatory production input since other production aspects, such as capital and labour, cannot be utilised without it. Consequently, energy utilization is considered as a factor that restrains economic progress. The second element is founded on the neutrality theory, that states, energy don't have any effect on economic development. The reason energy is impartial to economic progress is because of the fact that energy costs are negligible in comparison to GDP. In addition, the effect of energy utilization on economic development will be contingent on the economy framework and the rate of economic progress. As discussed by Denison (2011) and Solow (1978), as a consequence of economic progress the structure of production is expected to transform in a direction of service sectors, that have not their main focus on energy. Prevailing Granger causation researches on the energy and GDP link for Turkey typically employ a two-factor configuration, with the exception of Halicioglu (2011) and Soytas and Sari (2009). The first study reveals indication of a long-term causal relation among income and energy utlization, while the second study provides no such evidence.

In research of around one hundred nations, Chontanawat et al. (2008) discover that, connection among energy utilization and economic progress has been stronger among advanced nations than in emerging nations. In only 35% of the deprived nations, 42% of the countries of middling income, and 69% of the countries with high-income was a causal connection found among energy utilization and economic progress. In an analysis of six developing nations, Sari and Soytas (2007) discovered that power/energy is a vital aspect in production. Wolde-Rufael (2005) found contradictory evidence in a two-factor association among energy utilization and economic progress in countries of Africa, with the impartiality hypothesis supported in a considerable figure of nations and minute support for the theory that energy utilization results in financial progress. By means of a multivariable causation test, Akinlo (2008) also discovered contrary outcomes for eleven countries of African region. Chiou-Wei et al. (2008) application of linear and nonlinear Granger causation to eight afresh industrialized Asian and American nations yields contradictory results (Wolde-Rufael, 2009).

Researchers have proposed a number of testable hypotheses regarding the association among energy utilization and economic progress and the corresponding policy insinuations. First, the "growth" theory declares that power/energy utilization has noteworthy influence on economic development, both straightaway and as an accompaniment to labour and capital in the course of production. Granger-causation supports the "growth" hypothesis if an upsurge in power utilization results in a rise of actual gross domestic product (GDP). The policy insinuations of the "growth" hypothesis infer that power conservation-focused strategies might have an adverse impact on economic progress. Alternately, if a rise in power utilization has an adverse effect on the GDP, multiple interpretations appear. For instance, a growing economy may necessitate a decline in power utilization as production transfers to service sectors which are less focussed on energy. Alternately, the adverse effect of power utilization on GDP can be ascribed to unnecessary power utilization in segments of the economy which are unproductive, capacity restraints, or an ineffective supply of energy (Payne, 2010). Secondly, the "conservation" hypothesis suggests that power preservation strategies, like as the lessening in greenhouse gas emanations, efficiency enhancement actions, and policies for demand management, intended to decrease power utilization and waste may not have a negative influence on GDP. If an increase in GDP results in an improvement in power utilization, then the "conservation" hypothesis is supported.

However, a rising economy restrained by political, infrastructural, and mishandling of funds and resources might lead to inadequacies and a deterioration in demand for products and facilities, including power utilization. If this is the situation, then a rise in GDP may have an adverse effect on utilization of energy. Thirdly, according to the "neutrality" hypothesis, energy utilization is a minute percentage of GDP, so it must not have a momentous effect on financial progress. In this occurrence, energy preservation strategies (as in the "conservation" hypothesis) may have no adverse effect on GDP. The lack of Granger causality among consumption of power and GDP offers backing for the "neutrality" hypothesis. Fourth, the "feedback" hypothesis proposes that GDP and power utilization are co-dependent and may serve as complements to one another. Increase or decrease in energy or power consumption results in upsurge or reduction in GDP, and vice versa. In this instance, indication of bilateral Granger-causality among consumption of energy and GDP affirms the "feedback" hypothesis. Thus, the policy for energy focused on enhancing efficiency of power consumption might not have an adverse effect on GDP (Payne, 2010).

The relation between gross domestic product of India, direct foreign investment, and energy utilization has been studied by Kumari and Sharma (2018). Their data showed that energy utilization is having a substantial impact on the GDP, and that a higher GDP encourages foreign direct investment in India. In addition, Zhang et al. (2019) utilised the index composition method to determine which variables influenced China's energy consumption from 1990 to 2016. In addition, they compared the factors affecting economic progress and energy utilization to the current state of decoupling. Their data demonstrated that economic expansion is the primary cause of China's rising energy utilization. The impacts of adoption of renewable energy, electrical power costs, and emission trading on the Group of seven countries were examined by Ike et al. (2020). Green power and energy costs were discovered to have an adverse effect on emission of CO2, whereas international trade had a substantial positive impact. They also noted that the cost of energy is having an opposing effect on carbon dioxide (CO2) production. Magazzino et al. (2020) suggests a comprehensive examination of the procedure causing the abolition of nuclear power technology from Switzerland to evade negative impacts on economic progress. Magazzino and Cerulli (2019) discovered that although energy utilization is having an encouraging impact on GDP, it’s effect on urban population is negative. Table 1 provides summary of empirical studies performed until now. → denotes short term, ← denotes long term and ↔ means both long and short term.

Table 1
Selected Empirical Studies

References	Region	Variables	Methodology	Results
Narayan et al. (2010)	Global	GDP, energy utilization	Panel Granger causality	Energy utilization → GDP
Halicioglu (2011)	Turkey	Aggregated output, exports, energy, capital, labour	Granger causality	Energy utilization → output, Exports → output
Longxing et al. (2011)	China	energy utilization, GDP	Gradational mode	Energy utilization ↔ GDP
Shahbaz et al. (2012)	Pakistan	energy utilization, GDP	VECM, ARDL	Energy utilization ← GDP
Kasperowicz (2014)	Poland	energy utilization, GDP	Granger causality	Energy utilization ↔ GDP
Bekhet et al. (2016)	Malaysia	energy utilization, GDP	Multiplier approach	Energy utilization → GDP

Lu (2016)	Taiwan	energy utilization, GDP	Granger causality	Energy utilization ↔ GDP
Varma (2019)	India	Energy demand, energy supply	Dynamic modelling	Energy Demand ↔ Energy supply
Alsaedi and Tularam (2020)	Pakistan	Energy Utilization, electricity prices, GDP	VECM	Energy utilization ↔ Electricity prices, Energy utilization → GDP

1.1 Rationale and Scope of the Study

An examination of the available literature addresses the backgrounds, research areas, short- and long-term causal impacts, numerous econometric techniques, and pertinent variables utilised by the researches of specific time series from various nations in order to offer detailed insights into the possible causes influencing GDP. Recent studies have analysed a variety of crucial determinants of national GDP and found that economic expansion increases electricity consumption (Khan et al., 2021; Nasreen et al., 2020). Variables that influence a nation's GDP are discovered to be diverse. Urbanisation is having noteworthy impact on the rate of economic progress. Although the majority of Pakistan's 212.2 million people still reside in rural areas, urbanisation in Pakistan is the fastest in South Asia, occurring at a rate of 3% per year. According to projections made by the UN Population Bureau (Jabeen et al., 2017), urban areas will be home to almost half of the world's population by 2025. This research is novel because it employs an econometric model with new variables, such as carbon emissions, energy prices, and urbanisation, which have not previously been investigated in the Pakistani context.

The main objective of the study is to empirically analyses the impact of energy utilization, capital, labour and exports on Pakistan's economy. Moreover, the impact of each variable on dependent variable will also be the objective of this research. The following are specific objectives of the study;

- To apply advanced econometric methods, including the use of an augmented neo-classical aggregate production function, bounds testing for cointegration, and Granger causation analysis, on time series facts and figures to determine the dynamic causal relationships between the identified variables and their impact on Pakistan's economy. This will encompass both short-run and long-run analysis to thoroughly understand these relationships.

- Based on the econometric analysis and research findings, to derive meaningful policy implications and propose actionable recommendations for Pakistan's economic growth strategy. This should ideally focus on the optimal utilization and balancing of energy consumption, capital, exports, and labour to stimulate and sustain economic growth.

2. Literature Review

2.1 Energy Utilization and Economic Growth: World's Perspective

Regarding the energy Utilization and growth nexus, the observed literature offers contrary and vague evidence. This disparity in results is primarily attributable to the use of various econometric methodologies and time stages, as well as nation-specific heterogeneity in environmental situations, economic development, and energy utilization outlines, among other factors (Belke et al., 2011). After 1970s, there was considerable experiential research attention in the chronological causality among energy utilization and economic development or employment, but no convincing outcomes nor substantial clarifications have been revealed. The study endeavour, greatly aided by recently developed statistical techniques, required to determine that economic development takes priority on energy utilization or energy utilization can stimulate economic development. In recent years, the advancement of econometric procedures has encouraged additional experiential research on the energy utilization and economic development debate, albeit with enigmatic outcomes. Regarding policy concerns, the question is if the implementation of energy conservation processes is a growth stimulant or the contrary, the pertinent literature pertaining to the likelihood or practicability of the adoption of methods to save energy (Hondroyiannis et al., 2002).

In the worldwide discussion on worldwide warming and the decrease of greenhouse gas emissions, the issue of whether or not energy preservation regulations have an impact on economic activity is of major importance (Nazir et al., 2023; Wang et al., 2023). Although the linking among energy use and economic development has been extensively investigated, no agreement has yet been established on this so-called energy utilization and growth connection. For policymakers, the causality's direction is quite important. For instance, energy preservation agendas that attempt to lessen energy consumption might have a damaging effect on an economy's development if the causal chain connects energy usage to economic development. The literature presented by Apergis and Payne (2009) offers four distinct ideas addressing the potential results of causality. The growth theory posits that energy utilization is having a vital impact in economic development, either directly or indirectly, by serving as an accompaniment to capital and labor as participation components in the production process. Therefore, a reduction in energy usage results in a corresponding decline in real GDP. In the particular scenario, economy has been referred to as being energy dependent, indicating a significant reliance on energy resources.

The implementation of energy preservation agendas in such a context may have negative consequences for the actual GDP. In contrast, the conservation theory posits that actions aimed at reducing energy use may neither significantly or negatively affect real GDP. The hypothesis postulates a unidirectional causal link whereby real GDP influences energy use. The concept of two directional causation aligns with the feedback theory, which postulates that energy utilization and real GDP mutually affect one another in a simultaneous manner. In this scenario, it is imperative for policy makers to consider the reciprocal association among real GDP and energy utilization, and therefore, enact regulatory measures aimed at mitigating energy use. The neutrality theory posits that there is no momentous association among changes in energy utilization and financial development, suggesting that alterations in one parameter do not have a discernible influence on the other parameter, and vice versa. Therefore, it may be concluded that energy conservation regulations would not have any influence on the actual GDP (Belke et al., 2011).

The relationship among energy usage and economic growth has fascinated a great deal of scholarly consideration, generating a multitude of theoretical frameworks and empirical studies. Robert Solow's 1956 seminal work on the theory of economic development provided the initial foundation for discussions on the role of energy factor inputs. However, it was not until the oil crises of the 1970s that the relationship among energy utlization and economic prosperity came under intense scrutiny (Stern, 1993). In the context of macroeconomics, numerous models have been proposed to explain this relationship. For instance, the Cobb-Douglas production function has frequently been extended to include energy as an independent variable alongside labour and capital (Kraft & Kraft, 1978). These models generally hold that energy has been an indispensable participant in the production method, implying a unidirectional causal affiliation among energy usage and financial development. In contrast, the bidirectional causality theory suggests that energy utilization and financial growth mutually reinforce one another. Under this paradigm, an escalation in GDP would necessitate an upsurge in industrial energy consumption, whereas a rise in energy utilization drives economic activity (Apergis & Payne, 2014). The feedback theory, which expands on bidirectional causality, suggests that the association among energy use and financial development is energetic and subject to temporal fluctuations (Ozturk, 2010).

It is impossible to overstate the importance of energy efficiency as a mediator in this relationship. The Environmental Kuznets Curve (EKC) hypothesis proposes a U-shaped relationship between economic growth and environmental degradation, including energy inefficiency (Stern, 2004). Utilizing the EKC framework, Tugcu et al. (2012) investigated whether economic growth can be decoupled from energy consumption, thereby leading to sustainable development. In addition, the research direction has begun to examine the participation of renewable energy sources as a mediator between energy utilization and economic development. According to Inglesi-Lotz (2016), renewable energy reduces the negative externalities associated with conventional energy utilization, producing a more sustainable link among energy utilization and economic development.

Additionally, regional studies have augmented the existing literature. In emerging economies, the pliability of GDP to energy utilization is generally higher than in developed nations, indicating that energy utilization has a more pronounced impact on economic development (Wolde-Rufael, 2004). Finally, the policy implications of these investigations are numerous. Sign of a long-term equilibrium among energy utilization and economic development emphasizes the need for prudent energy policy planning. In particular, the changeover to renewable energy sources is a catalytic agent for sustainable economic development (Apergis & Payne, 2014).

2.2 Energy Utilization vs Economic Growth for CIS

The Commonwealth of Independent States (CIS) consists of twelve nations that were once part of the Soviet Union. Although several countries within the CIS may be classified as transition economies, they have significance in global energy markets as both oil and natural gas producers and as crucial hubs for the transportation and distribution of these valuable commodities. Given the significant role of this area in global energy markets, it is very unexpected that no empirical research has been published to investigate the correlation among energy utilization and economic development in this particular set of nations. Figure 1 presents a comprehensive depiction of the energy production, utilization and the environmental consequences associated with energy utilization and the degree of economic development in CIS area. Russia dominates the Commonwealth of Independent States (CIS) in terms of crude production and is the world's leading oil producer. Russia, Kazakhstan, and Azerbaijan are clear exporters of crude, whereas the remaining CIS nations are clear importers. Regarding natural gas production, Russia has the major natural gas reserves in the world with 1,680 trillion cubic feet, approximately double the reserves of Iran, which has the second major natural gas reserves.

In addition, Russia is the main producer and exporter of natural gas in the globe. Although Turkmenistan and Uzbekistan trail Russia in terms of natural gas production, both nations have writhed to bring their considerable oil and natural gas reserves to international markets due, in large part, to a lack of pipeline infrastructure for exporting natural gas to end-use markets. Over fifty percent of Ukraine's energy use is comprised of natural gas. The remaining CIS nations depend on natural gas imports from Russia to fulfil their natural gas utilization requirements. Compared to oil and natural gas production, coal production and usage in the CIS is less substantial. Coal production in the CIS is concentrated in Russia (who has the world's second major recoverable coal assets behind the U.S.), Kazakhstan, and the Ukraine (Apergis & Payne, 2009).

The association among energy usage and economic development in the Commonwealth of Independent States (CIS) entails a complex interplay that requires in-depth analysis. This relationship is especially significant for CIS nations due to their distinctive economic structures, abundant natural resources, and economies in transition. Given the central role that energy sectors such as oil, gas, and coal play in these economies, it is crucial not only for economic forecasting but also for policy formulation and strategic planning to comprehend the causality and interdependencies.

	Armenia	Azerbaijan	Belarus	Georgia	Kazakhstan	Kyrgyzstan	Moldova	Russia	Tajikistan	Ukraine	Uzbekistan
Petroleum											
Production	0.00	440.98	33.70	1.98	1337.90	1.96	0.00	9512.98	0.28	100.39	124.91
Consumption	40.00	115.00	156.00	13.40	234.00	12.00	14.50	2757.00	30.00	328.00	155.00
Natural gas											
Production	0.00	205.50	6.10	0.50	934.80	1.10	0.00	22,622.80	1.40	685.10	2108.00
Consumption	60.00	366.60	716.90	52.10	1075.30	26.10	86.50	16,153.10	50.50	3079.50	1702.20
Coal											
Production	0.00	0.00	0.00	0.00	95.40	0.40	0.00	320.60	0.10	66.50	3.30
Consumption	0.10	0.00	0.30	0.00	69.00	1.50	0.20	258.40	0.10	68.40	3.20
Electricity											
Production	6.32	21.22	30.96	7.27	67.92	16.42	3.86	951.16	17.09	185.92	47.71
% Oil	0.00	27.68	8.40	0.91	7.41	0.00	0.23	2.23	0.00	0.27	13.63
% Natural gas	28.94	58.14	91.38	13.28	10.68	9.52	98.14	46.16	2.35	18.65	68.85
% Coal	0.00	0.00	0.01	0.00	70.34	3.62	0.00	17.42	0.00	26.66	4.68
% Hydroelectric	28.07	14.18	0.11	85.81	11.57	86.87	16.30	18.15	97.65	6.65	12.84
% Nuclear	43.00	0.00	0.00	0.00	0.00	0.00	0.00	15.71	0.00	47.74	0.00
Consumption	4.20	19.20	29.50	7.40	58.00	8.20	5.60	779.40	14.70	142.20	40.90
Energy intensity	4.91	2.77	3.14	4.91	2.51	3.18	2.39	2.62	2.80	1.84	1.12
Carbon dioxide											
Emissions per capita	1.20	3.77	6.60	0.86	13.33	1.12	1.96	10.59	0.77	6.95	5.33
Real GDP											
Per capita	\$4162	\$4575	\$8541	\$3520	\$8699	\$1727	\$2191	\$11,858	\$1478	\$5583	\$2008

Figure 1: Summary of Energy Production and Utilization for CIS States

Cointegration analysis, which frequently employs the Vector Error Correction Model (VECM), is one of the most important techniques used to examine this relationship in CIS countries (Sisodia et al., 2023). Such econometric models have been instrumental in identifying long-term equilibrium associations among energy usage variables and Gross Domestic Product (GDP), while simultaneously accounting for short-term dynamics (Apergis & Payne, 2010). Importantly, these models have frequently discovered a unidirectional causal affiliation among energy usage and economic development in CIS nations, confirming the hypothesis that energy has been a constraining factor for economic growth. However, the conventional VECM method has been criticized for its inability to effectively model nonlinearities. It has been suggested that the use of nonlinear panel smooth transition vector error correction models (NPSTVECM) allows for a more accurate representation of regime shifts and threshold effects (Apergis & Payne, 2014). These are especially relevant for the economies of the Commonwealth of Independent States, which have undergone significant structural changes since the fall of the Soviet Union.

Considering the heterogeneity of CIS nations in terms of their energy mix and phases of economic development adds another layer of complexity. Traditional models frequently presume homogeneity, which can obscure country-specific nuances. Consequently, a more nuanced comprehension of the underlying causal mechanisms has been achieved by employing panel data models with fixed effects (Pavletic, 2010). The importance of energy efficiency and technological advancements is also widely acknowledged. Given the aging infrastructure and inefficient energy utilization in many CIS nations, the implementation of advanced technologies can substantially alter the elasticity coefficients among energy usage and economic output. Consequently, studies utilizing Stochastic Frontier Analysis (SFA) have investigated how technological advancements can function as a mediating factor, potentially altering the causal inferences derived from more conventional econometric models.

In addition, the expanding emphasis on renewable energy and its implications for sustainable economic growth cannot be overlooked. Given the increasing global emphasis on sustainability, CIS nations are diversifying their energy portfolios progressively. Incorporating renewables not only modifies the affiliation among energy and economic development, but also adds policy incentives and carbon emissions to the equation. Increasingly, game theory models, particularly in the context of international trade and cooperation, are used to analyse how renewable energy can serve as a strategic asset, thereby influencing the conventional paradigms of energy utilization and economic development.

2.3 Energy Utilization vs Economic Growth for Greece

Causal association among energy utilization and financial development, could be credited first to the varied institutional, structural, and policy outlines of the nations under contemplation, and then to procedural variations. Granger's and Sim's tests, which were utilized by numerous researchers to notice connexon, were being heavily criticized due to the circumstance that the time dependence of variables has reduced the sensitivity of both tests. In addition, the majority of studies were based on the assumption that time-dependent data of variables are stationary and, as a result, have employed improper assessment techniques (Hondroyiannis et al., 2002).

The growth of energy utilization in Greece has been shown in Figure 2. Specifically, during the 1960s and until the initial energy emergency in 1973, the Greek economy grew by an average of 7.7% annually as a consequence of the industrialization course, with the industrial sector's share of GDP rising. At the similar period, the average rate of growth of total energy usage, 12.3%, and industrial energy consumption, 14.3%, significantly surpassed that of output. Throughout the remainder of the 1970s and until the second energy catastrophe in 1979, the rate of GDP growth and energy usage slowed. During the 1980s and early 1990s, Greece's economic movement exhibited small average growth rates of 1.6%, and industrial production decreased, which can be noticed in the nation's energy usage outline. Since the mid-1970s, a faster increase in energy usage in transport and residential usages was noticed than in total energy usage, which is largely attributable to an overall development in Greece's living standards (Hondroyiannis et al., 2002).

	1960–1973	1974–1979	1980–1996
Real GDP	7.7	3.7	1.6
Energy consumption[a]			
–Total	12.3	3.9	2.2
–Industrial	14.3	4.7	–0.1
–Residential	10.9	1.2	3.2
–Transport etc.	11.7	4.5	3.1
Consumer price index	3.3	14.2	16.7

Figure 2: Energy Utilization, Economics Development in Greece

Greece's unique economic and energy landscape, characterized by its indebted economy, energy dependence, and policy adjustments toward renewable energy sources, necessitates a nuanced examination of the association among energy utilization and economic development. Given these peculiarities, the affiliation among energy consumption and economic output becomes a complex topic of study for both academics and policymakers. Vector Auto-Regressive (VAR) models and Vector Error Correction Models (VECM) have been widely utilized to investigate this relationship. These econometric techniques make it possible to investigate cointegration relationships and short-term dynamics among energy usage, GDP, and other control variables such as labour and capital. These methodologies are particularly applicable to Greece, where fluctuations in energy prices and policy interventions frequently result in temporary deviations from long-term equilibrium relationships.

One of the most prominent debates in the scientific literature concerns the causal direction. The conventional view posits a unidirectional causal association among energy usage and economic development, based on the concept of energy as a limiting factor in production (Shafiq & Zafar, 2023). Though, the experiential evidence for Greece is mixed. Some studies report bidirectional causality, suggesting that while energy consumption does indeed spur economic activities, economic growth also contributes to increased energy demand. This bidirectional causality is frequently represented using Granger-causality tests within a multivariate VECM framework, enabling the simultaneous examination of short-term and long-term causal inferences.

In addition, the pliability of GDP with respect to energy usage was also being studied extensively. To estimate these elasticity coefficients, the computational methodologies frequently employ sophisticated computational techniques such as Bayesian Model Averaging (BMA) or Generalized Method of Moments (GMM) (Nagou et al., 2021). When contemplating tax reforms or subsidy adjustments in the energy sector, the elasticity values are crucial for policy implications (Farooq et al., 2023). The implementation of nonlinear models such as Threshold Autoregressive (TAR) and Momentum-threshold Autoregressive (MTAR) models is another innovative trend in the literature (Rafailidis & Katrakilidis, 2014). These models are particularly useful for documenting regime shifts, particularly during economic crises or abrupt policy changes, both of which are commonplace in the Greek context.

Renewable energy's contribution to this equation adds another layer of complexity. With the European Union's emphasis on sustainability and Greece's commitment to renewable energy goals, traditional models are increasingly being modified to incorporate parameters such as renewable energy usage and carbon emissions. Utilizing Structural Equation Modelling (SEM) and Dynamic Stochastic General Equilibrium (DSGE) models, researchers are attempting to comprehend how the shift toward renewables may affect the extant energy-GDP dynamics, particularly under various policy scenarios (Koop et al., 2013). In addition, the impact of energy efficiency, which is frequently operationalized through the use of energy intensity indicators, is gaining prominence. Advanced econometric techniques as like Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are increasingly used to quantify efficiency scores and decompose energy consumption into efficient and inefficient components.

2.4 Energy Utilization vs Economic Growth for European Union

When discussing the economic growth of any nation, energy usage growth rates that exceeds those of gross domestic product are always being referred. This type of phenomenon always happens in the initial phases of progress and is being followed by the phases in which the proportion of energy usage to gross domestic product decreases. These characteristics are the result of structural changes in each economy and technological development. Pirlogea and Cicea (2012) examined the causal association among energy usage by fuel and economic development for two European nations, Romania and Spain, and for the EU-27 as a whole. Research conducted by Pirlogea and Cicea (2012) recognized that a long run association has been present Eu-27 among GDP per capita, energy utilization from renewable sources, and total petroleum goods. In addition to these two correlations, it was also found in above research that for Romania, a long run relation has been found among economic development and energy usage from natural gas sources. Long-term affiliation among GDP per capita and energy utilization resulting from petroleum and natural gas were detected for the specific case of Spain.

The association among energy utilization and economic development in the European Union (EU) has been the focus of academic research, especially given the region's unique combination of diverse economies, energy policies, and sustainable development objectives. The complex interaction between these variables necessitates a multifaceted methodological approach that includes econometric modelling, simulation techniques, and policy analysis. Vector Autoregressive (VAR) and Vector Error Correction Models (VECM) have been used extensively to analyse the cointegration relationships among energy utilization, Gross Domestic Product (GDP) and additional contributing factors such as labour and capital inputs. To encompass the broader macroeconomic landscape, these models are frequently expanded to include exogenous variables, such as technological innovations and carbon emissions. In addition, Granger-causality analyses within the VECM framework have been essential for determining the directionality of the causal association among energy utilization and economic development, thereby informing policy directives on energy efficiency and economic stimulation.

Given the diversity in economic structure and energy dependence among EU member states, panel data models have emerged as a robust methodology. These models frequently include fixed or random effects to account for cross-sectional variations, thereby providing a nuanced comprehension of the energy-growth relationship in various economic settings. Generalized Method of Moments (GMM) and Dynamic Panel Data (DPD) models have been especially successful in addressing endogeneity issues and temporal dynamics, resulting in more accurate estimations of elasticity coefficients.

Nevertheless, linear models frequently fail to capture the nonlinearities and regime shifts in the energy and growth affiliation, particularly in the context of policy shifts toward renewable energy and economic crises. Consequently, Threshold Autoregressive (TAR) models and Nonlinear Panel Smooth Transition Regression (NPSTR) models have been developed to identify energy consumption or economic output threshold levels beyond which the relationship's dynamics change substantially. These models are especially useful for comprehending how economic recessions or rapid transitions to renewable energy sources influence the long-term cointegration and short-term causality between variables. Existing models had to be modified due to the introduction of renewable energy variables. The use of Structural Equation Modeling (SEM) and Dynamic Stochastic General Equilibrium (DSGE) models to simulate scenarios under various renewable energy policies is on the rise. These models provide valuable insight into the short- and long-term effects of shifting from fossil fuels to renewable energy sources on economic growth.

In addition, the importance of energy efficiency as a mediating variable in this nexus is growing. Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) have been utilized to quantify energy efficiency scores and decompose energy consumption into efficient and inefficient components, respectively (Jacobs, 2001). These methodologies provide a more granular perspective, enabling policymakers to identify sectors or regions where energy utilization can be optimized for the greatest economic output. In addition, the incorporation of environmental variables such as carbon emissions and ecological footprints into existing models is being investigated in light of the growing emphasis on sustainable development. This extends the energy-economic growth discourse into a three-way relationship involving sustainability, which is typically modelled using three-stage least squares (3SLS) to capture the simultaneous interactions between variables (Fatma & Chichti, 2011). In conclusion, the literature on energy usage and economic development in the European Union is characterized by a plurality of methodologies designed to capture the dynamic and multidimensional nature of this relationship. The analytical frameworks have evolved from traditional econometric models to advanced simulation techniques to accommodate policy shifts, technological advances, and economic fluctuations. This intricate relationship continues to provide fertile ground for academic research and policy formulation as the EU navigates its complex energy landscape amidst commitments to sustainable development.

2.5 Renewable Energy Utilization vs Economic Growth

Bhattacharya et al. (2016) investigated the impact of renewable energy utilization for 38 different nations. They found that for the initial group of nations, the renewable energy sources are the significant economic development driver. The list of nations includes Austria, Bulgaria, Canada, Chile, China, the Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Kenya, the Republic of Korea, Morocco, the Netherlands, Norway, Peru, Poland, Portugal, Romania, and the United Kingdom. During their research period, a significant transition toward renewable energy occurred in the majority of the above-mentioned countries. In China, the Renewable Energy Law (REL) of 2005 and its 2009 amendment provide support for the deployment of renewable energy. The National Development and Regulation Commission (NDRC) and the National Energy Agency (NEA) are responsible for setting central and regional/local targets, respectively. In the long run Bulgaria, China, the Czech Republic, Denmark, Greece, Korea, the Netherlands, Poland, and Portugal are found to be the country’s most likely to switch from non-renewable to renewable energy sources. The application of renewable energy has been creating economic upsurge for several number of above-mentioned nations.

In the second group, it was discovered that renewable energy sources had shown an adverse impact on the economic development for five nations: India, Ukraine, the United States and Israel. Here, it was emphasized that characteristics of the energy balance in some of these nations may result in a deployment process that is sluggish and detrimental to economic development. For instance, coal accounts for 69% of India's energy sector, compared to 5% renewables other than hydro and 12% hydropower. Financing and coordination among the states (Tamil Nadu, Gujarat, and Rajasthan) having plenty of renewable sources and the remaining nations, are significant obstacles to integration to the grid. Ukraine is wealthy in natural reserves and a conduit for Russia's gas supply to Europe; however, renewable energy accounts for only 3% of its energy supply. Coal and natural gas provide 67 percent of the United States' total energy supply. Israel's energy sector is dominated by hydrocarbons, with 6% of electricity production coming from coal and 33% coming from natural gas and diesel, as reported by the Israel Electric Corporation (2009).

A thorough examination of their energy composition and the present standing of renewable energy reserves indicates that substituting non-renewable energy sources with renewable energy sources may threaten economic development. These nations must adopt a methodical approach to placement. In the last, for following eleven nations, Australia, Belgium, Brazil, Ireland, Japan, Mexico, Slovenia, South Africa, Sweden, Thailand and Turkey, it was not being concluded that whether the renewable energy resources are the significant contributor to the economic development or they are having the adverse impact on economic development. One of the reasons for this result for the above countries is the fact that these nations could not made it possible to utilize the renewable energy sources efficiently in the process of production and therefore it has approximately no effect on economic outcome. Hence, policy makers for these nations must emphasis on the investment in renewable energy efficiently so that the upsurge in the demand of energy usage from several economic actions can effectively use renewable energy resources.

The research on the association among renewable energy utilization and economic development has prompted a paradigm shift in both academic discourse and policy formation. This transformation coincides with the global push for sustainable development, climate change mitigation, and energy security (Farooq et al., 2024). In light of the multifarious complexities inherent in this nexus, the scholarly literature has evolved to include an abundance of methodological rigor, interdisciplinary frameworks, and empirical case studies. Significant portions of the existing literature have utilized econometric models such as Vector Auto Regressive (VAR) and Vector Error Correction Models (VECM) to investigate the cointegration and causal affiliation among renewable energy usage and economic variables. Nonlinear models, such as Threshold Autoregressive (TAR) and Nonlinear Panel Smooth Transition Regression (NPSTR) models, have emerged in response to the inadequacy of linear models in depicting the dynamics of complex systems.

Concurrently, Computational General Equilibrium (CGE) models have acquired popularity, enabling the evaluation of policy interventions across multiple sectors and scales. These models provide intricate simulations under a variety of scenarios, from the imposition of carbon taxes to the subsidies for renewable energy technologies, and thus provide exhaustive insights into the economic implications of the transition to renewable energy. Given the interrelationships between energy economics, environmental science, and policy studies, an interdisciplinary approach is now essential. Ecological economics, for instance, has contributed to the comprehension of how the utilization of renewable energy affects broader ecosystem services and natural capital. To evaluate the efficacy and sustainability of diverse renewable energy technologies, concepts such as the Energy Return on Investment (EROI) have been introduced.

Regional empirical studies have enriched the literature by considering the unique economic, social, and political contexts that influence the association among renewable energy and the economy. For instance, studies on developing economies frequently emphasize the performance of renewable energy in encouraging energy access and alleviating destitution, which subsequently results in economic growth. In contrast, in developed economies, technological innovation, energy efficiency, and how these factors contribute to economic competitiveness are frequently emphasized. The application of network analysis techniques to the study of renewable energy trade within economic blocs such as the European Union has yielded nuanced insights into how interdependencies influence economic outcomes.

The literature has increasingly begun to investigate the performance of technological novelty in mediating the relation among renewable energy and economic growth. Advanced methods, such as Data Envelopment Analysis (DEA), have been utilized to assess the technological advancements in renewable energy production. Similarly, the use of machine learning algorithms for predictive modelling reflects the expanding overlap between data science and energy economics (Cook & Seiford, 2009). Integrating sustainability metrics and indicators increases complexity. To evaluate the social, environmental, and economic impacts of renewable energy use, models such as the Three-Pillar Sustainability (3PS) framework have been employed. These frameworks are essential tools for policymakers, particularly in the background of the Sustainable Development Goals (SDGs) of the United Nations. The scholarly investigation into the relations among renewable energy utilization and economic growth has evolved into a multidimensional discourse that incorporates a variety of methodologies, interdisciplinary perspectives, and empirical contexts. Despite significant advancements, the field is primed for additional research, particularly in the areas of circular economy principles, blockchain technology in energy markets, and the sociopolitical factors influencing the adoption of renewable energy (Yang et al., 2024).

2.6 Pakistan's Energy Utilization vs Economic Growth: A Snapshot

Pakistan's main energy demand have increased by 80% over the past 15 years. Pakistan's energy needs are rising quickly, from 34 million TOE in 1994–1995 to 61 million TOE in 2009–10. In terms of energy sources, domestic natural gas accounts for 45% of the mix, followed by imported oil at 35%, hydropower at 12%, coal at 6%, and nuclear energy at 2%. To meet its energy consumption needs, Pakistan has large dependency on conservative energy sources. More than 99% of the power needs are met by traditional nonrenewable energy sources (Sheikh, 2010). However, the Pakistani government has given the Pakistan Alternative Energy Board the mandate to produce 5% of the nation's required power from alternative or renewable sources by the year 2030 (Shahbaz et al., 2012). Pakistan has been endowed with an abundance of natural energy sources that, if properly utilized, could lessen its reliance on extraneous support for crude imports. These unplumbed energy sources in Pakistan have the capability to not only meet national energy demands, but may also be exported to nations with energy shortfalls. However, these resources are not being sufficiently discovered.

Pakistan's location on the sunny belt provides it a relative benefit in solar energy production. This type of energy is significantly less expensive than conventional fuels due to non-requirement of any refining or transportation facilities. It is the most needed alternative to conventional fuels since it does not produce any pollution. Power Consumption (renewable and nonrenewable energy sources) is a momentous feature in economic development, comparable to labor and capital. Prevailing research offers four competing hypotheses regarding the association among energy utilization and economic growth in Pakistan. These challenging hypotheses have been crucial from a policy standpoint. For example, decrease in energy consumption may not be having a negative impact on economic growth if granger causation exists among economic development and energy usage or if there is a neutral relationship between the variables. If two-way causation is present among the factors, or if power utilization Granger causes economic development, then novel power resources must be promoted. Energy has been an essential progression stimulant, and energy should escalate the economic development, according to Granger. Increase in producing goods has been associated with an increase in energy requirement, and financial development may result in an upsurge in energy utilization (Shahbaz et al., 2012).

The results presented by Aqeel and Butt (2001) show that economic development increases the total energy utilization. Further research results indicated that economic development causes an upsurge in petroleum consumption, whereas neither economic growth nor gas consumption influence the gas sector. In the energy sector, however, it had been revealed that electricity utilization leads to economic expansion without feedback. Moreover, energy utilization causes direct employment. The implications of the study conducted by Aqeel and Butt (2001) also suggested that an energy preservation strategy concerning petroleum usage will not have any negative impacts on Pakistan's economic progress, while an energy advancement strategy regarding gas and electricity utilization should be adopted so as to stimulate economic growth. This expansion would increase employment opportunities in the country.

3. Material and Methods

The facts and figures for the study will come from the IMF, the World Bank, the International Energy Agency, and the State Bank of Pakistan. The data spans the years 1980 to 2020, as the majority of the data from the aforementioned sources was last updated in 2020. Secondary data are used because they are more precise and credible than primary data. From the aforementioned source, we will gather time series data on income (per capita in Pakistani rupee), energy consumption (KWh), exports (per capita in Pakistani rupee), capital (per capita in Pakistani rupee), and labour force participation, with all data on a logarithmic scale. This study’s methodology will be derived from the well-known work of Halicioglu (2011). The boundary cointegration test method established by Pesaran et al. (2001) will be utilized to investigate the dynamic causal relationships among the variables. This method concurrently approximates the short run and long run parameters and permits a variety of integration orders among variables. If cointegration is determined, an Error Correction Model (ECM) and an enhanced form of Granger causation analysis will be specified. The steadiness of long run parameters over time will be determined utilizing cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests grounded on recursive residuals. These investigations provide a graphical representation for detecting any instability in parameter estimation.

3.1 Data Collection

Data for this study has been from sources such as IMF, World Bank, International Energy Agency and State Bank of Pakistan. Time period of data is from 1980 to 2022 as most of the available data at above mentioned sources is updated in 2022. Time dependent data of income (per capita in US dollars), energy utilization per capita (KWh), exports (per capita in US dollars), capital (per capita in US dollars) and labour force participation is collected from world bank. Figures 3 to 7 shows the time series data of above-mentioned variables for Pakistan.

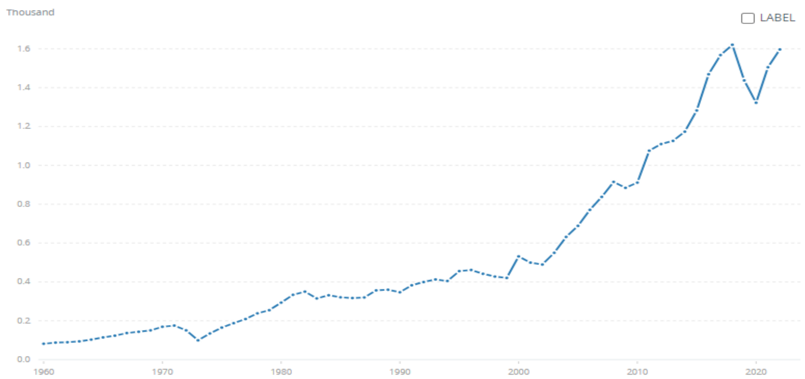

Figure 3: Per capita GDP (current US$) – Pakistan
Source: https://data.worldbank.org/indicator/

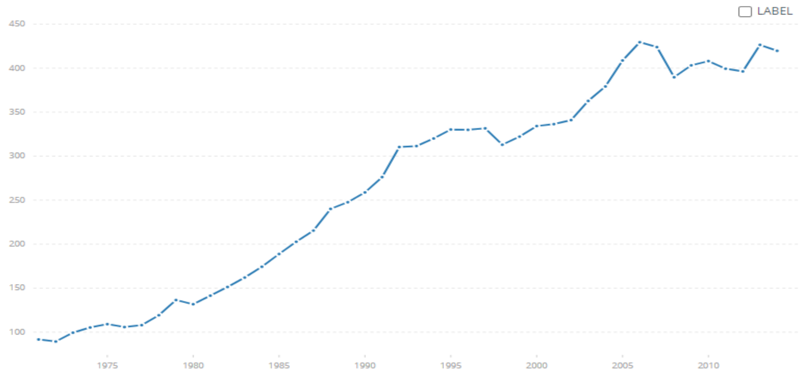

Figure 4: Electric power consumption (kWh per capita) – Pakistan
Source: https://data.worldbank.org/indicator/

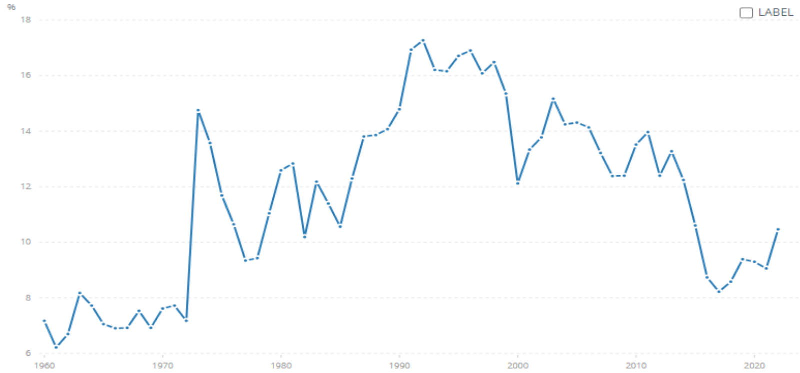

Figure 5: Goods and services Exports (% of GDP) – Pakistan
Source: https://data.worldbank.org/indicator/

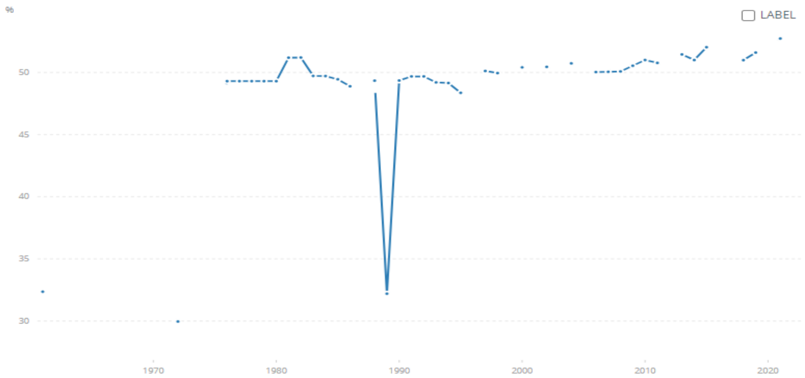

Figure 6: Labour force participation rate, total (% of total population ages 15+) (national estimate) – Pakistan
Source: https://data.worldbank.org/indicator/

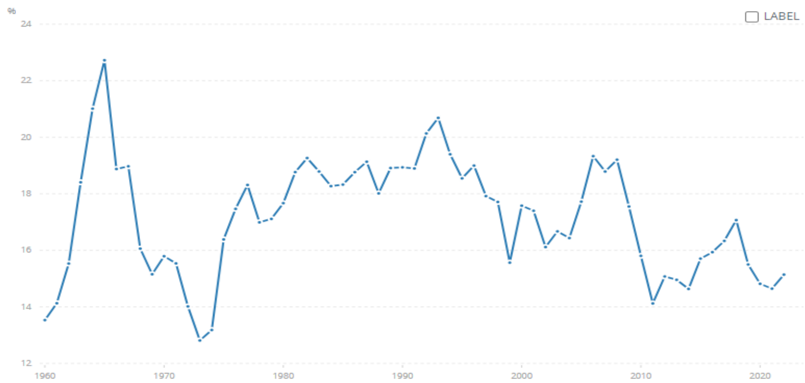

Figure 7: Gross capital formation (% of GDP) – Pakistan
Source: https://data.worldbank.org/indicator/

3.2 Methodology

Methodology of this paper will be derived from famous work of Halicioglu (2011). The approach of bounds testing to cointegration created by Pesaran et al. (2001) will be used to examine the dynamic causal linkages between the variables. This method concurrently estimates both the short run and long run parameters and permits a variety of integration's orders among the coefficients. If cointegration is determined, an Error Correction Model (ECM) will be specified, followed by an improved form of Granger causation study. Using cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests having basis on recursive residuals, stability of the long-run coefficients over time will be determined. These experiments provide a graphical representation for detecting any parameter estimation instability.

3.3 Explanation of Econometric Model

A traditional neo classical one sector cumulative production function is a theoretical construct that seeks to encapsulate the relation among a nation's output and its primary parameters of production i.e. capital and labour. This model underlines, significance of technology, which it assumes to be exogenously given and improves over time, thereby impacting productivity. The function generally takes the following Cobb-Douglas form:

$$Y = A \times K^{\alpha} \times L^{(1-\alpha)} \tag{1}$$

Where Y represents total output, K shows the capital stock, L signifies labour and A characterises the level of technology α is the output elasticity of capital, indicating the responsiveness of output to a change in the capital stock. In authors research by following the guidelines of Halicioglu (2011), this model will be expressed in linear econometric form as follows:

$$y_c = a_0 + a_1 e_c + a_2 x_c + a_3 k_c + a_4 l_c + e_c \tag{2}$$

Where y_c is aggregate or cumulative output, x_c relates to exports, e_c denotes energy consumption, k_c denotes the per capita real capital, l_c belongs to labour force participation rate and e_c denotes regression error. It is also noted that energy consumption, exports and capital are represented in per capita. Equation $y_c = a_0 + a_1 e_c + a_2 x_c + a_3 k_c + a_4 l_c + e_c$ may be written in the form of error correction model as follows:

$$\Delta y_c = \theta_0 + \sum_{i=1}^{n1} \theta_{1i} \Delta y_{c-i} + \sum_{i=0}^{n2} \theta_{2i} \Delta e_{c-i} + \sum_{i=0}^{n3} \theta_{3i} \Delta x_{c-i} + \sum_{i=0}^{n4} \theta_{4i} \Delta k_{c-i} + \sum_{i=0}^{n5} \theta_{5i} \Delta l_{c-i} + \varphi e_{c-1} + \omega_c \tag{3}$$

Where Δ denotes change, φ represents parameter of speed adjustment and e_{c-1} is modified error term as per Engle-Granger. If we face the problem of non-stationary variables in equation (1), then it can be modified through ARDL approach and its updated form is shown below:

$$\Delta y_c = \rho_0 + \sum_{i=1}^{m1} \rho_{1i} \Delta y_{c-i} + \sum_{i=0}^{m2} \rho_{2i} \Delta e_{c-i} + \sum_{i=0}^{m3} \rho_{3i} \Delta x_{c-i} + \sum_{i=0}^{m4} \rho_{4i} \Delta k_{c-i} + \sum_{i=0}^{m5} \rho_{5i} \Delta l_{c-i} + \rho_6 y_{c-1} + \rho e_{c-1} + \rho_8 x_{c-1} + \rho_9 k_{\rho-1} + \rho_{10} l_{\rho-1} + \omega_t \tag{4}$$

The above equation can further be simplified as follows:

$$\Delta y_c = \beta_0 + \sum_{i=1}^{z1} \beta_{1i} \Delta y_{c-i} + \sum_{i=0}^{z2} \beta_{2i} \Delta e_{c-i} + \sum_{i=0}^{z3} \beta_{3i} \Delta x_{c-i} + \sum_{i=0}^{z4} \beta_{4i} \Delta k_{c-i} + \sum_{i=0}^{z5} \beta_{5i} \Delta l_{c-i} + \tau EC_{c-1} + \omega_t \tag{5}$$

Where τ can be used to find out the supporting cointegration between the variables. Besides the adjustment's speed, a negative and analytically noteworthy approximation of τ also signifies another way of supporting cointegration among the coefficients. EC_{c-1} has been shaped by means of the long run coefficient approximations from equation (3). In contrary to the other single cointegration methods, Cointegration method described by Pesaran et al. (2001), also recognized as bounds testing is having many econometric benefits. Some of these benefits are enlisted below.

- Endogeneity difficulties and incapability to assess hypotheses on the approximated parameters in the long run related to the Engle Granger technique are evaded.
- The long run and short run coefficients of the model in query are evaluated simultaneously.
- The ARDL method for testing the presence of a long run relation among the parameters in levels is pertinent regardless the underlying regressors are purely $I(0)$, purely $I(1)$, or fractionally integrated.
- A multivariate cointegration is pretty much inferior than the small sample settings of bound testing approach.

After the adjustment is completed, equation no. 3 offers the short run and long run properties concurrently. The short run properties among the dependent and independent parameters are contingent by the magnitude of ρ_{1i}, ρ_{2i}, ρ_{4i} and ρ_{5i}. The estimates of ρ_7 , ρ_8, ρ_9 and ρ_{10} normalized on the approximation of ρ_6, show the long run effects.

The Granger depiction theorem proposes that there exists a Granger causation in at least one direction if there is a cointegration relation among the parameters of equation (1), only if they are integrated order of one. The presence of a cointegration resulting from equation (2) may not essentially infer that the projected parameters are stable (Halicioglu, 2011). The stability of variables of regression equations are, verified by a technique called as cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests having their basis on the recursive regression residuals, might be applied to that end. These tests also include the short run dynamics to the long run by residuals. The CUSUM and CUSUMSQ statistics have been upgraded recursively and graphed against the break points of the model. One assumes that the coefficients of a given regression are stable if the plots of these statistics lie within the significance limits of 5%. Typically, these evaluations are implemented through graphical representation.

4. Results and Discussions

4.1 Augmented Dickey Fuller (ADF) Test

Annual data over the period 1968-2008 were used to estimate equation (2) by the Pesaran et al. (2001) procedure. ADF has been a commonly used analytical test to check whether under consideration time series variable is stationary or not. It is utmost frequently used statistical test to analyse the stationarity of any time varying parameter. Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1981) has been used in present study to check the time series properties of the variables of equation (1) and to make certain that none of the variables are not over the integrated order of one. Table 2 shows the results.

Table 2 shows that all the time series of equation 1 except labour force participation rate (l_t) have unit roots as for all series t-stat values are greater than the t-critical except l_t . Critical values have been taken from MacKinnon (2010). Moreover, p values for all the time series except l_t are greater than 0.1 which shows that null hypothesis cannot be rejected. Second half of table 2 shows that all the variables of equation 1 have t-stat values less than t-critical which means the time series mentioned in equation (1) are stationary in their first difference which in turn demonstrates that the series are integrated at the order 1 i.e. I (1). Lag levels have been selected to maximize the AIC (Akaike Information Criteria).

Table 2
ADF Test (Levels)

Variables	**t-stat**	**t-critical**	**k-lag**	**AIC**	**p-stat**
y_t	-1.73581	-3.50988	2	11.17471	> 0.1
e_t	-1.55942	-3.50988	0	7.82978	> 0.1
x_t	-1.87587	-3.50988	0	3.203602	> 0.1
k_t	-3.21867	-3.50988	0	2.688684	0.09546
l_t	-8.41864	-3.50988	0	9.011801	< .01
ADF Test (1st Differences)					
y_t	-5.9345	-3.51239	1	11.20729	< 0.1
e_t	-5.7157	-3.51239	0	7.908019	< 0.1
x_t	-6.23844	-3.51239	0	3.315959	< 0.1
k_t	-6.41571	-3.51239	0	2.92193	< 0.1
l_t	-5.47719	-3.51239	3	9.413511	< .01

4.2 ARDL Bounds Test

To examine the long run relation among several variable ARDL bounds test method has been widely used which was established by Pesaran et al. (2001). This approach has numerous advantages over the conventional cointegration tests. This method can be used for either I(0) or I(1) time series. The past researches show that the method is superior and offer steady results for trivial samples Çetin et al. (2015). As a next step ARDL procedure has been applied, as a first step ARDL bounds test has been performed by considering the model with unrestricted constant and trend. Null hypothesis is no level relationship. The results are shown in Table 3.

Table 3
ARDL bounds Cointegration Test

Calculated F-statistics	**Lag**	**Lower Bound I (0)**	**Upper Bound I (1)**
6.277253	4	3.47	4.57
Calculated t-statistics			
-3.322099	4	-3.41	-4.36

Precise critical standards for the F-statistics (I (0), I (1) variables) do not exist. However critical values boundaries for different k (lags) have been given by Pesaran et al. (2001). For each situation, the lower bound is based on the supposition that all of the variables are I(0), and the upper bound is based on the assumption that all of the variables are I(1). Table 3 shows that the f-stat is greater than the upper and lower bound, which means that the null hypothesis can be rejected and there exists a cointegration. Moreover, as stated by Pesaran et al. (2001) if computed t-statistics is greater than the upper bound value I (1), this shows that there exists the long run relationship between the variables. Results presented in Table 3 also supported the existence of long-run relationship among the variables.

4.3 Johansen Cointegration Test

There are numerous tests to demonstrate the long run connotation among the time varying parameters, most commonly used among then is the Johansen cointegration test. It is founded on the maximum probability technique and provides two main statistics:

- Eigen value statistic
- Maximum Eigen statistics

In the present research, the exitance of long-run relationship between variable has also been verified by the test results of Johansen Cointegration Test, presented in Table 4. Null hypothesis is no cointegrating equations.

Table 4
Johansen Cointegration Test

Cointegrating Vectors	Statistics	Critical Value	Prob.
None*	48.42559	38.33101	0.0026
At most 1*	40.75345	32.11832	0.0035
At most 2*	31.02320	25.82321	0.0094
At most 3*	27.30158	19.38704	0.0029
At most 4*	15.61984	12.51798	0.0147

Null hypothesis can be rejected if max eigen statistics is more than critical value at 0.05% or prob value is less than 0.05. Table 5 shows that both of these null hypothesis rejection criteria are fulfilled. Therefor it can be concluded that long-run relationship exists between five variables and it shows five cointegrating equations.

4.4 ARDL Cointegration

Now as it is established that there is an existence of long run relationship, as next step ARDL cointegration method has been employed. The results are presented in Table 5. These results are based on Akaike information criterion (AIC).

Table 5
ARDL Cointegration Results

Long run Coefficient Dependent y_t		
Regressors	**Coefficient**	**t-statistics**
e_t	2.927907	3.375716
x_t	2.836752	0.339080
k_t	14.54801	1.540989
l_t	0.750721	1.997356
Constant	-24.71201	-1.083391
Trend	1.785063	2.168042

4.5 Granger Causality Test

Granger causality test is an analytical hypothesis test which is extensively used for investigating that if one-time dependent variable is beneficial in predicting the other time dependent parameter. It was first introduced by Granger (1969). Granger established an extensively utilized description of causality that is often applied by political experts interested in the inter relation impacts of two variables A and B. B is said to Granger cause" A time dependent properties of B provide some assistance to forecast the behavior of A, this can be accomplished when only evidence about the history of A is used for this purpose (Wei, 2013). Cointegration results presented in table 4 shows that long run relationship exists among five variables. Therefore, as a next step, granger causality test has been performed for the following equation.

$$(1-L)\begin{bmatrix} y_t \\ e_t \\ x_t \\ k_t \\ l_t \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} d_{11i} & d_{12i} & d_{13i} & d_{14i} & d_{15i} & d_{16i} \\ d_{21i} & d_{22i} & d_{23i} & d_{24i} & d_{25i} & d_{26i} \\ d_{31i} & d_{32i} & d_{33i} & d_{34i} & d_{35i} & d_{36i} \\ d_{41i} & d_{42i} & d_{43i} & d_{44i} & d_{45i} & d_{46i} \\ d_{51i} & d_{52i} & d_{53i} & d_{54i} & d_{55i} & d_{56i} \\ d_{61i} & d_{62i} & d_{63i} & d_{64i} & d_{65i} & d_{66i} \end{bmatrix}\begin{bmatrix} y_{t-i} \\ e_{t-i} \\ x_{t-i} \\ k_{t-i} \\ l_{t-i} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{bmatrix}[EC_{t-1}] + \begin{bmatrix} V_{1t} \\ V_{2t} \\ V_{3t} \\ V_{4t} \\ V_{5t} \end{bmatrix} \quad (6)$$

Table 6 presents the results for granger causality. Results show that there exists long run relationship between GDP per capita, energy consumption, exports, per capita real capital and labor. In terms of short-run relationship, table 6 shows one eloquent bi-directional relationship between GDP and energy utilization. Results show that Granger causality between GDP and electricity utilization runs in both directions. Table 6 also shows that, Electricity utilization granger cause exports and per capita real capital. Exports granger cause per capita real capital. Per capita real capital granger cause GDP. Labor force granger cause GDP and exports.

Table 6
Granger Causality Results

Dependent Variable	Δy_t	Δe_t	Δx_t	Δk_t	Δl_t
Δy_t	-	2.84152 (0.0291)	0.98271 (0.4323)	0.84041 (0.6298)	1.66399 (0.1893)
Δe_t	4.198 (0.0420)	-	2.59552 (0.0343)	3.38890 (0.0216)	0.40644 (0.7313)
Δx_t	0.17983 (0.9470)	0.79411 (0.6276)	-	5.83545 (0.0018)	0.40583 (0.9069)
Δk_t	2.38845 (0.0350)	1.03355 (0.4068)	2.02693 (0.1139)	-	1.19333 (0.3347)
Δl_t	3.46438 (0.0197)	0.99922 (0.4239)	6.65851 (0.0239)	0.36697 (0.8301)	-
Causality Inference: $y \leftrightarrow e$, $e \rightarrow x$, $e \rightarrow k$, $x \rightarrow k$, $k \rightarrow y$, $l \rightarrow y$, $l \rightarrow x$					

4.6 Coefficient Stability Analysis

To measure the coefficient stability, the cumulative sum (CUSUM) of recursive residuals and the CUSUM of square (CUSUMSQ) tests are being frequently used. The former test recognizes the orderly variations in the regression coefficient, while the later test identifies the abrupt variations from the constancy of regression coefficient (Ravinthirakumaran et al., 2015). In the ongoing research, as a next step stability tests CUSUM and CUSUMSQ have been performed based on SBC error correction model of equation (3). CUSUM of recursive residual had been introduced by McCabe and Harrison (1980). Based on Null hypothesis, the recursive residuals have revealed to be self-determining and identically dispersed as normal with zero mean and constant variance. The graphs of CUSUM and CUSUMSQ are shown in figure 8 and 9 respectively. If there is any change in coefficients after some period of time, the plot of CUMSUM will show a drift, away from mean value. If the plot of CUMSUM crosses the theoretical bounds at any point of time, this will signify the rejection of null hypothesis. Null hypothesis states that the coefficients are stable and will remain with boundaries at 5% significance level.

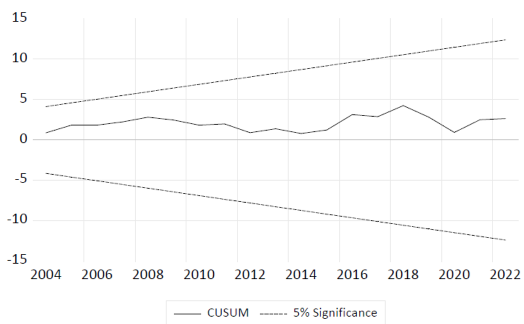

Figure 8: CUSUM

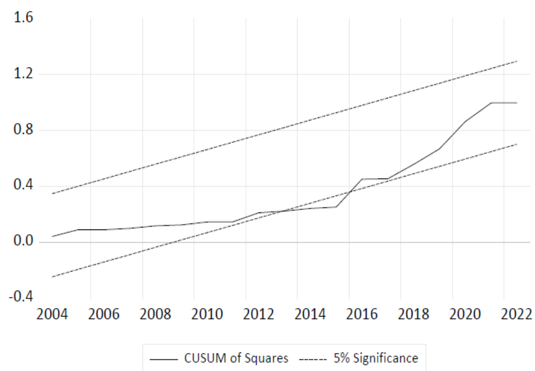

Figure 9: CUSUMSQ

Figure 8 shows the graph CUSUM statistics lies within the critical boundary values. Dotted lines show the critical values at 5% significance level. CUSUMSQ plot in figure 9 shows that, CUSUM statistics lies within the critical bounds for most of the time period, however it crosses the critical bounds for the period 2014 to 2015 and then again became stable for remaining period of time. Therefore, it can be concluded from both the graphs that all the coefficients in error correction model are appeared to be stable and the selected model can be utilized for policy making and decision-making purposes. The effect of policy changes by taking into consideration the descriptive variables described in equation (3) may not cause any significant diversion in the collective output as the coefficients in this equation appears to follow a steady outline during the assessed time period.

5. Conclusion and Recommendations

5.1 Conclusion

In this research, a comprehensive analysis has been performed to test the numerous hypotheses among the variables GDP, Electricity utilization, exports, real capital and labor force. The cointegration methodology and approach described by Pesaran et al. (2001) has been employed to check the causal relationships between the variables. The time dependent data for the above-mentioned variables have been taken from the sources like IMF and World Bank. The details that which variable is taken from which relevant source are mentioned in section 2.2. The time period considered in this study is from 1980-2022 i.e. the statistics for above stated variables is from the year of 1980 to the year 2022. As a first step ADF test has been conducted to check that whether existence of unit root in the under-consideration time series. The results for ADF test revealed that all the time series variables considered for this study are found to stationary in their first difference which also establishes that the series are integrated at the order 1 i.e. I (1).

In the next step ARDL procedure has been applied, firstly ARDL bounds test has been performed by considering the model with unrestricted constant and trend. No level relationship has been considered to be the Null hypothesis. Results revealed that the null hypothesis can be rejected and there exists a cointegration among the variables. Moreover, as specified by Pesaran et al. (2001), computed t-statistics is greater than the upper bound value I (1), this shows that there exists the long run relationship between the variables. Results supported the existence of long-run relationship among the variables. The presence of long run causality has further been verified by the Johansen cointegration test. The max eigen statistics found to be more than 0.05% and it reveals the existence of long-run relationship among the variables.

As next step, granger causality test has been conducted. Results show that Granger causality between GDP and electricity utilization runs in both directions. Moreover, the study discloses that Electricity utilization granger cause exports and per capita real capital. Exports granger cause per capita real capital. Per capita real capital granger cause GDP. Labor force granger cause GDP and exports. As a next step stability tests CUSUM and CUSUMSQ have been performed based on SBC error correction model. Null hypothesis states that the coefficients are stable and will remain with boundaries at 5% significance level. Results show that CUSUM and CUSUMSQ statistics lie within the critical boundary values. Therefore, it can be concluded from CUSUM and CUSUMSQ tests that all the coefficients in error correction model are appeared to be stable and the selected model can be utilized for policy making and decision-making purposes.

5.2 Policy Recommendations

Presence of short run bidirectional causality among the GDP and electricity utilization proposes that Pakistan must adopt the dual approach of investment by enhancing the electricity infrastructure and also by improving the electricity conservation polices to avoid lessening in electricity utilization unfavorably impacting the economic development. Moreover, as results unleashed that Electricity utilization granger cause exports and per capita real capital, therefore Pakistan should adopt the policies to invest in electricity production so that exports can be increased and policies to provide low-cost electricity to export industry may increase the exports which in turn results in increase in the economic growth. The GDP and exports can be enhanced by implementing the policies to utilize the skilled labor force efficiently. Economic policies must be implemented by Pakistan to enhance the labor force participation rate which will result in the increase in exports and economic developments.

5.3 Research Limitations

This research is susceptible to these limitations; (1) the availability and accuracy of data obtained from authoritative sources such as the World Bank, the State Bank of Pakistan, and the Pakistan Bureau of Statistics are crucial to the success of this study. Any limitations, inaccuracies, or voids in these data sources may compromise the validity and dependability of the research results. (2) The use of time-series data in this analysis presents a unique set of challenges, particularly in addressing non-stationarity and autocorrelation issues, which may impact the robustness of the econometric results. Moreover, time-series data may not completely convey the complexities and fluctuations of the variables over time, especially if there are unaccounted-for structural interruptions in the data series. (3) Although widely acknowledged, the use of the neoclassical production model and Granger causality tests entails certain assumptions and constraints. For example, the model assumes a linear and symmetrical relationship between variables, which may not hold true in real-world circumstances.

Authors Contribution
Wasif Ali Khan: study design, data collection, data analysis, write-up, drafting

Conflict of Interests/Disclosures
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