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Sectoral Analysis of Electricity Consumption on Methane and Nitrous Oxide Emissions: A Case Study of Pakistan

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Abstract: *The problem of environmental pollution is a burning issue in the current era. Many studies have been conducted on the relationship between environmental pollution and energy consumption, but there is rare literature on disaggregating sectors of energy consumption, especially focusing on electricity consumption that causes environmental pollution in the context of Pakistan. The study conducts quantitative research on the topic spanning from 1972-2022. Unit root was conducted, and as mixed integrating orders were found, I(0) and I(I) Autoregressive Distributive lag models were found appropriate for methodology. Furthermore, Causality was also conducted by applying Toda Yamamoto. Methane and Nitrous oxide emissions were found to have a long-run relationship. The most prominent sector in found contributing to pollution is the household sector, followed by industrial, commercial, and agriculture.*

Key Words: Electricity Consumption, Methane, Nitrous Oxide, Pakistan, Environmental Pollution, Energy, Sectoral Analysis

Introduction

In the progress of socioeconomic and technological advancement and development, it is safe to say that in the modern world, it is unimaginable that there would be no sources of energy, especially electricity. The role of energy utilization and consumption in bringing about economic growth is of utmost importance in the current global scenario (Yoo, 2006; Akinlo, 2009; Akinwale, 2013). Therefore, the availability of electricity is of vital importance for modern operational activities in every sector.

The supply chain of energy includes the production, distribution, and consumption of energy (Simion et al., 2023); where today, the world is more focused on sustainable development, which indirectly means a change in the energy mix, which was dominated by non-renewable resources in the past. Since the harmful effects of these non-renewable energy sources have been realized, one of the major agendas of today's world is to inculcate renewable energy resources at a higher percentage in our energy mix. Although the importance of the reduction of fossil fuels has been realized, this does not mean that coal, oil, or gas will lose their importance in the future, as the energy density of these resources is still much more than the ones found in renewable resources. The higher energy density is one of the crucial reasons why these energy sources are still in high demand in various sectors (Chowdhury et al., 2018). This ensures that in the coming era, the importance of renewable resources is likely to gain momentum, where nonrenewable resources might decline compared to what was being used previously but are still most likely to maintain a stronghold in the energy mix market.

In general, the classification of electricity demand is mostly classified on the basis of end users, which are divided into two three major groups: residential/ household, industrial, and commercial (Gellings, 2017), (Bharathi et al., 2017). The consumption of energy, more specifically electricity, is attributed as an engine of growth in all of the sectors of the economy, be it a developed nation or a developing one.

In the household sector, the consumption of electricity can be associated with levels of income, electricity prices, household sizes, age groups, etc. (Twerefou & Abeney, 2020; Ye et al., 2018; Grottera et

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al., 2018). It is commonly found, though not always, that higher incomes, household sizes, and age brackets tend to increase electrical consumption in the energy sector, while increased electrical prices decrease electrical consumption. Moreover, the number of electrical appliances used in a household (Sakah et al., 2019; Auffhammer & Wolfram, 2014) and spatial factors such as rural and urban affect the consumption patterns based on their electricity availability considering a range of distribution and weather conditions (Lenzen et al., 2006). Additionally, a major factor in the increase in the consumption of household electricity is cultural shifts, where the decline of outdoor spaces resulted in a movement towards a more indoor lifestyle (Khalid & Sunikka-Blank, 2018). Increased indoor hours have resulted in extensive use of appliances. Since appliances are critical for the estimation of consumption, the efficiency and technology that are being utilized are what matters. Higher consumption due to any factor is likely to increase environmental pollution unless technological advancement is achieved.

This is specifically true for regions where the population is expected to grow at an increasing rate, mostly underdeveloped countries like Pakistan.

Another important sector that consumes electricity is the industrial sector, which is mainly associated with the manufacturing sector. In various cases, it is generally observed and linked that an increase in industrial activity or output would potentially lead to an increase in income or economic growth (Arisoy & Ozturk, 2014). Besides income, there are other factors that lead to increased energy or electrical demand in the industrial sector, one of which is intensity. If high-intensity methods, processes, techniques, or technology are used in the production sector or sub-production sector, this could also result in an increase in electrical utilization in industries. In both scenarios, the probability of environmental pollution increases and thus increases global warming and climatic changes.

The third major category that is covered is the commercial sector utilization of electricity. As with the other two major categories, the general result from the investigation in commercial sector energy results in increased productivity but also produces pollution, which tends to correlate in the same direction (Alola et al., 2024; Williams et al., 2023; Jiang et al., 2021). The commercial sector in some nations might not add as a major contributor to energy intensity, and can help in energy conservation while improving economic development and help in reducing emissions (Lin & Wang, 2015).

Generally, in various cases such as hotels and shops, old forms of technology such as old air conditioners, space heating, and cooling, lighting, etc., contribute to high energy losses and thus more power being utilized, adding to more polluted emissions (Subramanyam et al., 2017; Ponniran et al., 2012). To bring about energy conservation and reduce emissions, better appliances, and advanced technology are required, which might have higher costs initially but will give better results in the future.

The fourth category responsible for two major greenhouse gases is the agricultural sector. The current agricultural sector is highly dependent upon various external energy sources. Energy from fossil fuels and electricity has become a pivotal element in today's modern agricultural production practices (Squalli, 2017). As the commercialization of agriculture has increased, the utilization of various operations like processing and preservation of agricultural products has increased the amount of marketing and production in the agricultural sector (Toma & Naruo, 2017). At each stage of agricultural production, emissions are released, leading from the preparation of seed to harvesting and, finally, the storage of finished output (Lal, 2004). Since the population is increasing at an increasing rate, by 2050, it is expected that 10 billion people will have to be fed, which is an increase of 50% in food production when compared to 2010. Considering the environmental footprint of the agricultural sector, it is important that the cost to the environment be estimated in advance (Deep et al., 2021).

One of the leading causes observed for methane and nitrous emissions is agriculture activities. They are in charge of almost two-thirds of the human activities contributing towards nitrous oxides (N2O)(Fowler et al., 2015). The majority of the release of nitrous oxides is due to fertilizers and applying animal manure (Beaulieu et al., 2011). When organic fertilizers or dung are used in soil and crops are incapable of absorbing extra amounts of nitrous, which are not required, it is released into the atmosphere. This release is one of the leading causes of nitrous emissions (Anav et al., 2012; Baggs, 2008). As the population is increasing, this eventually leads to an increase in agriculture needs and production; this rise has currently resulted in an increase of almost 0.25% nitrous oxides annually (Beaulieu et al., 2011). The fundamental procedure that gives rise to nitrous oxides is nitrifier denitrification, denitrification, and nitrification (Fowler et al., 2015; Abdalla et al., 2011).

Methane is also extensively emitted from agricultural practices. More than 40% of MethaneMethane from human activities is a result of agricultural activities (Desjardins et al., 2018). There are basically four sources of agricultural MethaneMethane. First is enteric fermentation. It is created in the digestive system of animals such as goats, cows, and sheep. The second source is paddy rice fields, where anaerobic decomposition occurs in organic matter. Third is the application of dung for cultivable land. The dung applied is either left on the pastured land or treated as the management system of manure. Fourth, waste of crops and lighting of biomass (Tubiello et al., 2015). Moreover, in addition to these reasons, livestock output is also responsible for creating Methane (Liang et al., 2013). Development in the agricultural domain has led to a continuous increase in methane emissions. Since the population is rising at a rapid pace, the rise in demand and consumption of energy, as well as agricultural practices, specifically rice production and livestock maintenance, has caused large methane emissions to rise and thus turned it into a global concern.

Literature Review

Chataut et al. (2023) delve into reviewing the excretion of greenhouse gases due to agricultural soil. The greenhouse gases mainly consist of carbon dioxide, MethaneMethane, and nitrous oxides. The author focuses on MethaneMethane and nitrous oxides as they have a higher global warming potential. The study included both organic and inorganic ingredients utilized in the soil that are responsible for the emission of these gases. The author further suggests a need for deeper study in the context of physical, chemical, and biological aspects, where various kinds of crops and cereals have been found to release greenhouse gases.

Tarazkar et al. (2021) inspect the factors that impact methane emissions in OPEC nations and how important the agriculture sector is in this matter. For the investigation, a data panel consisting of 11 countries, ranging from 1995 to 2012, was chosen. Multiple econometric tools were applied, such as a cross-sectional test, homogeneity test, Hausman test, and cointegration test. The outcome was found to be an N-shaped relationship between income and methane emissions for these eleven countries. Moreover, a significant positive relationship was revealed between crops and livestock affecting methane emissions. In the long run, it was revealed that livestock is expected to affect methane emissions more than crop production; therefore, focus should be placed on minimizing livestock activities.

Smith et al. (2021) scrutinize the emissions of MethaneMethane from the agricultural sector and the possibilities of its mitigation. The author highlights the importance of reducing methane gases, though short-lived and highly potent. He emphasizes that in 2017, the largest source of methane emissions due to human activities was agriculture. The major practices insist on cultivating rice, management of manure, enteric fermentation, and blazing the residue. A high percentage of methane emissions is controllable if these activities are managed in a controlled manner. Furthermore, the author highlights that besides some supply-side management tactics, some demand-side mitigation solutions can be taken to reduce methane levels released from agriculture, such as reducing food losses and moving towards diets that are plant-based.

Ramzan et al. (2020) scan into the agriculture sector as a major source of nitrous oxide release. The study highlights that the release of nitrous oxides and MethaneMethane since 1990 has increased by 17%, due to which crop production contributes to 50% of the release of nitrous oxides, which are emitted from farmer's community and from the dismissal of fertilizers that consist of nitrous elements. After the revolution that took place in industries, an increase in the release of nitrous oxides was observed at up to 60 ppb. On the other hand, soil is not the only factor of release; the other factors include PH value, temperature, soil structure, denitrifying microbial population, moisture, and C: N ratio. The author proposes some solutions to mitigate nitrous oxide release, including managing the chemistry of soil, organic farming, phytoremediation, and adding reductase for nitrous oxides in agricultural soil.

Kudeyarov (2020) conducts an analytical review on emissions of nitrous oxides from fertilized soil. The study is conducted in Russia. The author shows that one of the biological determinants of nitrous oxide release is soil, while denitrification and nitrification are the two most highlighted factors of nitrous oxide release. The Intergovernmental Panel on Climate Change (IPCC) has advised the utilization of emission factors to keep a check on national nitrous oxide emissions. The value of nitrous is dependent upon several factors, which include climate and soil conditions, amendments made to organic factors, kinds of mineral fertilizers used, and waste containing nitrogen. A limited number of studies have been done on this topic in Russia. Moreover, the lack of direct availability of data on the release of nitrous oxides from soil hinders progress in this field; this further postulates that there is a large probability of the production of huge amounts of crops at the cost of mineralized soil nitrogen.

Wadanambi et al. (2020) inspect the impact of industrial activity on climate change. The study was conducted on selected industries in Sri Lanka, such as the tea, rubber, and cement industry. High levels of greenhouse gas emissions have been witnessed in electricity purchasing because of the utilization of fossil fuels. Therefore, a target has been set for 2020-2030 in the energy sector to reduce the reduction. Various options have been suggested, including renewable sources of energy to counter harmful emissions. The GHG management hierarchy is to be followed by all industries and includes four-step processes. Different mitigation methods, international standards, and equipment are suggested in the study to be followed. The study eventually concludes the evident damaging impacts of anthropogenic activities on the climate and how various monitoring methods of environmental assessment and evaluation of the industry can assist in greenhouse gas emissions reduction.

Naser and Alaali (2021) explore the link between economic growth, nitrous oxides and financial development, electrical power consumption, and foreign direct investment in Bahrain. The time period selected for the study is 1980-2012. The methodology for the study is conducted using the ARDL model. The outcome of the model represents an adverse inverted U-shaped link in the long run between nitrous oxide and economic growth. Furthermore, both in the long run and short run, nitrous oxide emissions are affected by energy consumption and have a positive relation. On the other hand, nitrous oxides are negatively affected by financial development and foreign direct investment. The conclusion given by the author is that Bahrain should work on its financial sector and that the country should aid in the installation of solar panels in the residential sector in order to promote clean energy forms.

Bouznit et al. (2018) work on the economic growth of Algeria induced through residential electricity consumption. The study was piloted for the period 1970-2013. Extended Autoregressive Distributive Lag Model is applied to conduce estimations. The outcome depicts the connection between the two variables as an upside-down N-shaped curve, where the second extreme point has been attained. Due to the fact that growth in the economy is not associated with residential electricity consumption in Nigeria, it would be easy to reduce consumption by incorporating better and more efficient appliances into households. Furthermore, growth in electricity consumption can also be covered by the incorporation of renewable resources.

Marcotullio et al. (2012) give an insight into two basic objectives: the first one is to find the greenhouse gases in urban places in the Asian region. The second is to analyze covariates of greenhouse gas emissions of urban areas. The time period selected for the study is the year 2000, and data is collected from the Emission database for global atmospheric research evaluated for the greenhouse gases Carbon dioxide, Nitrous oxides, Methane, and Sulphur hexafluoride. The gas discharge was derived from 3535 urban locations that had populations over 50000. The methodology adopted for the empirical test was to run regression analysis for growth and urban areas and their characteristics of economic and biophysical nature. The results depict that in urban locations, 30% to 38% of greenhouse gas emissions can be justified as anthropogenic emissions. The principal covariates for overall greenhouse gas emissions incorporate growth rate and density, population size, development status and elevation, and income per capita.

Karakurt et al. (2012) present an analytical perspective on the origin and mitigation of Methane released from various sectors. Diverse sources have been explored that are responsible for the emissions of Methane. The sources include agriculture, waste, industry, and energy. Moreover, mitigation methods have been discussed in the paper, such as the utilization of Methane for the production of energy. The analysis of the sources of methane emissions and their mitigation methods concludes that the largest source of Methane is released from the agricultural sector.

Yusuf et al. (2012) delve into the discovery of methane release in various sectors; the sectors being studied as a source include waste, agriculture, and energy. The author discovers that over the course of several years' MethaneMethane is responsible for an increase of 20% in overall global warming. This increase is mainly due to anthropogenic activities, of which the contribution of energy is 28%. Economic development and the rise in population would result in an increase in gas release. Therefore, different abatement options have been suggested for the future to control and sustain its release.

Sharma et al. (2011) reports human activities responsible for the release of greenhouse gas emissions by source and its mitigation options in India for 2007. The study has been prepared under the aegis of the Indian Network for Climate Change Assessment. Carbon dioxide, MethaneMethane, nitrous oxides, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are studied. These gases have been studied on an aggregate level by various sectors, including the energy sector. The percentage share of the energy sector contribution was 69. The research helps in tracing the progress made in estimations of the inventory made in the national aggregate stage. Progress included the domains of expansion of sources for coverage, the addition of new methodologies, and the reduction of uncertainties. Various upcoming domains of work are also included.

Methodology

The data was collected from an economic survey of Pakistan and the World Bank and published through an online database. Time series data spanning from 1972-2022 on a yearly basis has been taken for estimation.

The study explores the influence of the electricity consumption sector, involving electricity consumption in households, electricity consumption, commercial electricity consumption industries, and electricity consumption in agriculture, on the environmental variables for methane, methane, and nitrous oxides.

1) Methane Consumption

lmet = f (lecag, lech, lecc, leci)

$$lmet_t = \alpha_0 + \beta_1 lecc_{it} + \beta_2 lech_{it} + \beta_3 leci_{it} + \beta_4 lecag_{it} + v_{t1} \ldots..(1)$$

2) Nitrous oxides Consumption

lno= f(lecag, lecc, lech, leci)

$$lno_t = \alpha_0 + \beta_1 lecc_{it} + \beta_2 lech_{it} + \beta_3 leci_{it} + \beta_4 lecag_{it} + v_{t1} \ldots. (2)$$

Table 1

Data source

Series	Denoted by	Measure	Source	Type of variable
Methane Emissions	met	Kiloton of Co2 equivalent	World Bank	Dependent Variable
Nitrous oxide Emissions	no	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
Electricity Consumption (agriculture)	ecag	GWH	Economic Survey of Pakistan	Independent Variable

Table 1 shows the variables selected for the study. Moreover, the table also shows the source of the series taken and whether the variable is taken as dependent or independent.

Descriptive Statistics

Descriptive statistics have been obtained for the variables involved in the study. Descriptive statistics are important for any study as they allow researchers to scrutinize the mean, skewness, kurtosis, normality, and standard deviation of all the variables. Mean is the average of all the observations. The purpose of standard deviation is to determine how far the gap is from the average estimate. Skewness highlights the level of asymmetry of the variables. The peak or flatness of the series is measured by kurtosis. Jarque-Bera shows the normality of the series.

Table 2

Pollutants

	Nitrous oxide emissions in energy sector (thousand metric tons of CO2 equivalent)	Methane (Kt of Co2 equivalent)
Mean	1,249.84	108,069.53
Median	680	87,596.80
Standard Deviation	1,173.74	63,206.23
Coefficient of Variance	93.92%	58.48%
Kurtosis	11.073	8.839
Skewness	3.054	2.826
Jarque Bera	7.584895	26.42744
Probability of Jarque-Bera	0.02254	0.000002
Minimum	430	56,999.70
Maximum	6,734.63	381,185.28

Table 2 shows the descriptive statistics of all the pollutants included in the paper. The pollutants are carbon dioxide, nitrous oxide, Methane, and other greenhouse gases.

The average amount of nitrous oxides is 1,249.844 metric tons. The minimum value is 18,929.054, while the maximum is 6,734.631. The skewness of the series is 3.054, which shows right skewness. Kurtosis stands to be 11.073, suggesting that the distribution holds heavier tails and sharper peaks; therefore, it is leptokurtic. The standard deviation of the series is 1,173.742. P-value of jarque bera is 0.02, showing that the series is not normal. The coefficient of Variance is high,93.92%, indicating that nitrous oxide emissions have a high level of variability.

The minimum value of the Methane is 56999.700, which ranges towards a maximum of 381,185.0280. The mean of the series is 108069.533 kilotons. The skewness of the series is 2.826, depicting right-skewness, while the kurtosis is 8.839, indicating a sharper peak with heavier tails, highlighting that the curve is leptokurtic. The standard deviation of the sequence is depicted to be 63206.228.P-value of Jarque bera is depicting 0.00, representing no normality. The coefficient of variance is 58.48%, highlighting moderation and showing a significant amount of variability for methane emissions.

Table 3

Disaggregated sectors of electricity consumption

	Electricity consumption (Household)	Electricity consumption (Commercial)	Electricity consumption (Industrial)	Electricity consumption (Agriculture)
Mean	20,289.84	3,274.88	13,612.49	5662.75
Median	17,757.00	2,333.00	12,528.00	5772.00
Standard Deviation	16,389.82	2,429.49	7,825.52	2939.94
Coefficient of Variance	80.77%	29.36%	57.48%	51.92%
Kurtosis	-1.024	-0.864	-1.223	-1.28
Skewness	0.45	0.65	0.162	-0.0997
Jarque Bera	5.932372	2.876063	4.921734	3.53
Probability of Jarque Bera	0.051499	0.237395	0.085361	0.046455
Minimum	635	378	2,855	997
Maximum	54,028.00	8,606.00	28,760.00	10247.00

Table 3 shows the descriptive statistics for consumption sectors and pollutants.

For the case of household electricity consumption, the mean is 20289.843gwh. Its minimum is from 635 to a maximum of 54028. The skewness of the series is depicted as 0.450, showing positive skewness that is right-tailed; as, for kurtosis, it is -1.024, depicting a platykurtic curve. The standard deviation of the series turns out to be 16.389.820. Jarque Bera shows the p-value to be 0.05, which is considered acceptance of normality. The coefficient of variance is 80.77%, which is an indication of the high level of variability.

Moving towards commercial electricity consumption, the minimum value is 378, and the maximum is 8606. The average of the variables is 3274.882. The skewness is 0.650, which highlights moderate positive skewness. Kurtosis shows to be -0.864, meaning it is a platykurtic curve. The standard deviation of the series is 2429.488. The P-value of Jarque Bera is 0.237, therefore depicting normality in the series. The coefficient of variance is 29.36%, showing less variability in comparison to household consumption.

The minimum electricity consumption in industrial is 2855, which ranges to a maximum value of 28760. The average value of the series is 13612.490. The skewness of electricity consumption industrial is 0.162, an indication of nearly symmetrical skewness tilting towards positive skewness; as for Kurtosis, it is -1.223, highlighting the platykurtic curve. The standard deviation of the series is 7825.515. The P-value of Jarque bera is 0.085, showing normality as it is greater than a 0.05% confidence interval. The coefficient of variance is 57.48%, showing moderate relative variability.

The average value of electricity consumption in agriculture is 5662745098. Where its minimum is 997, which varies to the maximum of 10247. The skewness of the sequence is -0.099665699, which is an almost symmetrical distribution with a slight negative distribution, while the kurtosis is -1.281, showing a platykurtic curve. The standard deviation of the series is 2939.941.P-value of jarque bera, which, when rounded off to two decimal places, turns to be 0.05. Therefore, it can be considered that the series is normal. The coefficient of variance is 51.92%, depicting moderate relative variability.

Unit Root Test

Log values were taken for the variables where unit roots were conducted using the Augmented Dickey-Fuller (ADF) test and Phillips Perron (PP) test.

Table 4

Unit root test augmented dickey fuller test (ADF and PP)

Augmented Dickey-Fuller			Phillips Perron		
Variable	P-Value At level	P-Value at First Difference	Variable	P-Value At level	P-Value at First Difference
Gross Domestic Product	0.4593	0.0417	Gross Domestic Product	0.0428	
Methane	1.0000	0.0055	Methane	1.0000	0.0045
Nitrous Oxide	0.9301	0.000	Nitrous Oxide	0.8118	0.000
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
Electricity consumption Agricultural	0.2029	0.0000	Electricity consumption Agricultural	0.1150	0.0000

Where the Series with a p-value is greater than 0.05, H0 is accepted. Therefore, they are all non-stationary at a 5% significance level. Where it is less than 0.05 H0, it is rejected, and the series is stationary.

According to Table 4, stationarity is estimated through the Augmented Dickey-Fuller method and Phillips Perron method. The results depict stationarity of all variables on the first difference I(I) at a confidence level of 5% except for electricity consumption household and electricity consumption total, which are seen to be stationary at level integrating order I(0) at a confidence level of 5%. The stationarity is further investigated through the Phillips-Perron method. According to the table, it is seen that except for electricity consumption household and gross domestic product, which are stationary at level integrating order of I (0) at 5% level of confidence, all other series are stationary at level, integrating order I(0) at 5% level of confidence.

Since some variables are found to be stationary at first difference while others are at level, the Augmented Regressive Distributive lag model is best suited for this situation; moreover, Error Correction Models are checked for robustness. Residual Diagnostics and Stability Diagnostics are shown separately for each of the four models. Causality is also estimated where long-run co-integration exists. Toda Yamamoto is applied as there are different integrating orders for the four models, which would result in the following equations:

Methane

Table 5

ARDL bounds test methane consumption.

Order of Lag	ARDL Bound Test (F-Stats)	Significance Level	Lower Bound	Upper Bound	Co-integration
6	10.9593	10%	2.45	3.52	Exists
		5%	2.86	4.01	
		2.50%	3.25	4.49	
		1%	3.74	5.16	

$$\Delta lmet_t = a_{01} + b_{11}lmet_{t-i} + b_{21}lech_{t-i} + b_{31}lecc_{t-i} + b_{41}leci_{t-i} + b_{51}lecag_{t-i} + \sum_{i=1}^{p} a_{1i}\,\Delta lmet_{t-i} + \sum_{i=0}^{q1} a_{21}\,\Delta lech_{t-i} + \sum_{i=0}^{q2} a_{3i}\,\Delta lecc_{t-i} + \sum_{i=0}^{q3} a_{3i}\,\Delta leci_{t-i} + \sum_{i=0}^{q4} a_{4i}\,\Delta lecag_{t-i} + \lambda ECT_{t-i} + \epsilon_{it}$$

Table 5 shows the bounds test results for methane release due to various consumption sectors. As is evident by the results in the table, a long-run relation exists because the F-test value is greater than the level of the upper bound.

Table 6

ARDL Co-integrating And Long Run Form

(6, 6, 4, 5, 6)				
ARDL Short Run Coefficient				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D (LMET (-1))	-0.095173	0.308292	-0.30871	0.7624
D (LMET (-2))	-0.38195	0.21116	-1.808821	0.0937
D (LMET (-3))	-0.31088	0.238738	-1.302182	0.2155
D (LMET (-4))	-1.178565	0.24272	-4.855664	0.0003
D (LMET (-5))	-0.206392	0.267224	-0.772355	0.4537
D(LECAG)	-0.41114	0.12289	-3.345583	0.0053
D (LECAG (-1))	0.415415	0.138166	3.006643	0.0101
D (LECAG (-2))	0.016356	0.139596	0.117164	0.9085
D (LECAG (-3))	-0.067621	0.117709	-0.574476	0.5755
D (LECAG (-4))	0.085212	0.105656	0.8065	0.4345
D (LECAG (-5))	0.285292	0.103436	2.758156	0.0163
D(LECC)	0.217223	0.14507	1.497361	0.1582
D (LECC (-1))	0.203608	0.169947	1.198067	0.2523
D (LECC (-2))	0.090745	0.118734	0.764273	0.4584
D (LECC (-3))	-0.164933	0.125051	-1.31892	0.21
D(LECH)	0.134296	0.242158	0.554581	0.5886

(6, 6, 4, 5, 6)				
ARDL Short Run Coefficient				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D (LECH (-1))	-1.31154	0.332672	-3.942444	0.0017
D (LECH (-2))	0.375287	0.349595	1.07349	0.3026
D (LECH (-3))	-0.889687	0.334981	-2.655933	0.0198
D (LECH (-4))	0.961499	0.229698	4.185931	0.0011
D(LECI)	-0.296068	0.204002	-1.451296	0.1704
D (LECI (-1))	1.212896	0.267727	4.530339	0.0006
D (LECI (-2))	-0.705354	0.301945	-2.336032	0.0362
D (LECI (-3))	0.636218	0.338936	1.877104	0.0831
D (LECI (-4))	-1.46874	0.321841	-4.563551	0.0005
D (LECI (-5))	0.51906	0.18946	2.739682	0.0169
CointEq (-1)	0.323424	0.194255	1.664946	0.1198
Long Run Coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LECAG	2.683653	1.874308	1.43181	0.1758
LECC	0.719657	0.263284	2.73339	0.0171
LECH	-0.890868	0.633554	-1.406144	0.1831
LECI	-1.617728	1.42636	-1.134165	0.2772
C	6.49977	3.598722	1.806133	0.0941

Table 6 shows the role of different sectors emitting methane gas. For the short run at 5% level of confidence, 4 lag of Methane, electricity consumption agriculture, first lag of electricity consumption agriculture, fifth lag of electricity consumption agriculture, first lag of electricity consumption household, third lag of electricity consumption household, fourth lag of electricity consumption household, first lag of electricity consumption industrial, second lag of electricity consumption industrial, fourth lag of electricity consumption industrial and fifth lag of electricity consumption industrial are all significant at 5% level of confidence. Among these variables, the first lag of electricity consumption agriculture, the fifth lag of electricity consumption agriculture, the fourth lag of electricity consumption household, the first lag of electricity consumption industrial, and the fifth lag of electricity consumption industrial all have positive coefficients while the other significant variables have negative coefficients.

As for the co-integrating equation, it is insignificant and positive. In the long run, at a 5% level of confidence, the p-value of electricity consumption commercial is less than 0.05; therefore, it is significant in the long run.

Residual Diagnostics

Table 7

Heteroskedasticity (ARCH test)

F-statistic	1.075509	Prob. F (1,42)	0.3056
*Obs*R-squared*	1.098592	Prob. Chi-Square (1)	0.2946

Table 7 shows the outcome of the ARCH test for methane release. Since the P-value of the observed R square is greater than 0.05, it means acceptance of the null hypothesis; therefore, heteroskedasticity is not present in the model.

Table 8

Serial LM Correlation

F-statistic	0.270822	Prob. F (1,12)	0.6122
Obs*R-squared	0.993169	Prob. Chi-Square (1)	0.319

Table 8 depicts the probability value to be greater than 0.05. It highlights the nonexistence of correlation in the model.

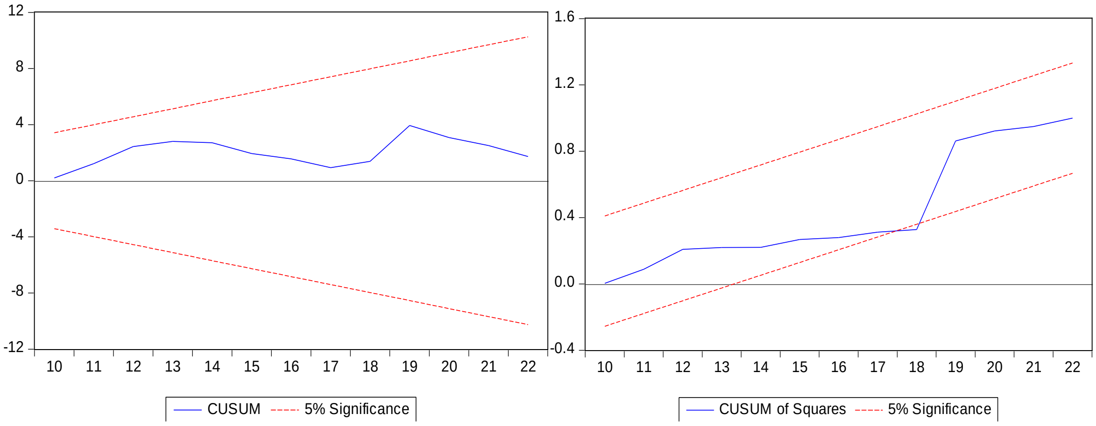
Table 9

Normality

Jarque-Bera	P-Value
1.253367	0.534361

Table 9 shows a 5% level of confidence interval, with the p-value at 0.53, which is greater than 0.05, ensuring the normality of the model.

Stability Diagnostics (CUSUM And CUSUMQ)



CUSUM and CUSUMQ results show that methane for methane is stable and within the prescribed range.

Causality

Table 10

TODA YAMAMOTO

Methane Consumption			
Dependent variable: LMET			
Excluded	Chi-sq	df	Prob.
LECAG	9.121194	6	0.1669
LECC	8.221269	6	0.2223
LECH	15.33024	6	0.0178
LECI	30.46893	6	0
Dependent variable: LECAG			
Excluded	Chi-sq	df	Prob.
LMET	13.5331	6	0.0353
LECC	35.68971	6	0
LECH	30.3973	6	0
LECI	19.51718	6	0.0034
Dependent Variable: LECC			
Excluded	Chi-sq	df	Prob.
LMET	11.29197	6	0.0798
LECAG	8.522501	6	0.2023
LECH	6.796074	6	0.3401
LECI	6.441981	6	0.3755

Dependent Variable: LECH			
Excluded	Chi-sq	df	Prob.
LMET	17.76319	6	0.0069
LECAG	12.23743	6	0.0569
LECC	6.175039	6	0.4039
LECI	21.07127	6	0.0018
Dependent Variable: LECI			
Excluded	Chi-sq	df	Prob.
LMET	13.98829	6	0.0298
LECAG	8.648451	6	0.1943
LECC	6.958825	6	0.3247
LECH	12.72677	6	0.0476

Table 10 shows a link between methane and four power consumption sectors including household, industrial, agriculture, and commercial, at a 5% level of confidence interval. Electricity consumption in households, electricity consumption in industries, electricity consumption in commercial, and methane all have one-way causality towards electricity consumption in agriculture.

Methane causes electricity consumption in commercial; electricity consumption in agriculture causes electricity consumption in households at a 10% level of the confidence interval.

Electricity consumption household and methane, electricity consumption industrial and methane and Electricity consumption industrial and electricity consumption household have a bidirectional link with each other.

Nitrous Oxide

TABLE 11

ARDL bounds test nitrous oxide consumption.

Order of Lag	ARDL Bound Test (F-Stats)	Significance Level	Lower Bound	Upper Bound	Co-integration
6	3.724518	10%	2.45	3.52	Exist
		5%	2.86	4.01	
		2.505	3.25	4.49	
		1%	3.74	5.06	

$$\Delta lno_t = a_{01} + b_{11} lno_{t-i} + b_{21} lech_{t-i} + b_{31} lecc_{t-i} + b_{41} leci_{t-i} + b_{51} lecag_{t-i} + \sum_{i=1}^{p} a_{1i}\, \Delta lno_{t-i} + \sum_{i=0}^{q1} a_{21}\, \Delta lech_{t-i} + \sum_{i=0}^{q2} a_{3i}\, \Delta lecc_{t-i} + \sum_{i=0}^{q3} a_{3i}\, \Delta leci_{t-i} + \sum_{i=0}^{q4} a_{4i}\, \Delta lecag_{t-i} + \lambda ECT_{t-i} + \epsilon_{it} \ldots (3)$$

Table 11 shows bound test results for the release of nitrous oxides because of four consumption sectors: industrial, agricultural, commercial, and household. The bound test results show that at a 10% level of significance, the value of f-statistics is greater than the upper bound long-run relationship exists at a 10% level of significance.

Table 12

ARDL co-integrating and long-run form.

(5, 6, 5, 5, 6)				
ARDL Short Run Coefficient				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (LNO (-1))	0.158742	0.292047	0.5436	0.5959
D (LNO (-2))	-0.186601	0.272711	-0.684	0.5058
D (LNO (-3))	-0.033865	0.256448	-0.132	0.897

(5, 6, 5, 5, 6)				
ARDL Short Run Coefficient				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (LNO (-4))	-0.902172	0.311268	-2.898	0.0124
D(LECI)	-2.67976	1.514143	-1.77	0.1002
D (LECI (-1))	5.315516	1.905303	2.7899	0.0153
D (LECI (-2))	-3.098891	2.037702	-1.521	0.1523
D (LECI (-3))	4.827781	2.301231	2.0979	0.056
D (LECI (-4))	-7.81774	2.416506	-3.235	0.0065
D (LECI (-5))	2.554562	1.372781	1.8609	0.0855
D(LECH)	1.534312	1.75077	0.8764	0.3967
D (LECH (-1))	-4.141723	2.325048	-1.781	0.0982
D (LECH (-2))	1.511436	2.541991	0.5946	0.5623
D (LECH (-3))	-5.618983	2.532777	-2.219	0.0449
D (LECH (-4))	5.547641	1.683387	3.2955	0.0058
D(LECC)	1.89471	1.205846	1.5713	0.1401
D (LECC (-1))	0.01923	0.993158	0.0194	0.9848
D (LECC (-2))	0.242881	0.840219	0.2891	0.7771
D (LECC (-3))	-0.812379	0.905242	-0.897	0.3858
D (LECC (-4))	-0.585552	0.759822	-0.771	0.4547
D(LECAG)	-2.105765	0.880733	-2.391	0.0326
D (LECAG (-1))	2.376038	0.950171	2.5006	0.0266
D (LECAG (-2))	-0.134091	0.854344	-0.157	0.8777
D (LECAG (-3))	-0.315478	0.822895	-0.383	0.7076
D (LECAG (-4))	0.574009	0.768421	0.747	0.4684
D (LECAG (-5))	1.025036	0.689058	1.4876	0.1607
CointEq (-1)	-0.057803	0.262859	-0.22	0.8294
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LECI	18.457141	103.25805	0.1787	0.8609
LECH	26.684577	120.35014	0.2217	0.828
LECC	3.682604	13.926589	0.2644	0.7956
LECAG	-68.87473	312.76549	-0.22	0.8291
C	133.21355	536.82102	0.2482	0.8079

Table 12 shows emissions of nitrous oxides from various sectors of the economy. According to the table at a 5% level of confidence, in the short run, the fourth lag of nitrous oxides, the first lag of electricity consumption industrial, the fourth lag of electricity consumption industrial, the third lag of electricity consumption household, fourth lag of electricity consumption household, electricity consumption agriculture and first lag of electricity consumption agriculture is significant. Among these variables, the first lag of electricity consumption industrial, the fourth lag of electricity consumption household, and the first lag of electricity consumption agriculture all have positive coefficients, while the other significant variables have negative coefficients.

The co-integrating equation for the case of nitrous oxide, though negative, is insignificant. The co-integration equation, although negative, is insignificant. In the long run, none of the variables can be seen as significant. None of the variables can be seen as significant in the long run impact on nitrous oxides at a 5% level of confidence.

Residual Diagnostics

Table 13

Heteroskedasticity (ARCH Test)

F-statistic	1.075509	Prob. F (1,42)	0.3056
Obs*R-squared	1.098592	Prob. Chi-Square (1)	0.2946

Table 13 shows the probability of the observed R square for the ARCH test to be greater than 0.05. Thus, there is no issue of heteroskedasticity in the model.

Table 14

Serial LM correlation

F-statistic	0.659162	Prob. F (1,12)	0.4327
Obs*R-squared	2.343147	Prob. Chi-Square (1)	0.1258

Table 14 shows the outcome of the correlation for the nitrous oxide emissions model of consumption. It is depicted in the table that observed R squared has a p-value of 0.126, which is greater than 0.05, confirming the acceptance of null hypotheses, so there is no issue of correlation in the model.

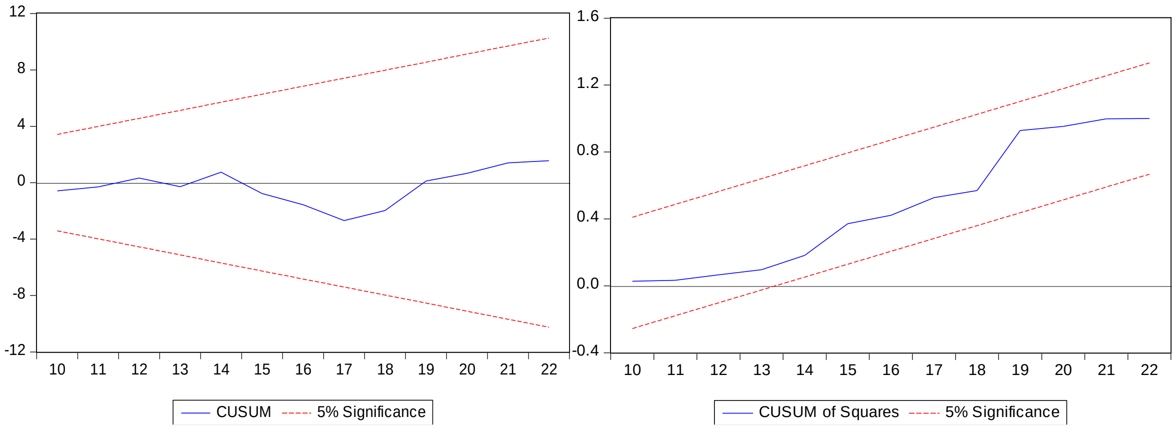
Table 15

Normality

Jarque-Bera	P-Value
0.188922	0.909863

Table 15 shows the normality results for the nitrous oxides model. Since the p-value of Jarque bera is greater than 0.05, it authenticates that the model is normal.

Stability Diagnostics (CUSUM AND CUSUMQ)



CUSUM and CUSUMQ, according to the 5% level of significance, clearly are within the range provided. Therefore, the model is stable.

Causality

TABLE 16

TODA YAMAMOTO

Nitrous Consumption			
Dependent variable: LNO			
Excluded	Chi-sq	df	Prob.
LECAG	12.36836	6	0.0542
LECC	6.178953	6	0.4034
LECH	11.74086	6	0.068
LECI	21.0056	6	0.0018

Dependent variable: LECAG			
Excluded	Chi-sq	df	Prob.
LNO	4.660535	6	0.588
LECC	8.195317	6	0.2241
LECH	7.611209	6	0.268
LECI	9.244719	6	0.1603
Dependent variable: LECC			
Excluded	Chi-sq	df	Prob.
LNO	9.685694	6	0.1385
LECAG	3.790028	6	0.7051
LECH	3.396661	6	0.7577
LECI	4.579503	6	0.5988
Dependent variable: LECH			
Excluded	Chi-sq	df	Prob.
LNO	5.091741	6	0.5321
LECAG	3.887929	6	0.6918
LECC	5.548968	6	0.4756
LECI	13.37832	6	0.0374
Dependent variable: LECI			
Excluded	Chi-sq	df	Prob.
LNO	7.478868	6	0.2788
LECAG	4.452325	6	0.6157
LECC	7.347304	6	0.2899
LECH	13.037	6	0.0425

Table 16 depicts Toda Yamamoto's causality link between nitrous oxides and four power-consuming sectors, including electricity consumption in industrial, electricity consumption in households, electricity consumption in commercial, and electricity consumption in agriculture.

The table shows one-way links between electricity consumption in agriculture, electricity consumption in industry, and electricity consumption in households towards nitrous oxides.

A bidirectional relationship exists between electricity consumption in households and electricity consumption in industries at a 5% level of the confidence interval.

Conclusion and Future Prospects

Environmental pollution is a burning issue in modern civilization. Energy consumption, especially electricity, is a vital resource for growth in the current era. Unfortunately, this energy type also contributes to environmental pollution. The study explores how various gases are emitted due to the consumption of electricity in several sectors. For methane and nitrous oxide emissions, electricity consumption in households, electricity consumption in commercial, electricity consumption in industrial, and electricity consumption in the agriculture sector are scrutinized.

It was found after conducting the prerequisite unit root test of both ADF and PP that all variables are stationary at the first difference I(I) except for electricity consumption household. Therefore, the Autoregressive Distributed lag Model was applied. The bounds test showed f-statistics to be greater than the upper bound in the case of methane at a 5% level of significance. In the case of nitrous oxides, the f-statistics were greater than the upper bound at a 10% level of significance.

After the bounds test, long-run estimates were calculated, and an error correction coefficient was observed. For the model of methane emissions, various variables and their lags were shown to be significant in the short run, including electricity consumption in agriculture, electricity consumption in households, and electricity consumption in industry. The ECM coefficient for methane was shown to be insignificant. In the long run, only electricity consumption commercials were found to be significant, with methane at a 5% level of the confidence interval.

The probability value of observed R squared for the ARCH test and Serial LM correlation for nitrous oxides are greater than 0.05, depicting acceptance of the null hypothesis that there is no heteroskedasticity and no correlation in the model. Moreover, the normality test also confirmed acceptance of the null hypothesis and, therefore, the presence of normality. For stability diagnostics, both CUSUM and CUSUMQ were seen as being within the specified range.

For Toda Yamamoto, a bidirectional link is found between electricity consumption in households and methane and electricity consumption industrial and methane and among electricity consumption household and electricity consumption industries. Furthermore, methane is found to cause electricity consumption in commercial and electricity consumption agriculture.

The nitrous oxide emission ECM is insignificant and does not show robustness with the bounds test results. In the short run, the first and fourth legs of the electricity consumption industry are seen to have a significant relationship with nitrous oxides. Moreover, the third and fourth lags in electricity consumption in households are significant, while electricity consumption in agriculture and its first lag are also significant in the short run. In the long run, none of the variables were found to have a long-run link with nitrous oxide emissions.

ARCH test and Serial LM correlation were greater than 0.05; thus, no Heteroskedasticity or correlation was found. Normality was also called confirmed. CUSUM and CUSUMQ were also within the given range.

Causality results for nitrous oxides show a one-way causality towards nitrous oxides, leading to electricity consumption in households, electricity consumption in agriculture, and electricity consumption in industries.

According to the results obtained, the household sector is the leading sector that emits methane and nitrous oxides. Industrial sector dominantly releases methane and nitrous oxides, Agricultural sector can be seen to release nitrous oxides prominently.

The Government should focus on policies that ensure and motivate these sectors especially household for the limitation of these gases. It is important to study the sources of these gas emissions in the givens sector so that the problem can be addressed at the root.

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