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Assessing Electricity-Driven Emissions: A Sectoral Dual Model Approach

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ABSTRACT

One of the major issues of environment is of hazardous gas emissions. The current study focuses on the emissions of carbon dioxide emissions and other greenhouse gas emissions, which is released by three consumption sectors that are household, commercial and industrial. The time period for the study has been chosen to be 1972-2022. Stationary test was conducted to infer the appropriate methodology for the model. All the variables were found to be stationary at first difference except for electricity consumption household which is found stationary at level. Thus, the appropriate model for carbon dioxide emissions would be Autoregressive distributive Lag model (ARDL). While when the bounds test for the model of other greenhouse gasses was conducted no co-integration was found therefore, only short run results were reported. For the case of carbon dioxide emissions electricity consumption household and electricity consumption commercial are significant in long run.

Keywords: Environmental Economics, Energy Economics, GHG Emissiona, Autoregressive distributive Lag model

1. INTRODUCTION

The consequence of increasing greenhouse gases in global environment during the last century has led to severe climate change effects (C. Zou et al., 2016). The studies conducted by scientist have exhibited how these greenhouse gases especially carbon dioxide emissions have led towards degradation of the environment and increased natural calamities that immensely affect the safety and health of humans (Walter et al nature 2002).
A complex relationship exists between energy consumption, oil prices and quality of environment (Ashraf et al., 2022). One of the major reasons of increased carbon dioxide emissions is due to usage of non-renewable energy sources such as crude oil. The demand or supply of crude oil is highly affected by its price (Krichene, 2008).
Many economies especially developing ones deliberately ease environmental rules in their country to attract foreign direct investments and transnational corporations. Although these corporations bring investment and therefore contribute to the economic growth of the host country, but they are also a concern for the international community in general. The critics of transnational corporations debate upon the consequences of such organizations that have led to major problems of which one of the most important and prominent are ethical and environmental effects(Monshipouri et al., 2003). The transnational corporations not only export hazardous goods many times they are involved in producing hazardous processes as they install industries in host countries that produce high levels of toxins and pollutants. The act, therefore, results in creating complications in pollution control, dumping of waste, and perils for considerable accidental events and safety and health concerns for the labour. This proves the Theory of Pollution Haven hypothesis.

The modern world cannot survive without energy sources. Social, economic and technological aspects of modern life all require energy forms either primary or secondary. Even in this modern era where the world seeks to utilize renewable energy sources the major share of global energy production is still fulfilled by fossil fuels mainly crude oil. The prices of oil are volatile in nature. The volatility, therefore, affects the economic activities. The fluctuation in prices is mainly of concern for the developing or oil importing countries (Lescaroux & Mignon, 2008),(Mehrara & Oskoui, 2007),(Umar et al., 2022) Industrial, commercial, households, agricultural and transportation sectors all use energy in various ways. Prices of crude oil are a detrimental factor for oil importing economies which in turn affects the demand of energy and its consumption and therefore, economic growth. The demand patterns thus would affect carbon dioxide emissions in the nation (Yang et al., 2019). A large number of literatures assume a linear relationship between oil prices energy consumption and carbon dioxide emissions, which can be true in some cases, but does not hold true for every country (Ashraf et al., 2022).

Pakistan is included among the developing countries of South Asia. As with all economies trying to achieve economic progress they require large amounts of energy sources. Pakistan being a developing country mainly utilizes non-renewable energy specially oil as its major power source, (Elahi et al., 2024), where most of it is imported. Fluctuations in oil prices are considered to have a strong impact on the consumption patterns of the country. International oil price shocks, political scenario or social structure all play a part in adjusting the consumption as well as production sectors of the economy. These adjustments thus alter the production of carbon dioxide emissions in the environment. Pakistan is one of the major countries which is said to have been affected by climate change and global warming (Shahid, 2021). Another reason that affects the climatic conditions of Pakistan is transboundary pollution from its emerging economic neighbours(Abas et al., 2019).

2. LITREATURE REVIEW

Rasheed et al. (2022) inspects the long run relationship in thirty European countries among the variable's energy consumption (non-renewable and renewable energy), oil prices and carbon dioxide emissions. Global climate change is an immense issue throughout the world due to this reason Europe seeks to attain carbon neutrality by the year 2050. The sample data has been taken from 1997-2017. The adapted methodology is fully modified ordinary least square (FMOLS), Westerlund co integration and Driscoll-Kraay Regression. The results depict a long run relationship between non-renewable energy consumption and carbon dioxide emissions. Moreover, the study also shows that as the energy prices increases people move towards alternate which n turn reduces the emissions of carbon dioxide energy sources.

Leitão (2021) explores the relationship between the severity of energy consumption, carbon dioxide emissions, income per capita and trade intensity in Portuguese economy from the time period of 1970-2016. Various econometric methodologies have been applied is such as Autoregressive Distributive Lag model (ARDL), Co integration models namely fully modified ordinary least square (FMOLS) and Quantile regression and Dynamic Ordinary least square. The results are in alignment with the results found in literature. Energy consumption has a positive effect on climate change. The ARDL model in the long run shows decrease in carbon dioxide emissions. The outcome has been shown to improve both in according to Paris Agreement and Kyoto Protocol.
Mujtaba & Jena, (2021) scrutinizes the causal and asymmetric effect of energy use, oil prices, economic growth and foreign direct investment inflows on carbon dioxide emissions for the case of India. Moreover, the study also investigates the exponential growth of all the variables from the period of 1986-2014. The approach utilized is Non-linear autoregressive distributive lag (NARDL) and asymmetric causality test. The results depict significant and favourable impact on carbon dioxide emissions of positive and negative shocks of the oil prices. Furthermore, positive shocks in energy consumption also show significant and positive impact on emissions of carbon dioxide.

Jia et al. (2021) review the influence of Covid-19, emissions and oil price slum on the economy of China. The impact of the pandemic and oil price slump has differing effect on the emissions on Chinese economy. The economy of China is far more affected by the change in the international oil prices then it is by the pandemic. In Short run lower oil prices leads to higher oil consumption which further leads to increased carbon dioxide emissions. Decreased international oil prices also affect domestic oil industry (Abumunshar et al., 2020). The study applies extensive empirical methods for the investigation, three co-integration tests have been applied, the bootstrap autoregressive distributed lag which is a new development as suggested by (McNown et al,2018), second is the modern technique of Bayer-Hanck (2013) combined co integration and the third is H-J co-integration technique that includes two structural breaks. For long run ARDL, DOLS, CCR and FMOLS were applied. Granger causality was also applied to inspect the direction of the variables. The outcome illustrates, in long run, a negative impact of oil prices on carbon dioxide emissions. Non-renewable energies cause an increase in the emissions of carbon dioxide, while renewable energies have an opposite effect on the release of Carbon dioxide emissions and therefore decrease environmental pollution. The results show these effects due to the fact that Turkey is heavily dependent on imported oil and thus renewable energy sources should be adopted to decrease fluctuations and achieve sustainable development.

Agbanike et al. (2019) gives an insight of the causal relationship among the variables oil prices, energy consumption and carbon dioxide emissions in case of Venezuela. Additional variables are also included for enhanced estimations namely economic growth, trade openness and government consumption expenditure. The duration investigated is from 1971-2013. Technique utilized if ARDL bounds approach for co integration. The results highlight a long run relationship between the variables incorporating structural breaks in the series. Increase in the prices of crude oil results in the increase in energy consumption and thus carbon dioxide emissions. Causality has been investigated among the variables utilizing the novel innovative accounting approach. It was found that energy consumption in caused by the crude oil prices. Energy consumption causes carbon dioxide emissions in the economy.

Usman et al. (2019) scrutinizes the degree of consumption of electricity for the Nigerian commercial sector, where its economy seems to enhance in urban as well as rural domain. The aim of the study is to explore the variables that determine the volume of electricity in the commercial sector of Nigeria. For methodology forecasting methods and multiple linear regression has been applied. For initial nature's seven variables of explanatory nature are chosen where it was found that rainfall, relative humidity, temperature, total primary energy and total electricity delivered gave the best outcome. Time span for the study ranges from 1990 to 2014.

It was concluded that these variables should be given primary importance in designing sustainable electricity policies for commercial sector in case of Nigeria.

X. Zou (2018) inspects linkage between American oil prices, GDP and carbon dioxide emissions. The duration of investigation is taken form 1983-2013. The paper utilizes the technique of Vector error correction model (VECM) to explore co integration and stability. Moreover, as a prerequisite stationarity was applied and for exploring the direction Granger causality is adopted. The results highlight that variation in the prices of oil impacts in the shifting of carbon dioxide emissions, both in the short run as well as long run. Furthermore, the impact of oil prices is greater in short run on carbon dioxide emissions while in the long run the impact tends to soften.

Grottera et al. (2018) highlights that in order to attain lower greenhouse concentration levels achieving low carbon releasing technology are not sufficient; rather it is important that consumption patterns should be altered. Household electricity consumption pattern is considered an important factor as it reflects the household choices. The study is conducted in France and Brazil, where it is explored how different appliances used in households are responsible for releasing carbon dioxide emissions. The outcome shows the existence of an income gap between France and Brazil. While it is also depicted that there is presence of trend convergence in the requirements of electricity and that although intuitively the gap that was expected to exist between energy consumption due to income differences was not as prevalent as expected.

Khalid & Sunikka-Blank (2018) focuses to explore the divergence between in the Global south of domestic energy use advancing within a socio-technical angle. It investigates in Lahore, Pakistan a trend of household electricity consumption methods based on area for the latest century. The research explores multiple links of practice spatial arrangements of urban housing, shaped by evolving practices that have emerged, persisted and transformed over time leading to unsustainable electricity consumption for middle class households. The approach used for the data collection consists of a mixed approach that includes a review of building regulations, archival documents, house plans, expert interviews, oral history narratives and case studies. Three central themes have been found via the analysis to explore increase in the demand of electricity in households. Shifting of activities from outdoor to indoor and shift from an inward focused design to an outward oriented approach which is also accompanied by a spatial dispersion of practices. The study further indicates that analyzing the longitudinal dynamics of practice arrangement can help recognize and prevent the normalization of sustainable configurations that gradually integrate I to social structure and routines. Modern standards are likely to drive higher electricity demands due to increased consumption l, specialized spatial requirements, culturally mismatched indoor and outdoor layouts, an unquestioned dependence on electricity and the underutilization of outdoor spaces.

Zaghdoudi (2017) examines causality for the case of The Organization for Economic Cooperation and Development (OECD), among the variable's renewable energy, oil prices and carbon dioxide emissions. The sample period is taken from 1990-2015. Panel co-integration has been undertaken for methodological purposes. The outcome brings out significant and negative link among renewable energy, carbon dioxide emissions and oil prices. In long run as well as short run the granger causality depicts two-way causality between oil prices and carbon dioxide emissions.

Nwani (2017) scrutinizes the causal link between crude oil prices, energy consumption and carbon dioxide emissions for Ecuador. The duration investigated is taken from 1971-2013. The technique applied is ARDL bounds test with structural breaks. The ARDL test indicates existence of co integration among variables. The relationship of Ecuador is found to be significant and positive in the long run for energy consumption on carbon dioxide emissions. Furthermore, the causal relationship of crude oil on carbon dioxide emissions, in short run and long run is also found to be positive and significant. This outcome emphasizes that as the price of crude oil increases it induces conditions in the economy that eventually increases more energy consumption and thus carbon dioxide emissions increases.

To et al. (2017) explores for the case of Hong Kong the seasonal characteristic of electricity consumption. The time period for inspection ranges from 1970 January to 2014 December. For the commercial and residential sectors two new seasonal nonlinear models have been adopted as methodology. It was found that the two described sectors have variation in season. Especially, residential demand for electricity in the summer period is depicted to have a quadratic relationship with variables such as monthly mean air temperature. On the other hand, it was also explored that there is a linear between monthly mean air temperature and electricity consumption in the commercial sector. A non-linear relationship model was also found between the period of January 2015 and December 2016.

Apergis & Payne (2014) investigates the dynamic causal relationship among real GDP, renewable energy, emissions and Oil prices for OECD countries. The time period for exploration has been selected by the author form 1980-2011. A preliminary analysis was conducted on the panel data that indicated presence of crosssectional dependence. Therefore, Smith et al. (2004) and Pesaran (2007) second generation test of panel unit root was applied. The outcome of the panel co integration test and error correction model depicts a relationship of long run between renewable energy consumption per capita, real GDP per capita, carbon dioxide emissions per capita and real oil prices. Moreover, long run elasticity measures are found to be significant and positive for the variables carbon dioxide emissions per capita, real Oil prices and real GDP per capita.

Ponniran et al. (2012) aims to scrutinize, for Malaysia, electricity consumption in commercial and residential sector by monitoring various electrical appliances utilized in the household that dispense high electricity volume. The characteristic of each major load is analyzed. Moreover, for comparison purposes efficient electrical appliances usage is compared with potential energy saving. As for methodology, a questionnaire method has been used. For the residential sector three different classes have been scrutinized; low, middle and high where 150 respondents were involved. On the other hand, for the commercial sector 100 respondents were involved from places such as restaurants, workshops, hotels etc. The outcome depicts that in the commercial sector compressors utilized large amounts of electricity while in domestic sector refrigerators were responsible for high consumption. Furthermore, it was revealed that efficient electrical appliances do reduce electricity usage, but human factor plays a significant role in the reduction.

Sadorsky (2009) estimates for the presentation of empirical model on renewable energy consumption, carbon dioxide emissions and oil prices in G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, as well as the European Union). For methodology two different co-integration techniques have been applied to check the robustness of the results; FMOLS and DOLS with error correction model. In the long run panel co integration estimates a raise in oil prices to have negative but small impact on renewable energy consumption. Carbon dioxide elasticities were found to be variable across various countries on the other hand oil price elasticities are negative and positive respective to the country but significant in all of them.

Shanthini & Perera (2007) explores the oil price fluctuation incorporated model (OPFI) for emission in carbon dioxide and energy consumption of high earning economies. Since Environmental Kuznets curve (EKC) is known to exist for these economies, the OPFI model has capability to eliminate autocorrelation which exists in per EKC or per capita linear model. The data has been taken form 1960-1997. The results highlight that during 1991-1997 fluctuations in oil prices generate diversification on the dependability of the per capita emissions and consumption of energy.

3. METHODOLOGY

Sources such as the Economic survey of Pakistan and World Bank online data has been utilised for acquiring the data. The period selected for the study ranges from 1972-2022 on annual basis. The research investigates the impact of electricity consumption on the basis of sectors; household sector, industrial sector and commercial sector on the environmental variables which are carbon dioxide emissions and other greenhouse gasses.

H_1= Household, Commercial and Industrial sector of electricity consumption has an impact on carbon dioxide emissions.

H_2= Household, Commercial and Industrial sector of electricity consumption has an impact on other greenhouse gasses.

1) Carbon dioxide consumption

lco= f(lecc,lech,leci)

$$lco_t = \alpha_0 + \beta_1 lecc_{it} + \beta_2 lech_{it} + \beta_3 leci_{it} + v_{t1} \ldots..(1)$$

2) Other Greenhouse gases consumption

oghg =f(lecc, leh, leci)

$$oghg_t = \alpha_0 + \beta_1 lecc_{it} + \beta_2 lech_{it} + \beta_3 leci_{it} + v_{t1} \ldots..(2)$$

TABLE 1. DATA SOURCE

SERIES	Denoted by	Measure	Source	Type of variable
Carbon dioxide Emissions	co	Kiloton	World Bank	Dependent Variable
Other Greenhouse Gas Emissions	oghg	Thousand metric tons of CO2 equivalent	World Bank	Dependent Variable
Electricity Consumption (Household)	ech	GWH	Economic Survey of Pakistan	Independent Variable
Electricity Consumption (Commercial)	ecc	GWH	Economic Survey of Pakistan	Independent Variable

Electricity Consumption (Industrial)	eci	GWH	Economic Survey of Pakistan	Independent Variable

Table 1 depicts variables utilized for the study. Furthermore, the table also highlights the source of series taken and if the variable is taken as dependent and independent.

4. DESCRIPTIVE STATISTICS

For the variables included in the research descriptive statistics has been conducted for the purpose of exploring average, kurtosis, skewness, standard deviation and normality of all.

TABLE 2. POLLUTANTS

	Carbon dioxide emissions (Kt)	**Other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO2 equivalent)**	**Electricity consumption (Household)**	**Electricity consumption (Commercial)**	**Electricity consumption (Industrial)**
Mean	101,016.22	-3,027.45	20,289.84	3,274.88	13,612.49
Median	94,447.25	-4,470.95	17,757.00	2,333.00	12,528.00
Standard Deviation	64,751.55	6,576.67	16,389.82	2,429.49	7,825.52
Kurtosis	-1.126	0.798	-1.024	-0.864	-1.223
Skewness	0.389	1.388	0.45	0.65	0.162
Jarque Bera	4.100923	16.19804	5.932372	2.876063	4.921734
Minimum	18,929.05	-9,873.90	635	378	2,855
Maximum	240,839.11	13,940.00	54,028.00	8,606.00	28,760.00

Table 2 shows the descriptive statistics for the pollutants and sectors included in the research, which are carbon dioxide emissions, other greenhouse gases, Electricity consumption (household), Electricity consumption (Commercial) and Electricity consumption (Industrial).

The average carbon dioxide emissions are about **101,016 Kt**. The emissions have ranged from as low as **18,929 Kt** to as high as **240,839 Kt**. The distribution of these emissions is **slightly right skewed**, meaning there are a few high values that stretch the data toward the right, but it's not a huge difference. The **kurtosis** value is **-1.126**, which indicates that the distribution is a bit flatter than a typical bell curve. So, there's not much of a sharp peak or extreme outliers.

The **standard deviation** is very large (**647,510,547**), which suggests there's a lot of variability in the emissions, especially when comparing the lowest and highest values. Finally, the **Jarque-Bera statistic** is **4.1**, which is a bit low and suggests that, while the distribution isn't perfectly normal, it's close.
In short, while the data shows some variability and skew, it's still somewhat normally distributed overall.
The average for other greenhouse gases is about **-3027.454**, with values ranging from a low of **-9873.901** to a high of **13,940**. The data is a bit **positively skewed** (with a skewness of **1.388**), meaning there are a few higher values that pull the data to the right. The **kurtosis** value of **0.798** shows that the distribution is close to normal, though it's a little flatter.

The **standard deviation** is **6576.671**, which means there's some spread in the data, but nothing too extreme. The **Jarque-Bera test** comes in at **16.198**, suggesting the data doesn't stray much from normal distribution.
Household electricity consumption depicts a mean of 20289.843, a range of 635-54028 exists, slight right skew with skewness of 0.450 and slight platykurtic with distribution with -1.024. The Standard deviation is about 16,389.820 and the series appears to be normal with Jarque berra to be 5.93.

The commercial electricity consumption data exhibits a minimum value of 378 and a maximum value of 8606, with a mean of 3274.882. The distribution displays positive skewness (0.650), indicating a rightward skew. The kurtosis value of -0.864 suggests a platykurtic distribution, indicating a relatively flat curve compared to a normal distribution. The standard deviation is 2429.488, and the coefficient of variation is 74.19, reflecting considerable variability relative to the mean. The Jarque-Bera test statistic yields a probability of 0.0785, which suggests the data does not significantly deviate from normality.

The industrial electricity consumption data ranges from a minimum of 2,855 to a maximum of 28,760, with a mean value of 13,612.490. The skewness of the distribution is 0.162, indicating a slight positive skew. The kurtosis value is -1.223, which suggests a platykurtic distribution, characterized by a flatter peak compared to a normal distribution. The standard deviation is 7,825.515, and the coefficient of variation is 57.49, reflecting a moderate degree of relative variability. The Jarque-Bera test statistic is 3.38.

TABLE 3. UNIT ROOT TEST AUGMENTED DICKEY FULLER TEST (ADF and PP)

Augmented Dickey Fuller			**Phillips Perron**		
Variable	**At level**	**At First Difference**	**Variable**	**At level**	**At First Difference**
Carbon Dioxide Emissions	0.8507	0.0000	Carbon Dioxide Emissions	0.8507	0.0000
Other Greenhouse Gases	0.9936	0.0000	Other Greenhouse Gases	0.9659	0.0000
Electricity Consumption Commercial	0.1015	0.0000	Electricity Consumption Commercial	0.1015	0.0000
Electricity Consumption Household	0.0000		Electricity Consumption Household	0.0001	
Electricity consumption Industrial	0.2628	0.0000	Electricity consumption Industrial	0.2548	0.0000
Where the Series with p-value are greater than 0.05 H0 is accepted therefore they are all non-stationary at 5% significance level. While where it is less than 0.05 H0 is rejected and the series is stationary.					

Table 3 portrays the product of two-unit root tests for each variable of the two models. The two tests are Augmented dickey Fuller test (ADF) and Phillips Perron (PP). According to both test all the variables are stationary at First difference except for electricity consumption household which is stationary at level. Thus, ARDL test is considered to be appropriate for both models.

TABLE 4. ARDL BOUNDS TEST CARBON DIOXIDE CONSUMPTION

Order of Lag	**ARDL Bound Test (F-Stats)**	**Significance Level**	**Lower Bound**	**Upper Bound**	**Co-integration**
1	6.382643	10%	2.72	3.77	EXISTS
		5%	3.23	4.35	
		2.50%	3.69	4.89	
		1%	4.29	5.61	

$$\Delta lco_t = a_{01} + b_{11}lco_{t-i} + b_{21}lech_{t-i} + b_{31}lecc_{t-i} + b_{41}leci_{t-i} + \sum_{i=1}^{p} a_{1i}\,\Delta lco_{t-i} + \sum_{i=0}^{q1} a_{21}\,\Delta lech_{t-i} + \sum_{i=0}^{q2} a_{3i}\,\Delta lecc_{t-i} + \sum_{i=0}^{q3} a_{3i}\,\Delta leci_{t-i} + \lambda ECT_{t-i} + \epsilon_{it} \text{ …….(1)}$$

As shown in table 4 it is evident that there is existence of long run relationship at 5% level of confidence interval.

TABLE 5. ARDL CO-INTEGRATING AND LONG RUN FORM

(1, 0, 0, 0)				
ARDL SHORT RUN COEFFICIENT				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LECC)	4320.316	0.044088	97992.34	0.0000
D(LECH)	0.120919	0.038494	3.141259	0.0030
D(LECI)	-0.05651	0.081225	-0.69571	0.4902
CointEq(-1)	-1.94802	0.057235	-34.0354	0.0000
LONG RUN COEFFICIENTS				
LECC	2217.804	65.1521	34.0404	0.0000

LECH	0.062073	0.019458	3.190085	0.0026
LECI	-0.02901	0.041959	-0.69135	0.4929
C	0.774218	0.169346	4.57181	0.0000

Table 5 presents the results of the model analyzing carbon dioxide emissions across various consumption sectors. In the short run, both commercial and household electricity consumption exhibit a significant positive impact on carbon dioxide emissions, with positive coefficients for each. The co-integration coefficient in the model is significant and negative, indicating a tendency toward convergence and equilibrium in the long run. Similarly, in the long run, both household and commercial electricity consumption continue to show a significant positive effect on carbon dioxide emissions

5. RESIDUAL DIAGNOSTICS

TABLE 6. HETROSKEDASTICITY (ARCH TEST)

F-statistic	1.448218	**Prob. F (2,45)**	0.2457
Obs*R-squared	2.902699	**Prob. Chi-Square (2)**	0.2343

Table 6 summarizes the results of the ARCH test for heteroscedasticity. The null hypothesis posits the absence of heteroscedasticity. As indicated by the R-squared values, which exceed 0.05 in the model, the null hypothesis is not rejected. This suggests that, at the 5% significance level, there is no evidence of heteroscedasticity in the model.

TABLE 7. SERIAL LM CORRELATION

F-statistic	0.27097	**Prob. F (2,43)**	0.7639
Obs*R-squared	0.622319	**Prob. Chi-Square (2)**	0.7326

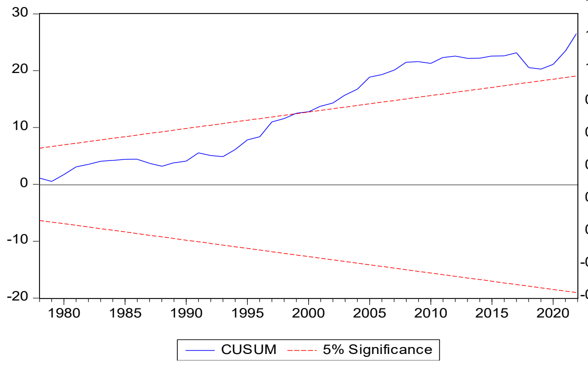
Table 7 presents the results of the Breusch-Godfrey serial correlation LM test, developed by Trevor S. Breusch and Leslie G. Godfrey (1981), to assess autocorrelation within the model. The null hypothesis, which asserts the absence of autocorrelation, is not rejected, as the p-values for the observed R-squared value in all models is greater than 0.05, indicating no autocorrelation at the 5% significance level.

TABLE 8: NORMALITY

Jarque-Bera	4.408982	**P-Value**	0.1103

Table 8 depicts the normality of the carbon dioxide consumption model. Where it is clear that p-value is above 0.05 thud there is presence of normality in the model.

DIAGNOSTIC TEST (CUSUM AND CUSUMQ)



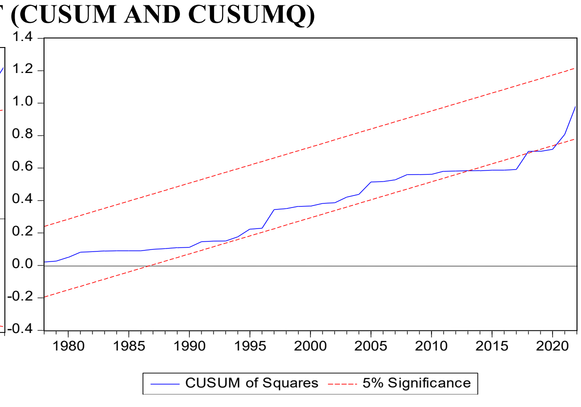


Figure 1

Figure 1 shows CUSUM and CUSUMQ for the carbon dioxide model. Cusum shows some divergence beyond the limits while Cusumq highlights to be mostly within the prescribed range.

6. CAUSALITY TEST

TABLE 9. TODA YAMAMOTO

Carbon Consumption			
Dependent variable: LCARB			
Excluded	**Chi-sq**	**df**	**Prob.**
LECC	0.066383	1	0.7967
LECH	2.420151	1	0.1198
LECI	0.038546	1	0.8444
Dependent variable: LECC			
Excluded	**Chi-sq**	**df**	**Prob.**
LCARB	0.199919	1	0.6548
LECH	0.194067	1	0.6596
LECI	0.649764	1	0.4202
Dependent variable: LECH			
Excluded	**Chi-sq**	**df**	**Prob.**
LCARB	2.136705	1	0.1438
LECC	1.289909	1	0.2561
LECI	11.36456	1	0.0007
Dependent variable: LECI			
Excluded	**Chi-sq**	**df**	**Prob.**
LCARB	1.834068	1	0.1756
LECC	0.157873	1	0.6911
LECH	7.080516	1	0.0078

Table 9 illustrates the Toda-Yamamoto causality test results between carbon dioxide emissions and three electricity consumption sectors, analyzed at the 5% confidence level. The findings indicate a bidirectional causal relationship between household electricity consumption and industrial electricity consumption.

7. OTHER GREENHOUSE GASES

TABLE 10. ARDL BOUNDS TEST OTHER GREENHOUSE GASES CONSUMPTION

Order of Lag	**ARDL Bound Test (F-Stats)**	**Significance Level**	**Lower Bound**	**Upper Bound**	**Co-integration**
4	2.870353	10%	2.72	3.77	Non Existent
		5%	3.23	4.35	
		2.50%	3.69	4.89	
		1%	4.29	5.61	

As ARDL bounds tests in table 10 yield no co-integration in results at 5% significance level thus we are going to inspect the short run output of the ARDL model.

As it was found that co-integration does not exist for the case of greenhouse consumption table 11 highlights the short run outcome of the model. It is evident that third lag of electricity consumption commercial, second lag of electricity consumption household, third lag of electricity consumption household, second lag of electricity consumption industrial and third lag of electricity consumption industrial are significant.

TABLE 11. ARDL CO-INTEGRATING AND LONG RUN FORM

(3, 4, 4, 4)				
ARDL SHORT RUN COEFFICIENT				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(OGHG(-1))	-0.26	0.16	-1.58	0.1246
D(OGHG(-2))	0.24	0.17	1.43	0.1633
D(LECC)	-2877.03	4455.22	-0.65	0.5237
D(LECC(-1))	-95.61	6129.74	-0.02	0.9877
D(LECC(-2))	7513.44	5964.63	1.26	0.2182
D(LECC(-3))	-12704.07	4653.79	-2.73	0.0108
D(LECH)	294.74	8825.18	0.03	0.9736
D(LECH(-1))	-22599.95	14302.60	-1.58	0.1253
D(LECH(-2))	44730.34	16248.32	2.75	0.0103
D(LECH(-3))	-30786.10	10845.49	-2.84	0.0083
D(LECI)	-3599.95	8948.60	-0.40	0.6905
D(LECI(-1))	16629.45	14007.38	1.19	0.2451
D(LECI(-2))	-28502.67	14953.70	-1.91	0.067
D(LECI(-3))	23373.40	9689.46	2.41	0.0227
CointEq(-1)	-0.09	0.08	-1.14	0.2658

TABLE 12: HETROSKEDASTICITY (ARCH TEST)

F-statistic	0.556256	**Prob. F (4,38)**	0.6957
Obs*R-squared	2.378518	**Prob. Chi-Square (4)**	0.6665

Table 12 shows the ARCH test of the model, where it is clearly depicted that there is no issue of Heteroskedasticity as the p-value is greater than 0.05.

TABLE 13: SERIAL LM CORRELATION

F-statistic	0.556256	**Prob. F (4,38)**	0.6957
Obs*R-squared	2.378518	**Prob. Chi-Square (4)**	0.6665

Table 13 shows the result of serial LM correlation highlighting level of significance to be greater than 0.05 thus, there is no issue of auto correlation in the model.

TABLE 14: NORMALITY

Jarque-Bera	**5.986986**	P-Value	**0.050112**

Table 14 presents the outcome of normality test where the p-value of Jarque bera signifies normality on the model.

DIAGNOSTIC TEST (CUSUM AND CUSUMQ)

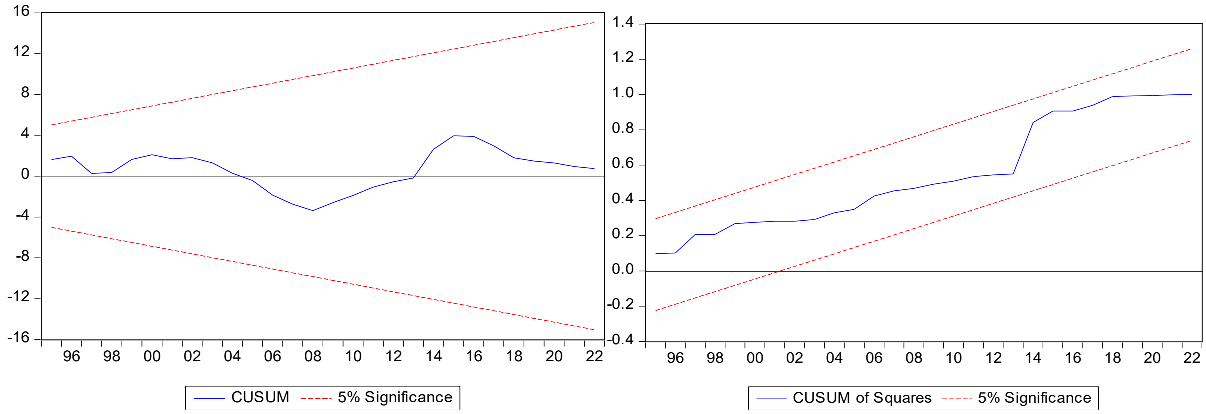


Figure 2

The output of CUSUM and CUSUMQ shows that for both the trend is within the described limits thus the model is stable.

8. CAUSALITY

TABLE 15. TODA YAMAMOTO

Other Greenhouse Gases Consumption			
Dependent variable: OGHG			
Excluded	**Chi-sq**	**df**	**Prob.**
LECC	4.701936	4	0.3193
LECH	6.776314	4	0.1482
LECI	5.267279	4	0.261
Dependent variable: LECC			
Excluded	**Chi-sq**	**df**	**Prob.**
OGHG	6.759726	4	0.1491
LECH	7.898073	4	0.0954
LECI	6.69737	4	0.1528
Dependent variable: LECH			
Excluded	**Chi-sq**	**df**	**Prob.**
OGHG	4.724749	4	0.3167
LECC	0.496954	4	0.9738
LECI	8.872008	4	0.0644
Dependent variable: LECI			
Excluded	**Chi-sq**	**df**	**Prob.**
OGHG	3.278539	4	0.5123
LECC	0.447313	4	0.9784
LECH	11.27093	4	0.0237

Table 15 presents the results of the Toda-Yamamoto causality test examining the relationship between three energy consumption sectors—household, commercial, and industrial—and other greenhouse gases. The findings indicate a unidirectional causality running from household electricity consumption to commercial electricity consumption at the 10% confidence level. Additionally, a bidirectional causality is observed between household electricity consumption and industrial electricity consumption.

9. CONCLUSION

The study aims to examine the impact of electricity consumption on carbon dioxide and other greenhouse gases, focusing on the effects of electricity usage across three sectors: household, commercial, and industrial. The data used for the analysis spans from 1972 to 2022.

As a prerequisite, stationarity was assessed using the ADF and PP tests. The results from the ADF test indicate that household electricity consumption is stationary at level I (0), while all other variables are stationary at first difference I (1). Based on this, the ARDL test was determined to be the appropriate method for analysis. The Bound test and long-run cointegration were calculated and residual and stability diagnostics were performed to evaluate the model's fitness and stability.

Equation 1 represents the consumption of carbon dioxide, where the error correction term for carbon dioxide emissions exhibits robustness, as evidenced by the bounds test, which confirms a long-run relationship. The significant and negative p-value of the coefficient suggests a process of convergence toward equilibrium. Both household and commercial electricity consumption are statistically significant in both the short and long run, with positive coefficients, indicating their substantial contribution to carbon dioxide emissions during electricity use. In contrast, industrial electricity consumption proves to be insignificant in both time frames.
In terms of model diagnostics, heteroskedasticity was examined using the ARCH test, serial correlation was assessed via the LM test, and normality was evaluated accordingly. The p-values for all tests were found to exceed 0.05, thereby suggesting the absence of heteroskedasticity, serial correlation, and non-normality within the model. Stability diagnostics, conducted through the CUSUM test, indicated some deviation beyond the specified boundaries, while the CUSUMQ test remained consistently within the defined limits. The Toda-Yamamoto causality test revealed bidirectional causality between household and industrial electricity consumption. However, no causal relationship was identified between carbon dioxide emissions and electricity consumption across the different sectors.

Equation 2 presents the findings regarding the consumption of other greenhouse gas emissions. The ARDL bounds test fails to establish a long-run relationship. The absence of long run relationship directs us to focus on short run results of the model showing second lag of household and industrial to be significant while third lag of household, consumption and industrial to be significant.

Moreover, the model does not have any issue of heteroskedasticity and auto correlation. Normality is also present in the model as seen by Jarque Bera. Furthermore, diagnostics test shows the model to be stable. The Toda-Yamamoto causality test reveals significant interconnections between the three electricity consumption sectors (household, industrial, and commercial) and the emissions of other greenhouse gases. Stability diagnostics, as assessed by both the CUSUM and CUSUMQ tests, confirm the stability of the model, with both tests remaining within the prescribed limits.

10. FUTURE PROSPECTS

Based on the findings from the analyses of carbon dioxide and other greenhouse gas emissions, several policy implications can be drawn that could guide future interventions aimed at reducing emissions and promoting sustainability:

- **Energy Efficiency Standards**: Implementing stricter energy efficiency standards for household appliances, lighting, and heating systems could reduce overall electricity consumption and, consequently, emissions.
- **Incentives for Renewable Energy**: Providing subsidies or tax incentives for households and commercial entities to invest in renewable energy sources such as solar or wind power would directly decrease reliance on carbon-intensive electricity generation.
- **Awareness Campaigns**: Promoting awareness about the environmental impact of electricity consumption and encouraging energy-saving behaviours (e.g., use of energy-efficient appliances, reducing energy waste) could help mitigate emissions in these sectors.

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