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Determinants of Electricity Demand: An Empirical Analysis of Pakistan

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Abstract
This study employs a rigorous analytical approach, specifically employing cointegration and vector error correction analysis methodologies, to elucidate the intricate dynamics existing in both the long and short run relationships between electricity demand and its determinants. Through the systematic application of these advanced statistical techniques, our investigation aims to discern and characterize the nuanced interdependencies that govern the fluctuations in electricity demand, providing a comprehensive understanding of the underlying mechanisms at play. The study relies on a comprehensive dataset spanning the years 1970 to 2008, focusing on the context of Pakistan. The application of the Johansen cointegration test reveals compelling evidence that the variables under consideration exhibit a significant degree of integration in the long run. This finding underscores the enduring and interconnected nature of these variables over the specified temporal horizon, contributing valuable insights into the sustained relationships within the studied economic context. The error correction term serves as an indicator of the convergence of variables towards equilibrium. It encapsulates the adjustment mechanism through which deviations from the long-run equilibrium are rectified, emphasizing the dynamic process through which the studied variables align over time. In the short run, electricity functions as an essential commodity, meeting fundamental needs and playing a pivotal role in sustaining daily activities. Conversely, in the long run, it transforms into a luxury, indicative of an elevated standard of living and an increased capacity for discretionary consumption. This distinction underscores the evolving nature of electricity's role, transitioning from a basic necessity to a symbol of affluence and enhanced lifestyle over an extended temporal horizon. The study draws the conclusion that optimal management of electricity demand necessitates the implementation of effective price and income policies, along with the adoption of group pricing policies and peak-load pricing strategies. These recommendations underscore the importance of a multifaceted approach to address the complexities of electricity demand, emphasizing the need for strategic interventions in pricing structures, income considerations, and targeted policies for managing peak loads.
Keywords: electricity demand, cointegration, vector error correction analysis
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1. INTRODUCTION

Electricity is widely acknowledged as the cornerstone of an economy's prosperity and progress, playing an indispensable role in fostering socio-economic development. Its pivotal importance stems from its pervasive influence on various sectors, serving as a catalyst for growth, innovation, and improved living standards. In essence, electricity stands as a fundamental driver that underpins the socio-economic fabric, enabling nations to achieve sustainable development and enhance the quality of life for their citizens. Over time, the swift pace of development and technological innovation has led to a substantial escalation in the utilization of energy resources. Consequently, there has been an instantaneous surge in the demand for energy, coinciding with a concurrent reduction in available resources. This juxtaposition highlights a pressing challenge wherein the growing need for energy is outpacing the available resources, emphasizing the critical importance of sustainable and efficient energy management practices. Hence, addressing the escalating energy demand necessitates insightful and practical research efforts. This particular body of literature delves into the realm of "electricity demand," recognizing its significance as a crucial energy source on a global scale and particularly within the context of Pakistan. In the Pakistani landscape, electricity stands out as one of the most extensively utilized energy resources, making the exploration of its dynamics and management imperative for informed decision-making and sustainable energy practices.

Electricity serves diverse purposes across residential, industrial, commercial, and agricultural sectors, establishing itself as an indispensable necessity within each domain. Its ubiquitous application underscores its integral role in powering essential functions and processes, contributing significantly to the overall functionality and productivity of these sectors. Presently, Pakistan is grappling with the most severe energy and electricity crisis in its history. The deficit in electricity supply has surged by approximately 5000 megawatts, leading to a substantial escalation in daily load shedding from 8 to 14 hours. This persistent power shortage has had cascading effects, precipitating a decline in industrial growth and adversely impacting the overall economy. The repercussions of this crisis are multifaceted,

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posing significant challenges to the nation's economic stability and development. Among the various contributing factors to the electricity crisis, the escalating demand for electricity emerges as a pivotal element. Consequently, this research study meticulously examines the estimates and determinants of electricity demand, aiming to provide comprehensive insights for more effective policy management. By scrutinizing these aspects, the study seeks to contribute valuable information and recommendations that can guide strategic interventions to address the challenges posed by the increasing demand for electricity. This study investigates the influence of real income, electricity prices, the stock of electric appliances, and the number of customers on electricity consumption. Through a rigorous examination of these variables, the research aims to elucidate the intricate relationships and dynamics that shape patterns in electricity consumption. The findings from this analysis are poised to contribute valuable insights into the multifaceted factors influencing electricity usage, thereby informing potential strategies for efficient energy management and policy development. This study delves into the contemporary electricity crises, meticulously examining their root causes, influences, and consequential impacts. Furthermore, it conducts empirical analyses of electricity demand spanning the extensive period from 1970 to 2008. Through this comprehensive examination, the research seeks to provide a nuanced understanding of the ongoing electricity challenges, offering valuable insights that can inform strategic responses and policy measures to address the complexities surrounding electricity demand. The primary objective of this research study is to formulate an accurate estimation of the electricity demand function in Pakistan, operating at both aggregate and disaggregate levels. Through a meticulous analysis, the study aims to unravel the underlying factors and dynamics shaping the demand for electricity, providing valuable insights that can inform policy decisions and strategic interventions in the energy sector.

This research study endeavors to assess the influence of electricity demand determinants in both the short and long run. It systematically analyzes the factors shaping electricity demand to discern their respective impacts over varying time horizons. Additionally, the study delves into the discourse surrounding the ongoing energy crisis, providing an in-depth examination of its current manifestations, root causes, and potential consequences. The dual focus on understanding demand determinants and addressing the contemporary energy crisis contributes to a comprehensive exploration of critical issues within the energy landscape. The discourse in this study furnishes valuable policy implications aimed at fostering a more robust management of electricity demand for governmental consideration. The identified outcomes are designed to offer practical guidance, facilitating informed decision-making to address the complexities associated with electricity demand and contribute to the development of a healthier and more sustainable energy framework.

2. LITERATURE REVIEW

The practical implications and analytical examination of electricity demand have become increasingly pressing concerns over the last few decades, characterized by challenges in estimation, validity, and substantial fluctuations. Recognized as a linchpin for economic prosperity and progress, electricity assumes a pivotal role in socio-economic development. It is not an exaggeration to assert that electricity functions as the engine of growth, wielding significant influence both domestically and globally. This underscores the critical need for comprehensive understanding and effective management of electricity demand to sustain and propel economic advancement. The escalating demand for electricity underscores the heightened significance of research within the electricity sector. Simultaneously, the scarcity of electricity resources necessitates a meticulous examination of demand policies. According to projections by the International Energy Agency, developing countries are anticipated to augment their portion of global electricity consumption from 20.5 percent in 1999 to 35.8 percent in 2020 (IEA, 2002). Consequently, addressing the intricacies surrounding electricity demand becomes imperative, emphasizing the need for comprehensive policies to effectively manage this critical resource. Prior investigations into electricity demand have underscored the pivotal role of electricity in driving economic progress and development. Ghosh (2002) highlights the centrality of electricity as a crucial infrastructural input for socio-economic development. The effectiveness and significance of electricity are notably apparent in contemporary society, as also emphasized by Ghader et al. (2006). These insights collectively reinforce the indispensable nature of electricity in fostering individual well-being and broader societal advancement. Filippini and Pachauri (2004) elucidate that the upward trajectory in industrialization, population expansion, income growth, modernization, and urbanization has been instrumental in augmenting electricity consumption in the past. Furthermore, they posit that this trend is anticipated to intensify in the future, necessitating substantial investments to effectively address the burgeoning demand within the electricity sector. The elucidation underscores the imperative for strategic planning and investment to meet the evolving needs of a growing and modernizing society. Filippini and Pachauri (2004) further advocate for the significance of demand-side management in the context of constrained electricity supply. They posit that economic progress, promotion, and sustainability necessitate significant utilization of energy and electricity resources to stabilize the escalating demand and development. This underscores the critical role of electricity, which exhibits a high level of elasticity in response to economic growth and development. The recognition of demand-side management becomes pivotal in optimizing resource utilization and ensuring the stability of the electricity sector amid growing economic activities.

Electricity assumes a crucial role in driving economic development and growth. To discern the correlation between electricity consumption and economic growth, scholars often employ the Electricity Intensity ratio, calculated as the ratio of electricity consumption to GDP. This metric provides a quantitative measure of the relationship between the utilization of electricity and the overall economic output, serving as a valuable indicator in assessing the impact and

efficiency of electricity in fostering economic development. The Electricity Intensity ratio (electricity consumption/GDP) serves as a metric that illuminates the extent and variation in electricity usage across different countries. Al-Faris (2002) elucidates the significance of this ratio as a crucial indicator. A higher value of the electricity intensity ratio indicates a propensity for electricity consumption to outpace GDP growth, signaling an anticipation of accelerated growth in electricity consumption relative to the overall economic output. This insight becomes valuable in predicting and understanding the dynamics of electricity consumption in relation to economic growth. De Vita et al. (2006) delve into the concept of electricity intensity, emphasizing its implication of causality between electricity consumption and economic growth (GDP). This observation holds critical significance for policy considerations, as it underscores the bidirectional association between electricity consumption and economic growth. The intricate relationship suggests that policies aimed at controlling electricity consumption may potentially impact economic growth, and vice versa. The findings accentuate the need for a nuanced and balanced approach to policy formulation, recognizing the interdependence between these two vital elements in economic development. Theoretically, numerous studies have conceptualized the electricity demand function as a derived demand, contingent upon the household and firm's production theory. Filippini and Pachauri (2004) expound upon the production theory, which posits that economic agents employ input factors to generate output. In this context, the demand for electricity is perceived as a derivative of the underlying production processes, where the consumption of electricity is an instrumental input in the larger framework of economic activities and output generation. This theoretical foundation enriches the understanding of the intricate relationship between electricity demand and the broader economic production landscape.

According to Narayan et al. (2007), the production of a unit of product necessitates input factors, with electricity being a crucial element. Consequently, electricity demand becomes an integral component of the overall production function. Similarly, Vete (2005) has formulated a theoretical electricity demand model based on household production theory, emphasizing the role of electricity in the household production process. Building upon this theoretical foundation, various economists have developed diverse models, each tailored to capture the nuanced relationships and factors influencing electricity demand. These models serve as valuable tools for understanding and predicting the intricate dynamics of electricity consumption within different economic contexts. Erkan (2007) delineates two models for electricity demand function: the "reduced form model" and the "structural form model." The reduced form model encapsulates a direct linear association between electricity demand and its determinants. In the context of this specific research study, the chosen approach is the reduced form model. This modeling choice signifies a focus on establishing a straightforward and direct relationship between electricity demand and its influencing factors, providing a practical framework for analysis and interpretation within the scope of the study. The reduced form model, often referred to as the double-log linear demand model, establishes a direct and linear relationship between electricity demand and its determinants. In contrast, the "structural form model" takes a disaggregate approach, representing the electricity demand model as a set of equations. This structural form is also known as an indirect demand function, capturing the interdependencies and interactions between various factors influencing electricity demand through a system of equations. The choice between these models depends on the research objectives and the level of detail required to comprehensively understand the dynamics of electricity demand.

In the estimation process, Erkan (2007) has employed a dynamic form of the reduced model known as the partial adjustment model. This dynamic model is akin to the approach utilized in the earlier study by Berndt and Samaniego (1984). The partial adjustment model incorporates dynamics by considering the gradual adjustment of the system to changes over time. In the realm of theoretical modeling, Beenstock et al. (1999) have discussed nested and non-nested models. These distinctions in theoretical modeling provide a framework for considering the relationships among various elements in the model, allowing researchers to choose the most suitable approach based on the specific characteristics and complexities of the system under investigation. Beenstock et al. (1999) elucidate the concept of nested models, where consumers allocate resources for the consumption of competing goods after deciding on total consumption allocations. This approach mirrors the idea of "derived demand," indicating that the demand for one good is dependent on the demand for another. In contrast, non-nested models describe the simultaneous decision-making process of the consumer for all consumption goods, reflecting a "direct demand" approach. The distinction between nested and non-nested models provides insights into how consumer preferences and choices are structured, influencing the overall demand dynamics for various goods. In their study, Beenstock et al. (1999) have opted for the nested model, emphasizing the allocation of resources by consumers for competing goods after determining total consumption allocations. In a similar vein, Ghader et al. (2006) have employed a derived demand function, which conceptualizes the demand function as a system of equations, reflecting the interdependence of different goods in the consumption portfolio. This approach aligns with the notion that the demand for one good is derived from the demand for others, providing a comprehensive view of the interconnected dynamics in consumption patterns. As for Filippini (1999), further details or context would be needed to provide relevant information or insights.

The concept that electricity demand is derived demand implies that it can be delineated through production theory, which posits that economic agents require input factors for the production process. This relationship is embedded in both the cost and utility functions of the economic agent. Halvorsen (1976) holds the perspective that, within the household's utility function, electricity demand manifests as a form of direct demand. This dual characterization underscores the multifaceted nature of electricity demand, where it is not only a crucial input for production

processes but also a direct and essential component of household utility preferences. Wilder and Willenborg (1975) expound on the notion that household electricity demand is a derived demand, intricately linked to the primary demand for electric stock. This primary demand encompasses appliances, electric services, and other electric devices. In this framework, household electricity consumption is considered a consequence of the demand for various electrically powered goods and services, reinforcing the idea that it is derived from the broader array of electrically dependent items within a household. According to Anderson (1973), the household's electricity demand is characterized as derived demand originating from its utility function. Beyond considerations of income and commodity costs, this approach incorporates a comprehensive spectrum of factors. Geographical, demographical, and social behaviors of the household are integral components within this framework. This perspective recognizes the intricate interplay of various elements that contribute to the derived demand for electricity, providing a more holistic understanding of the factors influencing household electricity consumption. Reiss and White (2005) conclude that household electricity is a derived demand, contingent upon the stock of electric appliances. The durability of these appliances plays a pivotal role in shaping both short and long-term demand. They base their analysis on the utility maximization theory of households. Synthesizing insights from the reviewed theoretical literature, it can be asserted that electricity demand inherently exhibits derived demand characteristics. Consequently, the application of a reduced form model is deemed useful for capturing the intricate dynamics of such derived demand relationships.

Certainly, the empirical work in the field of electricity demand literature showcases considerable diversity across various dimensions. Notably, there is a wide array of studies with differences in terms of electricity demand determinants, model specifications, estimation techniques, and even the outcomes obtained. This diversity underscores the complexity of the electricity demand landscape and the myriad factors influencing it. As researchers employ different methodologies and focus on various aspects, the empirical literature reflects the multifaceted nature of electricity demand and the need for tailored approaches to comprehend its intricacies comprehensively. As elucidated by Espey and Espey (2004), the economic literature on electricity demand exhibits substantial diversification across various dimensions, including economic theory, estimation techniques, model specifications, the nature of data, and outcomes. For instance, the price elasticity of electricity demand ranges from -0.076 to -2.01 in the short run and -0.07 to -2.5 in the long run. This variation underscores the complexity of the field. In addition to economic variables such as income, prices, and appliance usage, socioeconomic, demographic, geographic, and meteorological factors are identified as crucial determinants in the multifaceted process of electricity demand determination. Certainly, the impracticality of covering all deterministic aspects in electricity demand research is acknowledged, primarily due to limitations in knowledge and data accessibility. Estimation techniques in this field span a wide range, with a notable prevalence of cointegration and Error Correction Model (ECM) approaches, often implemented through Vector Autoregressive (VAR) models. These methods are favored for estimating long-run relations, short-run dynamics, and elasticities, aligning with the characteristics of electricity data.

The choice of econometric techniques, including cointegration and ECM approaches, not only enhances the reliability of results but also provides statistical plausibility. Nonetheless, it is emphasized that the nature of the data should be carefully considered before applying any estimation technique. This recognition underscores the importance of methodological diligence in ensuring the robustness and validity of empirical findings in the study of electricity demand. In the context of this specific study on the empirical analysis of electricity demand in Pakistan, it is imperative to delve into the literature related to Pakistan's electricity sector and demand. Recognizing that international studies highlight the significance of diverse outcomes contingent on the country and region, a focused exploration of Pakistan-specific literature becomes essential. The literature underscores the profound impact of rapid developments and technological innovations, fostering the widespread utilization of appliances. This surge in appliance usage is a key contributor to heightened energy consumption, encompassing electricity, oil, and gas, on a considerable scale. Understanding the nuances of these dynamics in the Pakistani context is crucial for formulating insightful and context-specific conclusions in the empirical analysis of electricity demand in the region. In recent years, Pakistan has experienced a persistent decline in the growth rate of electricity consumption, primarily attributable to the severe electricity crisis afflicting the nation. This crisis is compounded by escalating electricity prices, elevated income levels, constrained supply, and inadequate management practices. It is noteworthy that this study exclusively concentrates on the demand-side aspects of these challenges. The repercussions of these crises have significantly impacted socioeconomic progress and various sectors within the economy, underscoring the urgent need for comprehensive strategies to address the multifaceted issues surrounding electricity consumption in Pakistan. Hence, there is a critical need for an in-depth exploration of electricity demand issues to offer valuable, constructive, and practical recommendations for addressing and managing the prevailing electricity crisis. The scarcity of literature on energy and electricity demand in Pakistan accentuates the urgency of this research endeavor. Although there have been some efforts in the recent past, the existing body of work appears to be insufficient and inadequate. This study aims to fill this gap by building upon and expanding the insights derived from the limited existing literature, with the goal of providing more comprehensive and nuanced perspectives on the electricity demand challenges in Pakistan.

From the brief literature review on Pakistan, it can be deduced that electricity demand assumes a pivotal role in the formulation of policies. Consequently, a thorough examination of the demand side of the electricity sector becomes indispensable. The review of significant studies on electricity demand functions, both in the context of Pakistan and internationally, reveals a substantial diversity in estimation techniques and results. This diversity underscores the

complex and multifaceted nature of electricity demand, emphasizing the need for nuanced and context-specific approaches to understand and address the challenges posed by variations in demand. The limited availability of research studies on electricity demand estimation in Pakistan underscores the necessity for more extensive exploration and investigation within both theoretical and experimental frameworks. The divergent results observed in different studies present challenges for the development of cohesive and unique policy formulations in the electricity sector. The existence of dissimilar findings highlights the complexity of the subject matter and emphasizes the need for further research to establish a more comprehensive understanding of the factors influencing electricity demand in the specific context of Pakistan. This ongoing exploration is crucial for informed decision-making and the development of effective and sustainable policies. Recognizing the sensitivity and significance of the issue at hand, this specific research study aims to ascertain the income and price elasticities in the context of electricity demand in Pakistan. By identifying the crucial determinants of electricity demand, the study seeks to contribute valuable insights that play a pivotal role in the derivation of electricity demand. This research opens a new paradigm for policy analysis concerning the management of electricity demand in Pakistan, providing a foundation for informed decision-making and the formulation of effective strategies to address the challenges in this critical sector. In following Table 1, results of some of the key studies about electricity demand at aggregate and disaggregate level (residential, industrial, commercial, and agriculture sectors) are stated.

3. RESEARCH METHODOLOGY

Indeed, theoretically, electricity demand is inherently derived demand, rooted in its dependence on the utilization of input factors within the production process. This conceptualization aligns with the foundations of "production theory," which posits that economic agents, whether households or firms, employ input equipment or stocks as integral components in their production processes. In this framework, the demand for electricity emerges as a consequence of the broader production activities within the economy, underscoring the interconnectedness between electricity consumption and the overall economic landscape. In the realm of electricity demand, economic agents utilize electricity consumption as an input factor in the production of commodities. This gives rise to derived demand, contributing to the agent's utility and cost functions. The intricacies of electricity demand are influenced by various factors, including the stock of electric goods, capital equipment, as well as demographic and geographic considerations. This dynamic interaction between electricity consumption, production processes, and the broader economic context highlights the multifaceted nature of electricity demand as a derived demand. Previous knowledge supports the understanding that electric appliances, income, and prices (both electricity and alternative sources) are influential fluctuation forces impacting electricity consumption. Additionally, demographic and geographic factors are recognized as having significant effects, contingent upon specific circumstances. This acknowledgment underscores the complexity of the determinants shaping electricity consumption, reflecting a combination of economic, technological, and contextual variables that contribute to the nuanced dynamics within the electricity demand framework. In the specific research study focusing on the empirical analysis of electricity demand in Pakistan, there is a recognition that electricity demand is sensitive to the prices of alternative fuels. It is apt to characterize alternative fuels, such as oil and gas, as complements to electricity. Across extensive regions, these fuels serve as crucial input factors for the generation of electricity, thereby establishing a complementary relationship between electricity demand and alternative fuel prices. This consideration adds a nuanced dimension to the understanding of the factors influencing electricity consumption in the Pakistani context.

Given the specific context of Pakistan, the demand function in this study will exclude alternative fuel prices, as they are not considered substitutes for electricity. Additionally, the focus of the study on annual data implies that temperature will not be incorporated in the analysis. Temperature, being a seasonal phenomenon, is outside the scope of this study, which aims to capture broader trends and determinants of electricity consumption over the annual timeframe. This targeted approach ensures a more focused and relevant analysis within the defined parameters of the research. The studies that have examined the impact of temperature typically utilize quarterly and high-frequency data. In contrast, this study employs annual time series data, which does not capture the seasonal fluctuations associated with temperature. Moreover, the primary objective of this study is to assess the influence of real income, prices, number of customers, and stock of electric appliances on electricity consumption. As a result, the demand function is articulated as follows

Electricity demand = f (real income, electricity prices, number of consumers, electric appliance)

In the empirical specification of the electricity demand model, studies such as those by Al-Faris (2002), Bose and Shukla (1999), De Vita et al. (2006), Galindo (2005), and others have adopted a double log-linear function of its determinants employing a "reduced form model". This particular specification is derived through utility maximization and cost minimization techniques. The double log-linear model yields elasticities, as emphasized by Varian (1988), which prove instrumental in demand management, analyzing demand behavior, electricity forecasting, and conducting policy analysis. The adoption of this model structure reflects a well-established approach in the literature for understanding and predicting electricity demand dynamics.

4. ESTIMATED RESULTS

This section presents the results obtained through empirical and estimation techniques, offering insights into the nature, behavior, performance, and characteristics of electricity demand models for Pakistan at both the aggregate and disaggregate levels. As outlined in the preceding section, these findings contribute to a comprehensive

understanding of the factors influencing electricity demand, shedding light on the dynamics and intricacies within the electricity consumption landscape in the country. In the data estimation process, the initial step involves checking the stationarity of the variables through a unit root test. This test is conducted using both the Augmented Dickey Fuller (ADF) and Phillip Perron (PP) tests. The results derived from these tests indicate the presence of unit root problems in all variables at a significance level of 5%. The unit root test specification incorporates an intercept (constant) term to assess the stationarity of the variables with drift, accounting for other factors in the analysis. All the referenced studies, including Al-Faris (2002) and Narayan (2007), have employed an intercept term in the unit root test specification. However, it is crucial to note that any result obtained from a non-stationary level series would be inconsistent and invalid. Fortunately, in this case, all variables exhibit stationarity at the first difference, and the hypothesis of non-stationarity is rejected at the 1% and 5% levels of significance. This finding suggests that differencing the data is effective in achieving stationarity, enabling the subsequent reliable estimation of the electricity demand models. The results from the unit root tests provide clarification that all variables, namely electricity consumption, real income, electricity prices, number of customers, and stock of electric appliances, are integrated at order I (1). This finding strengthens and justifies the application of the Johansen cointegration technique. The Johansen test requires a similar integration order as a necessary condition, and in this study, all variables in both aggregate and disaggregate models exhibit an integration order of one. This convergence in integration orders establishes a favorable condition for the implementation and reliability of the Johansen cointegration test in the subsequent analyses. Hence, the subsequent step involves analyzing whether the series of these variables integrate in the long run. In other words, the following section applies the Johansen test to determine the long-run relationships among the variables. This test is instrumental in investigating the presence and nature of cointegration, providing insights into the equilibrium relationships that may exist among the variables over an extended period.

Table 1: Results of Unit root Test

Variables	ADF		Philips-Perron (P)	
	I(0)	I(1)	I(0)	I(1)
Aggregate				
Elect	-1.53	-4.30*	-0.91	-4.36*
Rincome	-0.65	-4.38*	-0.34	-4.40*
Prelect	-2.28	-5.74*	-2.47	-5.73*
Cust	-0.22	-3.41***	-0.49	-3.42***
App	-2.09	-5.92**	-2.18	-5.91**
Residential				
Elect	-0.94	-4.83*	-1.19	-4.68*
Rincome	-0.53	-5.26*	-0.65	-5.28*
Prelect	-2.26	-5.77*	-2.39	-5.76*
Cust	-1.32	-4.45*	-1.35	-4.46*
App	-2.09	-5.92**	-2.18	-5.91**
Industrial				
Elect	-0.71	-4.10*	-0.1	-4.06*
Rincome	-0.94	-5.08*	-0.54	-5.15*
Prelect	-2.32	-5.68*	-2.48	-5.67*
Cust	-1.63	-9.62**	-1.6	-9.65**
App	-2.09	-5.92**	-2.18	-5.91**

The Johansen cointegration technique is applied to the series, which are non-stationary at the level form, to analyze and test their cointegration. The results from the unit root tests confirm that the variables are non-stationary at the level form. Subsequently, the Johansen cointegration test is conducted, and the results indicate that the null hypothesis of no cointegration relation is rejected at the 1% and 5% levels of significance. This rejection provides evidence in favor of the existence of cointegration relationships among the variables, suggesting a stable long-run equilibrium among them. The alternative hypothesis of cointegrating series is accepted and explicates that in aggregate and commercial sectors two cointegration relations exist as trace statistics is greater and significant than critical values at most rank ($r \leq 2$). Nevertheless, in the industrial, residential, and agriculture sectors, the null hypothesis of no cointegration cannot be rejected for two or more cointegration vectors. Therefore, based on the results presented in table (2), it can be inferred that long-run relationships exist in electricity demand and its determinants—namely, real income, electricity prices, number of customers, and stock of electric appliances—for all aggregated and disaggregated electricity models. The subsequent step involves analyzing the stability of this long-run linkage by estimating the Vector Error Correction Model (VECM).

Table 2: Johansen Cointegration Test

Hypothesized No. of CE(s)	Eigenvalue	Trace statistics	5 percent Critical Value	1 percent Critical Value
Aggregate				
None**	0.65809	112.8423	68.52	76.07
Residential				
None**	0.53587	78.87714	68.52	76.07
Industrial				
None**	0.63112	80.93393	68.52	76.07
Commercial				
None**	0.60973	100.4597	68.52	76.07
Agriculture				
None*	0.57285	71.38717	68.52	76.07

Following the discussion on the results of the long-run linkage among a series of electricity demand models, the subsequent step is to analyze the short-run dynamics through the Vector Error Correction Model (VECM). In short-run dynamics, the stability of the model is crucial, and this will be assessed by focusing on the Error Correction Term (ECT) obtained through VECM. The coefficient of ECT provides information on the speed with which a variable returns to its equilibrium position in the long run, and as such, the value of ECT should be negative and statistically significant. A negative sign indicates convergence in short-run dynamics. The results of the ECT are obtained from estimation and presented in table (3). The results of the Error Correction Term (ECT) indicate that in all five models, namely aggregated, residential, industrial, commercial, and agriculture, the coefficient is negative, confirming the convergence of the models to the long-run equilibrium. Table (3) further details that the ECT for all five models is statistically significant at the 5% level, as indicated by the t-statistics within parentheses. While the results concerning the speed of adjustment coefficient obtained through VECM are consistently significant and negative across all models, it is noteworthy that the magnitude or strength of the speed varies among them. These findings provide insights into the short-run dynamics and the adjustment process toward the long-run equilibrium in each electricity demand model. In the aggregate electricity demand model, the value of the Error Correction Term (ECT) is -0.565. This indicates that each year, 56.5% of the error is adjusted from the previous year, implying that over half of the short-run fluctuations are absorbed in the long-run trend. The moderate value of the adjustment parameter suggests that the speed of adjustment to the long-run equilibrium is moderate following short-run fluctuations. The t-value of the ECT in this model (aggregate electricity demand model) is 2.123, which is significant at the 95% level of confidence. This significance reinforces the reliability of the adjustment process towards the long-run equilibrium in the aggregate electricity demand model.

Table 3: Vector Error Correction Model and Short Run Dynamics

Variables	Aggregate	Residential	Industrial	Commercial	Agricultural
ΔElect (-1)	0.194	0.444	0.422	0.307	-0.037
Constant	0.009	0.062	0.025	-0.019	0.092
Δrincome (-1)	0.315	0.183	0.060	0.001	0.724
Δprelect (-1)	-0.189	-0.418	-0.214	-0.299	-0.139
ΔCust (-1)	0.289	0.060	1.738	0.547	0.471
ΔApp (-1)	0.028	0.290	0.025	0.085	0.003
ECT	-0.565	-0.222	-0.385	-0.330	-0.471

Table 4: Long Run Elasticities

Variables	Aggregate	Residential	Industrial	Commercial	Agricultural
Constant	3.167	5.388	5.243	2.321	14.910
Rincome	0.251	2.505	1.041	0.516	1.001
Prelect	-0.853	-1.743	-0.558	-1.834	-1.668
Cust	0.074	-0.067	-1.714	0.624	-0.930
App	0.640	0.292	0.230	0.264	1.690

Similarly, the coefficient value of adjustment parameter (ECT) in residential, industrial, commercial and agricultural electricity demand models is -0.222, -0.385, -0.330 and -0.471 respectively. These values indicate that 22.2%, 38.5%, 33.0% and 47.1% of the error is adjusted and corrected in respective models. All these values are negative indicating convergence to long run equilibrium and statistically significant at 1% and 5% levels of significance. To explore the more responsive behavior of elasticities of electricity demand determinants long and short run elasticities are estimated. Long run elasticities are acquired through Johansen cointegration technique and stated in table (4). Results of long run income elasticities explain that in all sectors the value of income elasticity is positive

confirming it as normal good. As far as the value of income elasticity is concerned it is greater than unity in all sectoral models except aggregate and commercial sectors. Income elasticity in aggregate, residential, industrial, commercial and agriculture sectors is 0.251, 2.505, 1.041, 0.561, and 1.001 respectively. As income elasticity is greater than unity in all sectors except aggregate and commercial sectors, based upon this upshot it can be deducted that according to income changes electricity acts as luxury good in residential, industrial and agricultural demand models. On other hand income elasticity at aggregate and commercial sectors is 0.251 and 0.561 respectively, which affirm it as a necessity. Price elasticity at aggregate, residential, industrial, commercial and agriculture sectors is -0.853, -1.743, -0.558, -1.834, and -1.668 respectively. Signs of price elasticity in all five models are negative; affirming that as the electricity prices raise the electricity demand falls. Long run price elasticity in all models except aggregate and industrial sectors is greater than unity indicating that electricity is a luxury commodity at residential, commercial and agriculture level. While at aggregate and industrial sectors price elasticity is less than unity and describes electricity as a necessity due to the fact that in present times consumption of electricity is significantly high and one cannot think of developed and comfortable life without electricity. Results of both income and price elasticities are statistically significant at 1 and 5 percent level of significance.

The analysis reveals that the number of customers and the stock of electric appliances exhibit positive long-run effects on electricity consumption in all models, except for the negative sign associated with the customer variable in the residential, industrial, and agricultural sectors. This negative sign indicates that at the residential, industrial, and agricultural scales, an increase in the number of customers is associated with a reduction in electricity consumption, possibly due to insufficient electricity availability in these sectors. The results indicate that the elasticity of customers is significant in all sectors, and it is less than unity in all models except the industrial sector. This suggests that the response of customers to changes in electricity consumption is inelastic, meaning that the demand for electricity is relatively insensitive to changes in the number of customers. Similarly, an inelastic response of electric appliances is observed in relation to electricity demand, with significant results across all five sectors. This implies that changes in the stock of electric appliances have a relatively small impact on electricity consumption in these sectors. Transitioning to the short-run dynamics and examining the short-run elasticity results, it is observed that short-run income elasticities are significant and positive in all five sectors. The values of income elasticity in all five models are less than unity, indicating that electricity is considered a necessity in the short run. The positive sign further suggests that, in the short run, an increase in income is associated with a proportional increase in electricity consumption across these sectors.

Examining short-run price elasticities, the results from table (3) indicate negative signs, reinforcing the notion that electricity is considered a necessity in the short run. Furthermore, the short-run price elasticities in all five models are less than unity, confirming that electricity consumption is relatively insensitive to changes in prices in the short run. These results are statistically significant at the 1% and 5% levels, except for the outcome in the commercial sector, which is moderately significant. The significance of these short-run price elasticities highlights the robustness of the relationship between electricity prices and consumption across different sectors. In terms of the short-run results for the number of customers, they reveal a positive behavior in all five sectors. The response of customers is inelastic in all cases except the industrial sector, where it is elastic. The number of customers has a significant impact on aggregate, residential, industrial, commercial, and agriculture sectors in the short run. Similarly, in the short run, electric appliances exhibit a significant and positive influence on electricity demand in all five sectors. These findings underscore the role of both customers and electric appliances as determinants of short-run electricity consumption dynamics across different sectors. If we talk about the goodness of fit and reliability of these long and short run dynamics we can analysis that F-statistic values are statistically significant for all five models used. Determination power of the model is also according to the expectations, as R^2 and adjusted R^2 are concern they range from 0.445 to 0.673 for five model now doubt these values of R^2 and adjusted R^2 are very low but previous studies of Al-Faris (2002). Galindo (2005). Khan and Qayyum (2008) and many others have recorded low determination power due to the nature of the study. The results of Durbin-Watson (DW) test for autocorrelation is stated in table (3). The value of DW ranges from 0 to 4, according to rule of thumb DW=2 reflects absence of autocorrelation problem. Results of DW test for all five models ranges from 1.700 to 2.177, indicating that problem of autocorrelation in all stated five models is not sever. To analyze the consistency of variance White heteroscedasticity test is used and results are provided in table (3). Results of White heteroscedasticity test reflect the presence of homoscedasticity as the value of F-probability of White heteroscedasticity test is well above 0.1 for all five cases. To check the specification of the models used, Ramsey Reset test is carried out which suggests that all five models are well specified. The null hypothesis of additive models is rejected as under F-statistics, probability (p-values) ranges from 0.001 to 0.090 in all five cases.

Drawing conclusions from the elasticity results of electricity demand models, it can be inferred that, in the long run, electricity consumption demonstrates elastic behavior with income levels in all sectors except the aggregate and commercial sectors. Additionally, electricity consumption exhibits elastic behavior with electricity prices in the long run for all sectors except the aggregate and commercial sectors. These findings shed light on the varying sensitivity of electricity consumption to changes in income and prices across different sectors over an extended period. Conversely, in the short run, income and electricity prices exhibit an inelastic response with electricity consumption. Both income levels and electricity prices show the expected positive and negative signs, respectively, in relation to electricity demand. Furthermore, the number of customers and the stock of electric appliances emerge as significant determinants of electricity demand with the anticipated signs. However, their response is generally inelastic across

the majority of the sectors. These short-run dynamics highlight the immediate, yet relatively insensitive, reactions of electricity consumption to changes in income, prices, and other determinants. In summary, the results from various studies related to different countries and Pakistan, with respect to income and price elasticities for electricity demand, reveal consistent patterns. In the long run, income consistently shows positive signs and exhibits elastic responses for electricity demand, suggesting that electricity is considered a luxury good. These findings align with the results obtained in the current study, reinforcing the notion that as income levels increase, electricity consumption tends to rise proportionally, indicating a positive relationship between income and electricity demand. Contrastingly, the long-run price elasticities exhibit mixed behavior in both previous and current studies, consistently demonstrating a negative influence on electricity consumption in both cases. In some sectors, the long-run price elasticity is elastic, while in others, it is inelastic. Specifically, in the current study, long-run price elasticity shows an elastic response in residential, commercial, and agriculture sectors, indicating that electricity consumption behaves as a luxury good in these sectors. However, in aggregate and industrial sectors, the long-run price elasticity is inelastic, suggesting that in these sectors, electricity acts as a necessity. These diverse responses underscore the nuanced relationship between price changes and electricity demand across different sectors. Regarding short-run dynamics, a comparison between prior studies and the current literature in this study strengthens the finding that, in the short run, income and electricity prices exhibit inelastic responses with positive and negative signs, respectively, across all sectors. This indicates that electricity demand is less responsive in the short run and is considered a necessity for life. Consequently, the comparison of the results from this study with key studies mentioned in Chapter Two leads to the conclusion that both sets of results support each other and present a consistent path for policy implications and electricity demand management.

5. RESULTS AND DISCUSSION

For the last few years electricity demand has rapidly increased in Pakistan and asks for demand management policies and further investment for power generation to cope with the increasing demand. Thus this paper attempts to investigate the determinants of electricity demand, the current electricity crisis and the impact of electricity determinants on its consumption. For this aggregate and disaggregate data is used from 1970 to 2008. Current electricity crisis has influenced the whole economy. Electricity crisis has mainly affected the industries, exports and employment. Where industrial losses have reached to 157 billion rupees, unemployment losses are about 400,000. On average industrial and export growth has demised to 2.4 and 1.2 percent respectively in last few years due to ongoing electricity crisis, which pulled back the economic growth so economic growth has decreased to 2 percent in last few years.

For the determination of the order of integration and stationarity unit root test is applied. Results of Augmented Dickey Fuller (ADF) and Phillip Perron (PP) test confirm the existence of unit root problems as all variables are non-stationary at level form but are stationary at level form that awoke for the use of Johansen cointegration test for the verification of long run association among electricity demand and its determinants. Results of cointegration test fortify that in all five models (aggregate, residential, industrial, commercial and agriculture) vector of variables integrate, proving the existence of long run relationships among electricity demand and its determinants. As far as the stability of this linkage is concerned an error correction model is applied. Results of error correction term (adjustment parameter) gives significant values for all five models having negative sign, indicating that in all five models after fluctuation relation converge to equilibrium. Nevertheless, this speed of adjustment towards equilibrium varies among different sectors, where the aggregate sector has higher speed of adjustment having value -0.565 indicating that 56.5 percent of the error is adjusted in one-year time span. While the residential sector has a minimum value of about -0.222 reflecting that in the residential sector convergence towards equilibrium is slow. Results of short and long run elasticities elucidates that in short run all determinants have low elasticities; response of electricity demand with income and prices is inelastic, representing that in short run most of the people consider electricity as a necessity. Therefore, under this short run response, effective income and price policy requires a component of shock and that shock must be significant in order to influence the consumption levels in all sectors. Other determinants of electricity demand i.e. customers and stock of electric appliances also have inelastic and significant effect on electricity consumption. Electricity prices have expected negative influence on electricity consumption while real income, customer and electric appliances positively affect electricity demand. All of these short run results are significant at 1 and 5 percent level of significance in all five models. To the degree that long run elasticities are concern all variables explicate desire signs except the customer's variable in the residential, industrial and agriculture sectors indicating that as number of customer increases in these sectors electricity consumption decreases due to the insufficiency of electricity supply. In all five models estimates are significant. Long run income elasticity is greater than unity in majority of the sectors and refers to electricity as a luxury good justified by the fact that 30 to 40 percent of Pakistanis are lacking access to electricity. However income elasticity at aggregate and commercial sector is inelastic indicating electricity as a necessity in these sectors. Long run price elasticities in aggregate and industrial sectors are inelastic, suggesting electricity as a necessity in these sectors awaking for significantly responsive price policy in these sectors for changing consumption levels. Further, at the residential, commercial and agriculture sectors price elasticities are greater than unity as electricity appears a luxury good in these models. In the long run other influencing factors i.e. customers and electric appliances are inelastic and significant.

Results and analysis of this study suggest valuable policy implications that electricity demand management should focus on the effective income and price policies for each sector to control this increasing demand. In long run electricity demand is income and price elastic at residential and agriculture sectors thus price decrease is best response in these sectors. In aggregate and commercial sectors income elasticity affirms electricity as a necessity and in aggregate and industrial sectors price elasticity has inelastic response so keeping in view this inelastic reaction of electricity in stated sectors, increasing price policy is the best demand management policy to curb the increasing demand. Suggesting short run policy, it has been noticed that electricity demand has inelastic response in all sectors for both income and electricity prices thus in short run effective demand management policy should increase electricity prices and that effect should be significant. Results of this study explains that response of electricity demand in each sector is different thus unique demand management policy is not effective so based upon the response of each sector, different demand management and group pricing policies should formulated in each sector. In addition to that peak-load pricing policy should be practiced in Pakistan, where high prices should be charged at peak-load hours of electricity consumption in order to sustain the boasting electricity demand. Over the last few years such steps have been taken which rapidly raised the supply of electric appliances at a cheaper rate and consequently electricity consumption has drastically increased. Keeping in view that electric appliances have significant influence on electricity consumption, such policies should be reviewed. In addition to these policy measures government also needs to improve and install new energy generating plants and the infrastructure. Private sector should be encouraged in the electricity sector to break the existing natural monopoly and to increase competition. New clean and cheaper substitutes of electricity should be introduced. Finally energy and electricity conservation strategies should be applied in all sectors for effective and productive uses.

6. CONCLUSION

In conclusion, the study provides valuable insights into the dynamics of electricity demand in Pakistan, particularly highlighting the severe consequences of the ongoing electricity crisis on the economy. The results confirm the existence of unit root problems, necessitating the application of cointegration tests to establish long-run associations among electricity demand and its determinants. The findings underscore the widespread impact of the electricity crisis on industries, exports, and employment, leading to substantial economic losses. The error correction model reveals significant values for the adjustment parameter in all sectors, indicating a convergence towards equilibrium after fluctuations. However, the speed of adjustment varies across sectors, with the aggregate sector demonstrating a higher adjustment speed. Short and long-run elasticities analysis reveals that, in the short run, electricity demand is inelastic with respect to income and prices, suggesting that people consider electricity a necessity. Long-run elasticities vary across sectors, with income elasticity greater than unity in most cases, justifying electricity as a luxury good due to a significant portion of the population lacking access to electricity. The study provides crucial policy implications, emphasizing the need for tailored demand management policies for each sector. Long-run elasticity results suggest that a decrease in prices is the best response in residential and agriculture sectors, while increasing prices is effective in aggregate and industrial sectors. Short-run policies should focus on significant price increases to curb demand. Additionally, the study recommends unique demand management and group pricing policies for each sector, highlighting the importance of implementing peak-load pricing to manage electricity consumption during peak hours. Furthermore, the study calls for a review of policies that rapidly increased the supply of electric appliances at a cheaper rate, considering their significant influence on electricity consumption. It suggests that the government needs to invest in new energy-generating plants and infrastructure, encourage private sector participation to enhance competition, and introduce cleaner and cheaper substitutes for electricity. Finally, the implementation of energy and electricity conservation strategies across all sectors is advocated for effective and sustainable resource utilization.

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