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Effect of Environmental Tax on Ecological Quality Using Machine Learning Algorithm

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ABSTRACT

Many developing nations are considering environmental taxes as a way to raise money and fulfill their obligations in combating climate change and promote sustainable development. Recently, government of Ghana tax policy of E-levy as well as emissions tax has received mixed reaction by various stakeholders. This has called for the need to look at various forms of tax avenues that can serve as alternative tax policy to achieve the government developmental agenda for the years 2000 to 2019. Notwithstanding, it is indispensable to guise at the effect of the introduction of the environmental tax policy on environment-growth correlation in trying to achieve Sustainable Development Goals 8 and 13. The study employed machine learning algorithm such as Kernel-based Regularized Least Squares (KRLS) techniques to scrutinize the causal-upshot connection. One conspicuous result is that, environmental tax was found not significant but the parameter shows that, 1% change have inverse connection with ecological quality. That is, the change reduces the emission level by 0.037. Further findings vividly disclosed that, population and economic expansion have snowballing peripheral effects on emission level. Hence, there is a need to hone green tax policies to provide stronger spurs for industries within the state to adopt much greener habit in their activities. This policy strategy can be achieved through the provision of reducing the environmental rate for industries emitting emission within a certain threshold as well as educating industries on emission reduction strategies especially on how to benefit from carbon trade if they reduce their emission level.

Keywords: Environmental Tax, Ecological Quality, Economic Expansion, Population, KRLS
JEL Classifications: F64, Q01, Q51

1. INTRODUCTION

Many developing countries are systematically imposing environmental taxes to generate finance and meet their sustainable development and climate change mitigation obligations (Keen, 2023). Because of the magnitude of the government's environmental goals, notably on net zero, it must evaluate every option at its disposal if it is to achieve such target (Chuenwong et al., 2022). CO_2 emissions rank among the most potent greenhouse gas emissions (Environmental Protection Agency, 2022). On a global gage, attaining sustainable development depends on cutting carbon emissions, moving forward a less-carbon economy, and putting such practices in place. This opinion is reinforced by the Paris Climate Agreement (COP21), which predicts that in the absence of significant environmental reforms, the average global temperature of the atmosphere will rise by two degrees Celsius.

According to scientists' estimates in a latest shot by the Intergovernmental Panel on Climate Change (IPCC), a rise in temperature of 1.5°C relative to pre-industrial levels (0.5°C higher than current levels) would drastically alter the climate with negative effects on both natural and human systems. The Earth potency approach a slanting point when it is impossible to stop universal warming with a rise of 2°C (Wunderling et al., 2024). Voluminous communities all over the world, especially the most vulnerable, are already noticing and feeling the effects of climate variation. Ocean-level upswing, which results in flooding, the loss of sea side lands, and the annihilation of land mass; heat waves, which have a negative impact on humanoid health and cause droughts; enlarged precipitation, which results in overflowing and the obliteration of economic infrastructure; and more life-threatening weather events, like hurricanes, which cause sizable economic fatalities, are some of these effects.

Among scholars, environmental degradation, average temperature change, and universal warming are some of the most talked-about issues (Osuntuyi and Lean, 2022; Rehman and Rashid, 2017; Sibanda et al., 2024; Tetteh and Baidoo, 2022). Carbon taxes are a policy option aimed at restricting emissions blamable for climate alteration, in line with the assurances assumed by countries under the Paris Agreement (Falcao, 2021). Although, there are more difficulties with the necessity to be environmentally friendly as a result of the deteriorating effects of social processes and phenomena on the environment. Though attempts have been made to limit greenhouse gases (GHG) emissions according to the Global Metrological Organization (World Meteorological Organization, 2020). Based on this report, it is imperative to reduce climatic effect has become relevant to sustain the environment for living species. According to the obligations made by nations under the Paris Agreement, countries may choose to implement carbon taxes as a policy tool to reduce the carbon-based emissions that cause climate change (Falcao, 2021). Emission taxes place a cost on the emission of greenhouse gases, encouraging businesses to spend money on greener technologies or adopt more productive procedures (Green, 2021; Marten and Van Dender, 2019). Several countries have implemented environmental restrictions, emissions trading systems (ETS), and emission taxes in recent years to limit carbon emissions. Finland is the principal state in the world to impose a carbon tax in 1990. Since then, 18 European nations have followed suit, imposing carbon taxes stretching from a smaller amount than €1 per metric ton of CO_2 emitted in Poland and Ukraine to more than €100 in Sweden. In Africa, Ghana is a third country to adopt environmental taxes (Kombat and Wätzold, 2019). Hence, increased or more operative practice of ecologically related taxes by a country can initiate growth-oriented reform by unstable the tax encumbrance away from additional distortive taxes. Environmental taxes, have two functions: first, a regulatory one that gives the power to influence how those who destroy the environment behave, and second, one that will make up for the harm and provide a safety net in case of probable financial and environmental losses (Dabor et al., 2024; Domguia, 2023).

Environmental taxes can be imposed on carbon dioxide, methane, nitrous oxide, and fluorinated gases (F-gases), among other conservatory gases (Gailhofer, 2022). The latitude of each country's environmental tax varies, resulting in different shares of greenhouse gas emissions being taxed. Spain's environmental tax, for example, only applies to fluorinated gases and accounts for only 3% of the country's aggregate greenhouse gas emissions. Norway, on the other hand, recently eliminated most exemptions and lowered tariffs, covering more than 60% of its greenhouse gas emissions. In developing countries such as Ghana, does not have an explicit environmental tax, nor a CO_2 emissions trading system (Ali et al., 2021; Chien et al., 2022). However, it does collect environmental tax on energy use, including: A petroleum tax on gasoline, diesel, kerosene and LPG.

In its First Nationally Determined Contribution (NDC), the Ghanaian government pledged to pursue sustainable economic development policies aimed at increasing Ghana's revenue target. Subsequently, Ghana established a 2030 GHG emissions reduction goal of 15% below the Business as Usual (BAU) scenario in this NDC. The tax-to-GDP ratio of Ghana is 14.1%, which is lower than the averages in the OECD, LAC, and Africa of 33.9%, 22.8%, and 17.2%, respectively. Although it can be challenging to predict the income potential of a new tax, Ghana's estimated tax base from carbon dioxide equivalent (CO_2e) buried in fossil fuels in 2018 was close to 14.5 million tonnes. This shows that at environmental tax rate of $30 per tonne, revenue potential might be close to 0.7% of GDP. Ghana would bear a disproportionate share of the costs of climate change, but there would also be higher benefits from cutting carbon emissions (Sefa-Nyarko, 2024). In keeping with its international commitments under the United Nations Framework Convention on Climate Change (UNFCC) and the Paris Agreement, the Ghanaian government has been leading the way in firming up the international rejoinder to the growing hazard posed by climate change. An essential part of this plan is the introduction of an emissions tax, which is purposefully planned to support desperately needed domestic revenue mobilization initiatives. By prohibiting excessive greenhouse gas emissions and other associated detrimental environmental practices, this policy not only acts as a financial tool but also demonstrates Ghana's commitment to addressing climate change.

In Ghana, introduction of environmental tax has become so important due to expansion in the economy from raw material-based production to industrial production of products as a result of government policy of 1D1F. Additionally, COVID-19 pandemic has had an enormous impact on global public finances which Ghana is no exception. Subsequently, the Ghanaian government must immediately figure out how to pay its debts, as projected by the IMF (Acheampong, 2023). Hence, a tax on the environment would be a significant step toward reaching this goal as well as minimizing the negative effects on the ecosphere. Environmental tax is considered as one of the most effective and lowest-cost ways of inducing such cuts (Bashir et al., 2022; Rafique et al., 2022).

Several research works have looked at the effect on the premise of Environmental Kuznet Curve (Demissew Beyene and Kotosz, 2020; Ganda, 2023; Karahasan and Pinar, 2022; Sultana et al., 2022). One potential remedy for the issue of greenhouse gas emissions is environmental taxation (Babatunde et al., 2017). Hence, well-designed emission tax is an essential tool in the evolution to a less carbon-reliant economy (Miller and Vela, 2018; Shinwell and Cohen, 2020). Lai et al., (2020) matter-of-factly discovered that Environmental taxes are real policy mechanism gizmo in inhibiting degradation of the environment, according to their regression analysis results in China. Various studies have yielded different mixed results with some supporting the argument that environment tax improves the ecological life of living species (Rafique et al., 2022), whiles some are against this notion (Tekin and Şaşmaz, 2016), with other found in-between and in-conclusive in their findings of environmental tax on the environment (Wolde-Rufael and Mulat-Weldemeskel, 2021). A study of the interaction influence of environmental tax on ecological degradation is quite complex and has not so far been widely discussed in the literature particularly in Ghana. Hence, the study first lacks the use of machine learning algorithms to get an insight in the field of interplay between environmental taxation and ecological degradation. Subsequently, the study would also look at the interaction effect of revenue generated through environmental tax on the relationship between green dilapidation and economic fortune.

According to economic theory, the purpose of taxes is to meet the government's economic and environmental goals (Sinha and Shahbaz, 2018). Environmental taxes are intended to bill environmental harm or negative externalities so that manufacture and feasting decisions can be made in a more environmentally responsible manner (European Parliament, 2020). These include financial enticements for consumers and corporations to adopt more environmentally friendly decisions in order to lessen climate mischief and pollution, plus income generation to fund government environmental agendas. So, environmental levies are a hybrid of copious United Nations Sustainable Development Goals (SDGs). There is evidence that taxes can have affirmative influence on the environment, but far too little is known about their effects.

Given the foregoing justifications and arguments, the most important goal of this study is to conclude whether environmental taxation makes statistical and economic sense in explaining CO_2 emissions reductions in Ghana. The study also considered population energy intensity and economic progression as variables in the investigation, which the literature says have an impact on the environment, in order to meet the research goal and produce consistent estimations. The main question now is how the push for environmental tax affects the environment. The study's goal is to find an answer to this question. It is worth noting that numerous studies have looked at the environmental tax on economic growth, but few have looked at how they affect carbon emissions (Dogan et al., 2022; Telatar and Birinci, 2022). Consequently, the study addresses a gap in the writings, which has produced mixed results.

The present study addressed the aforementioned gap by utilizing KRLS. This machine learning algorithm prevail over the old-style econometric methods in several standpoints. A compromise between simple but often less interpretable machine learning methods and the more limited machine learning algorithms that many researchers rely on is provided by the KRLS method, which provides a modeling tool that is simple and practical. KRLS is a user-friendly style that helps scholars shield their inferences from bias due to mis-specification and does not force them to give up countless revelatory and statistical features they value. Thus, researchers just feed the X milieu of predictors to the KRLS estimator, which mug up the bull's eye function from the data, rather than performing a laborious specification search.

The authors consider this to be the first time this approach has been taken in Ghana on the interaction effect of ecofriendly tax and environmental footprint. To the best of our knowledge, the majority of earlier scholars' investigations in Ghana skipped using this reliable technique. The use of KRLS approaches to test for the causation nexus among green taxes and emissions within the framework of a time series dataset is the paper's innovative element. This study made a variety of contributions to already published literature. Our investigation is thus a groundbreaking study that aimed to look at the connections between the series in the nation. This study contributes to the nonfiction in three ways in order to achieve the investigation goal. This work adds three new pieces to the body of literature: Number one (1), the study compares how environmental taxes affect ecological degradation using machine learning algorithm. Number two (2), the study tries to capture counterfactual shocks in non-environmental taxes in the economy. That is, to investigate how phasing out of environmental tax will upset future economic sustainability. Number three (3), to use KRLS to investigate the causal-effect connection between taxes related to environmental damage and ecological quality.

The rest of the study is organized as: Section 2 presents the literature review, Section 3 grants research materials and methods. Section 4 provides results and discussion, while Section 5 provides conclusion, policy implication and extension of research.

2. LITERATURE REVIEW

The best legislative instrument for lowering greenhouse gas emissions is an environmental tax (Bashir et al., 2020). The objective of emissions taxation is to enhance energy adeptness, ease environmental issues, and aid in environmental preservation by internalizing adversarial externalities such as toxic waste (Bashir et al., 2021; Shahzad, 2020). The subject of whether ETs are helpful in preventing ED has gained prominence and begun to be studied since the Kyoto Protocol was signed in the late 1990s. As a result, there are no partnerships in the studies on the impact of environmental taxes on CO_2 emissions. The research on factors affecting CO_2 emissions has therefore been outlined, with a particular focus on environmental taxes, economic growth, population, and energy density. One of the duties of environmental taxes is to avert pollution, but also to mend the quality of the environment without affecting economic growth. Most pragmatic studies have inveterate that high environmental taxes have a progressive impact on the environment (Bosquet, 2000; Morley, 2012). Furthermore, the most crucial instruments for ensuring environmental improvements are environmental taxes and regulations (Shahzad et al., 2021; Wang et al., 2019).

The link amid renewable energy, environmental taxes, technology, and laws was examined by (Bashir et al., 2021) on a taster of 29 OECD nations between 1996 and 2018. Conferring to the study, environmental levies encouraged the business to invest in green technology and lower energy usage, all while increasing energy efficiency. Additionally, they stated that because renewable energy projects require a lot of capital, OECD nations must establish a green financing system. Additionally, in Latin American and Caribbean nations, (Wolde-Rufael and Mulat-Weldemeskel, 2022) probed the efficiency of renewable energy and environmental levies in plummeting CO_2 emissions. Their study's findings demonstrated that there are dissimilarities in the effects of renewable energy and environmental fees on CO_2 emissions. Hao et al., (2021) looked into how the G7 countries' CO_2 emissions were affected by green growth, environmental levies, human capital, and the use of renewable energy. According to their findings, CO_2 emissions are reduced by green tumor, environmental taxation, human resources, and the use of renewable energy. These scholars also came to the conclusion that the industry will employ more renewable energy sources as a result of the potential for green growth. Green growth is therefore a key strategy for achieving sustainable development.

Nonetheless, the lopsided long-standing cointegration affiliation between variables including the effect of leisure industry, globalization, and economic spreading out on CO_2 emissions was studied by Uzuner et al. (2020). They came to the conclusion that any environmental strategy aimed at lowering CO_2 over a decline in tourism in Turkey would merely be successful in the short term since both progressive and destructive shocks to the industry would eventually have a beneficial impact on CO_2 emissions. As previously discussed, there is currently insufficient evidence in the literature to support the starring role of environmental levies in setting carbon emissions levels. Thus, in light of the previously described research, our primary hypothesis is that economic expansion and environmental taxation are important factors in reducing CO_2 emissions in nations that practice environmental responsibility.

Similar study was also undertaken by (Bashir et al., 2020) to gauge the impact of environmental tax, financial development and environmental technology on OECD environment. The study employed system-GMM and quantile regression technique. Findings clearly indicate that the OECD environment is negatively affected by environmental tax. An investigation of the effect of environmental tax on environment (i.e. proxied by carbon emissions and ecological footprint) in Turkey was conducted by Telatar and Birinci (2022). The study deployed nonlinear technique to analyse the long run sound effects of the expounding variables on the outcome variable. Finding from the dataset spanning for the period 1994 to 2019 revealed that environmental tax has no effect on environment of Turkey in the long-standing. Hence, the resultant effect is that, environmental tax does not in any ways help to prevent the degradation of the environment of Turkey. Additionally, study by Telatarand Birinci (2022) also revealed same finding that environmental taxes do not have any long-run effects on CO_2 emissions. Study concluded that environmental taxes in Turkey do not affect foiling environmental degradation. A study by (Doğan et al., 2022) also add to the facts using panel model of cointegration of G7 states on how environmental tax and CO_2 emissions are related, which revealed strong cointegration among the variables and hence, a reduction of CO_2 emissions are caused by environmental tax.

Environmental Kuznets Curve Hypothesis is a popular theory used to explain the relationship stuck between economic growth and environment. According to (Grossman and Krueger, 1995) EKC theory, there is a negative link flanked by economic growth and environmental quality in anticipation of a definite point at which income increases are linked to notable improvements in environmental quality. However, a variety of contradictory but complimentary theoretical propositions have developed to explain the income-environment relationship; there is still no grounded theory on the subject. The primary drivers of the income-environment relationship—the scale impact, the technical effect, and the composition effect—are frequently used in explaining the supposed inverse-U form of the EKC curve.

Abdullah and Morley (2014) undertook a panel study of European and OECD states between 1995 and 2006 using standard Granger approach. Findings uncovered that, economic expansion cause's revenue upsurge of these economies through environmental tax mobilization in the long-run. However, in the short-term the reversed is the case. Study by (Abdullah and Morley, 2014) revealed pintsized effect of population size on the nexus between economic development and environmental tax. Dogan et al., (2022) applied novel quantile regression as modus operandi to analyse whether environmental tax and green economy system does play a role in dipping the emissions level. Using data spanning from 1994 to 2018 of 25 green economies, analytical coefficients points to the fact that, three key factors help to reduce CO_2 which includes environmental taxes.

3. MATERIALS AND METHODS

3.1. Data Pools and Variable Delineations

The process of enforcing environmental regulations to improve environmental quality in the direction of feasible economic development includes the application of environmental taxes. That is, any tax levied on a basis that has a demonstrated adverse effect on the environment is referred to as an environmental tax (ENT). The tax which is levied on the carbon content of various goods and is closely linked to the quantity of fossil fuels needed for their production, is without a doubt the environmental tax that has received the most attention. For the years 2000 through 2019, annual time series data were used. Data information was acquired from the World Development Indicators (WDI) and the Organization for Economic Cooperation and Development (OECD). One of the lapses of the study is the time span of the dataset. However, several studies have used same or similar time period for analysis (Esen and Dündar, 2021; Sarıgül and Topcu, 2021). The full discussion of each variable is stated in Table 1: ENT-Environmentally related tax revenue are energy items for transportation (diesel and gasoline), fossil fuels and electricity, waste management, and ozone-depleting compounds which are all subject to taxes relating to the environment impact expressed as a percentage of GDP.

Energy intensity (ENC) on the other hand, indicate the ratio of the energy supply to the GDP, expressed at purchasing power parity, is the level of primary energy. The amount of energy essential to produce one unit of economic output is known as energy intensity. Lesser ratio points out that less energy is used to yield one unit of output. Economic expansion (GDC) is the gross domestic product

Table 1: Variables description and source

Variable tag	Icon	Computing unit	Source
Carbon dioxide emissions	CO_2	CO_2 emissions (metric tons per capita)	WDI
Environmental tax	ENT	Environmental tax (% of GDP)	OECD
Energy Intensity	ENC	Energy intensity level of primary energy (MJ/$2017 PPP GDP)	WDI
Economic expansion	GDC	GDP (current US $)	WDI
Population	PPT	Population, total	WDI

of Ghana measured in current US$ while Population (PPT) consist of the total number of people living in the country at a point in time.

3.2. Pragmatic Model

The renowned theoretical EKC idyllic (Grossman and Krueger, 1995) provides the foundation of this investigation. According to this concept, in the early phases of economic expansion, pollution upturns as returns does, however, at a certain point of economic development, an upturn in income tips to environmental improvement (Grossman and Krueger, 1993). To undertake unit root test, there are some key assumptions that scholar need to consider. The first assumptions is that, the outcome variable in the series is I(1). The second subsequent assumption is that, the regressors are not integrated >I(1). Lastly the KRLS fits into error-correction form. To analyse the interaction, a model to articulate the rudimentary structure for the exploration was professed as equation (1):

$$\Delta CO2_t = \delta_0 + \varphi_0 CO2_{t-1} + \varphi_1 m_{1,t-1} + \ldots + \varphi_n m_{n,t-1}$$
$$+\sum_{i=1}^{r}\delta_1 \Delta CO2_{t-1} + \sum_{j=0}^{s}\varpi_{1j}\Delta m_{1,t-j} + \ldots + \sum_{j=0}^{sn}\varpi_{nj}\Delta m_{n,t-j} + \mu_t \quad (1)$$

Such interpretation is made possible and quick by the class of models that KRLS belongs to, which produce uninterruptedly differentiable elucidation surfaces with closed-form expressions. One run of the model generates all the inferential and interpretational values, and falsifiability is increased because the exemplary does not call for user input regarding parameter settings or serviceable form. There are two key assumptions underlying the use of KRLS. Selecting the regularization parameter (λ) is the first step. A typical cross-validation method is used by default in the KRLS function, selecting the value of λ that reduces the total of the squared leave-one-out errors. Second, the kernel bandwidth ($\sigma 2$) must also be selected. The kernel definition, which determines how far apart two covariate vectors can be and still be regarded as relatively, mostly incorporates this measurement choice. Therefore, it is crucial to remember that KRLS always regiments variables before analysis by deducting the sample means and apportioning by the sample standard deviations before looking at the selection of λ and $\sigma 2$. This is done in an attempt to tackle the optimization challenge over model complexity and empirical fit.

3.3. Unit Root Test, Optimal Lag Selection and Bounds Test

The study further looks at stationarity and non-stationarity to account for possible misleading regression properties of the variables using ADF and PP techniques while Ng-Perron was used as robustness test. To explore this, we run ADF, PP and Ng-Perron unit root tests. After undertaking the unit root test, we proceeded to determine the optimum lag for the recommended model via varsoc. Using the modified Pesaran, Shin, and Smith (PSS) precincts test with Johansen cointegration and verge on P-values, we evaluated cointegration after assessing the properties of the unit root and optimal lag of experimented variables. The cointegration method was used to assess the long-standing association between the variables, which are also referred to as F-statistics. The computed value of the F-statistics, which determines whether cointegration is present or not among the studied variables, has a weighty impact on the long-run nexus of the variables.

The PSS bounds test compares pairs of critical values (CV) with the results of traditional F and t statistics. The cointegration between the variables is shown by the F-statistics value; if the F-value is smaller than the critical bound values, we conclude that there is no cointegration. The test either conclusively rejects or does not reject the null hypothesis outside of these limitations. To put it correctly, a long-term bond between the projected variables is indicated if the F-statistics value is bigger than the perilous value of the boundaries. Nonetheless, the test is inconclusive within the parameters. Johansen cointegration test on the other hand, helps to determine if three or more time series data are counteracted and will converge in the long-run. The two statistical used in making decision in the Johansen approach are the Trace and Max-Eigen statistics. The decision for the presence of absence of cointegration is inferred based on either the values of Trace statistics or Max-Eigen statistics in Johansen test. The null proposition for the Johansen procedure is that there is no level connection in the midst of the series while the alternative theory is that there is a level relationship among the chains in the model. The adoption of Johansen approach comes with its own assumption which include that; the test deals with stochastic trend series and its best suited for series integrated at order (1). The test also assumes that all series are endogenous. Lastly, the test expects the researcher to fix the lag length of the model that will enable the scholar to have a Gaussian error term.

3.4. Diagnostic Test and Model Validation

As part of the initial conditions of time series, there is the need to run a number of tests in order to eliminate model misspecification, serial correlation, heteroskedasticity, normality violations, and mechanical breakdowns. First, we started by restoring the estimated regression that was saved. Second, we use the Breusch Godfrey LM test to look at the estimated model's residuals for autocorrelation. Third, we use Cameron and Trivedi's decomposition of the IM-test to check for heteroskedasticity in the residuals. Fourth, we used the Skewness/Kurtosis tests to check for normality and evaluate the residuals' independence. As a final point, the Ramsey RESET test was run to see if the model was accurately defined.

3.5. Kernel-based Regularized Least Squares (KRLS) Estimation

Using the KRLS model, the study followed the findings of (Ferwerda et al., 2017; Hainmueller and Hazlett, 2014; Sarkodie and Owusu, 2020). The estimator produces pointwise estimates of partial offshoots that describe each independent variable's marginal effects at each covariate space data point. The important point here is that, KRLS helps the researcher to either average these pointwise values to get run-of-the-mill partial derivative with similar parameters from linear regression or look at the giving out of these estimates to understand the variability in marginal effects. In other words, the KRLS approach combines interpretability and flexibility, making it appropriate for a variety of regression and classification problems where the precise functional form is uncertain. This covers model-based causal extrapolation, prediction problems that necessitate a correct approximation of a conditional expectation function to impute missing counterfactuals, and exploratory analysis to gain insight into the data-generating process. In a similar vein, it can also be used for other regression and classification tasks, such as estimating propensity scores, when it is crucial to estimate a quantity of interest using all the information from variables. The use of KRLS estimator is intended to limit over-fitting and guards against model dependency resulting from poor leverage points or extrapolation. The KRLS estimator offers benefits even in cases when the actual data-generating process is linear. Despite the availability of other kernels, the Gaussian kernel utilized in KRLS and throughout this paper is provided by:

$$K_R(m_j, m_i) = q - \frac{\| m_j - m_i \|^2}{\delta^2} \quad (2)$$

Where q^m is the exponential function and $\| m_j - m_i \|$ is the Euclidean distance between the covariate vectors m_j and m_i. The function demonstrates the normal distributions under similarity-based view. Hence, the target function can be presented under linear system $f = K_y$ as:

$$f = K_y = \begin{bmatrix} K_R(m_1, m_1) K_R(m_1, m_2) \ldots K_R(m_1, m_n) \\ K_R(m_2, m_1) \ddots \\ K_R(m_n, m_1) \ddots \ldots\ldots\ldots\ldots\ldots\ldots \; K_R(m_n, m_n) \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \\ S_n \end{bmatrix} \quad (3)$$

A key distinction between KRLS and other approaches, such the GLM approach, is brought to light in its application. To be clear, we assume that the result of GLMs is a weight sum of the independent variables. The foundation of KRLS, on the other hand, is the idea that information is programmed in the similarity of observations, meaning that superfluous comparable observations should provide more similar results.

In order to ensure that information in the columns of K_R becomes useful, smoother and less complicated function, we employed Tikhonov regularization (Tikhonov, 1963), in trying to solve key optimization problem of empirical fit and model complexity. Hence, we applied kernel matrix K_R by working out all pairwise remoteness and then add regularized parameter to the slanting. This forces the matrix symmetric in a big regularized coefficient to become positive definitive, and well-conditioned. The analysis of KRLS estimation would provide the long-term parameters of the variables under study. However, as a matter of interest of the study is to find out how phasing out of environmental tax in Ghana would affect the achievement of sustainable environment. To achieve this objective, we capture the varying marginal effects of the environmental tax by running lowess smoother derivative.

4. RESULTS AND DISCUSSION

4.1. Statistics Related to Correlation and Description

The summary of vivid statistics has been offered in Table 2 Ghana's pollution intensity is demonstrated by the mean value of carbon emissions (InCO$_2$), which is 16.225. This may be due to more industrialization activities based on government policy of One District – One Factory (IDIF). The mean value of environmental tax (InENT) is 19.786%, showing the rate of the environmental cost charged by government as percentage of GDP with a maximum value of 21.022 and a minimum value of 18.319. Economic expansion provides the highest mean of 23.973 with a maximum value of 24.972 and a minimum value of 22.329. The results of the mean, maximum and minimum is an indication of an upsurge in economic activities in Ghana due to IDIF.

Similarly, the mean worth of population (InPPT) is 17.020% which shows the average increase in population in Ghana. Subsequently, the maximum and minimum of the InPPT are 17.252 and 16.775 respectively. The average energy intensity is 1.202 of primary energy (MJ/$2017 PPP GDP). In terms of maximum and minimum values, primary energy intensity in Ghana has low as 1.577 and 0.967 individually.

The existence of variations among variables is shown by the standard deviation measurement or the model's degree of inconsistency. The standard deviation results in Figure 1 indicates InGDC as the ficklest variable, having the highest standard deviation of 0.925, followed by InENT, InCO$_2$, InENC and InPPT sequentially.

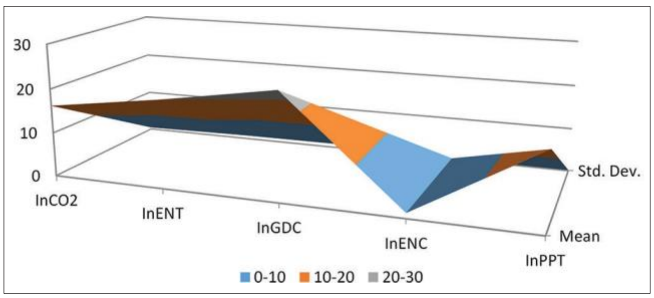
Table 2: Descriptive analysis

Descriptive statistics								
Var.	**Mean**	**Std. Dev.**	**Max.**	**Min.**	**Skew.**	**Kurt.**	**JB**	**Prob.**
InCO$_2$	16.225	0.422	16.881	15.563	−0.021	1.599	1.719	0.423
InENT	19.786	0.791	21.022	18.319	−0.074	2.306	0.441	0.802
InGDC	23.973	0.925	24.972	22.329	−0.616	1.908	2.371	0.306
InENC	1.202	0.174	1.577	0.967	0.832	2.677	2.515	0.284
InPPT	17.020	0.150	17.252	16.775	−0.071	1.771	1.340	0.512

4.2. Integration Test Results

The stationarity features of the variables are analyzed using the PP and ADF tests to look for any possible spurious regressions. For PP and ADF, we do unit root tests at both levels and initial differences in order to achieve this. Our results in Table 3 for the time series confirm the presence of some variables non-stationarity at the level (InENC and InPPT) and others as well at 1st difference (InCO$_2$), InENT, InGDC and InENC). Hence, in summary, failed to admit the unsound proposition that unit root ensued in the first- difference on the basis of 5% significance level. The results in Table 3 recognized that variables are integrated at matching direction.

Figure 1: The normality of the central predisposition and standard deviation of the series



4.3. Var Lag Order Collection Standards

Based on Table 4 results, majority of the test of LR, FPE, AIC, SIC and HQ all point to the selection of lag 2 as the lag for our analysis. The results are depicted as Figure 2 showing the Akaike Information Criteria.

4.4. ARDL Bound Test

The subsequent fallouts of the bounds assessment are re-counted in Table 5. Findings indicate that an assessed F-statistic grounded on a finite sample of 5 variables, coefficients is 18.203 whereas t- statistic is 4 — which is directly above the upper (i.e. Higher) bound perilous values (3.49) at 5% significance level and above the critical values of all I(1) variables in 10% and 2.5% level with the exception at 1%. This is further validated by Johansen cointegration test. Since the F-statistics value surpasses the value at the upper bound, there is a long-standing attachment among the variables. Johansen cointegration as a robustness test confirm trace test which indicates four (4) cointegrating equations at the 0.05 significance level from 'None' to 'At most 3' of the hypothesized No. of CE(s).

4.5. Diagnostic Test and Model Validation

As point out in the research materials and methods section of the study we performed several tests which are prerequisite for KRLS

Table 3: Unit root test results

Variable	ADF		PP		Int. Order
	t-Stat	Prob.	t-Stat	Prob.	
InCO$_2$					
Level	−0.440	0.884	−0.181	0.927	I (1)
1st Diff.	−5.198	0.000**	−7.117	0.000**	
InENT					
Level	−1.465	0.530	−1.490	0.518	I (1)
1st Diff.	−3.456	0.022**	−3.389	0.023**	
InGDC					
Level	−1.777	0.380	−1.992	0.287	I (1)
1st Diff.	−3.936	0.008**	−3.936	0.008**	
InENC					
Level	−3.565	0.017**	−3.282	0.030**	I (0), I (1)
1st Diff.	−4.461	0.003**	−4.509	0.002**	
InPPT					
Level	−4.533	0.003**	−3.798	0.010**	I (0)
1st Diff.	1.236	0.997	0.235	0.967	
	Ng-Perron				
	Mza	MZt	MSB	MPT	
InCO$_2$					
Level	1.120	0.990	0.884	56.619	I (1)
1st Diff.	−24.969	−3.533	0.142	0.981	
InENT					
Level	−1.065	−0.492	0.462	14.094	I (1)
1st Diff.	−9.052	−2.122	0.234	2.726	
InGDC					
Level	−0.425	−0.257	0.604	22.463	I (1)
1st Diff.	−9.431	−2.158	0.229	2.649	
InENC					
Level	−2.728	−1.074	0.394	8.625	I (0), I (1)
1st Diff.	−9.145	−1.945	0.213	3.366	
InPPT					
Level	−2.486	−0.852	0.343	8.529	I (0)
1st Diff.	0.560	0.365	0.651	30.593	

**Indicates that, at a 5% connotation level, the null premise—that there is no unit root—is rejected. Int. Order means integrated order

Table 4: Optimal lag collection

Lag	Ψ_{π}	ξ_{Π}	$\hbar_{\upsilon}$	$\Im_{\Re}$	Υ_{ρ}	κ_{Φ}
0	66.49654	NA	1.06e-09	−6.473320	−6.224784	−6.431258
1	222.4912	213.4663	1.22e-15	−20.26223	−18.77101	−20.00986
2	276.4403	45.43086*	1.18e-16*	−23.30951*	−20.57561*	−22.84682*

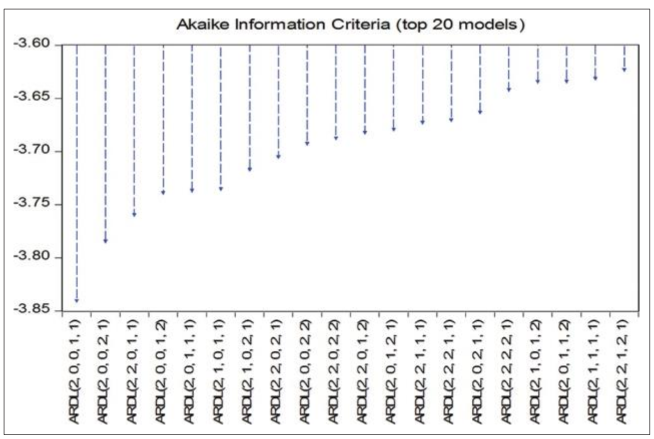
Where ψ_{π}, ξ_{Π}, $\hbar_{\upsilon}$, $\Im_{\Re}$, Υ_{ρ} and κ_{Φ} represents LogL, LR (sequential modified LR test statistic), FPE (Final prediction error), AIC (Akaike information criterion), SIC (Schwarz information criterion and HQ respect

Table 5: Cointegration test results

PSS Bounds test				
F-Statistics	18.203		K: 4	
Significant	I (0): Lesser Bounds		I (1): Higher Bounds	
10%	2.20		3.09	
5%	2.56		3.49	
2.5%	2.88		3.87	
1%	3.29		4.37	
Johansen Cointegration				
Hypothesized No. of CE (s)	**Eigen Value**	**Trace Stats.**	**0.05 CV**	**Prob.**
None*	0.953	141.810	69.819	0.000*
At most 1*	0.896	83.914	47.856	0.000*
At most 2*	0.704	40.972	29.797	0.002*
At most 3*	0.591	17.853	15.495	0.022*
At most 4	0.045	0.877	3.841	0.349

*Denotes refutation of the theory at the 0.05 substantial level. CV means Critical value

Figure 2: Lag selection akaike information criteria



is to get purge of serial correlation, heteroskedasticity, desecration of normality, model misspecifications and structural break. First, the resulting estimates of Breusch-Godfrey LM test with two lags are presented in Table 6. We failed to throwaway the null assumption of no serial correspondence based on 5% significance level — confirming the residuals of the estimated ARDL (2,0,0,1,1) model as displayed at Figure 2 are free from autocorrelation. Second, the heteroskedasticity test results disclosed that the unsound premise of homoskedasticity cannot be overruled at 5% significance level — ratifying the residuals are homoskedastic. Third, further diagnostic analysis results on the assessment of the individuality of the residuals by testing for status quo using Skewmess/Kurtosis revealed that the unsound supposition of normal distribution cannot be disallowed. The results of the trend of the VAR residuals of the study variables are shown as Figure 3.

Fourth, the results of Ramsey RESET test exposed that the data model specification is not misspecified. Finally, the CUSUM tests accessible in Figure 4 examined the stability of the parameters. While the CUSUM intrigues within the 95% confidence zone suggest the model's, residuals are steady over time devoid of structural breaks, the results validate the residual independence of the calculated models.

As shown in Table 7, a number of post-evaluation tests of the machine learning process were carried out to validate the estimated models, including lambda, forbearance, goodness-of-fit, and looloss. Lambda is designed to optimize the trade-off between the model's fitness and complexity, while tolerance tends to achieve non-divergence by optimizing the sensitivity of lambda. The degree to which the explanatory factors account for the dependent variable is measured by the goodness-of-fit. The entirety of the squared leave-out-one error (LOOE) is called looloss.

4.6. Dynamic KRLS and Lowess Smoother Test Results

After we used the adjusted PSS bounds test with KS acute values and approximation p-values to investigate cointegration after analysing the unit root qualities of the sampled variables and the dataset's lag selection criterion. We computed the long-run relationship using ARDL (2,0,0,1,1) which is depicted as Figure 3. Successively, we applied Kernel-based Regularized Least Squares (KRLS), a machine learning algorithm that trappings the pointwise derivatives to investigate the causal-effect association.

The parameter estimations of KRLS are reported in Table 7. The Looloss value of 0.3264 expresses the recapitulations from the cross-confirmation to find the regularization parameter that minimizes the leave-one-out error (LOOE). The Table 7 reports ins and outs about the model fit based on R-sq. of 0.9887. The Table 7 further reports the middling of the pointwise marginal effects (ℓ_{Avg}) of the predictors along with its standard error ($\hbar_{Se}$), t statistic, and P value (P>t). It also reports the diverse peripheral

Figure 3: Trend of VAR residuals of the variables

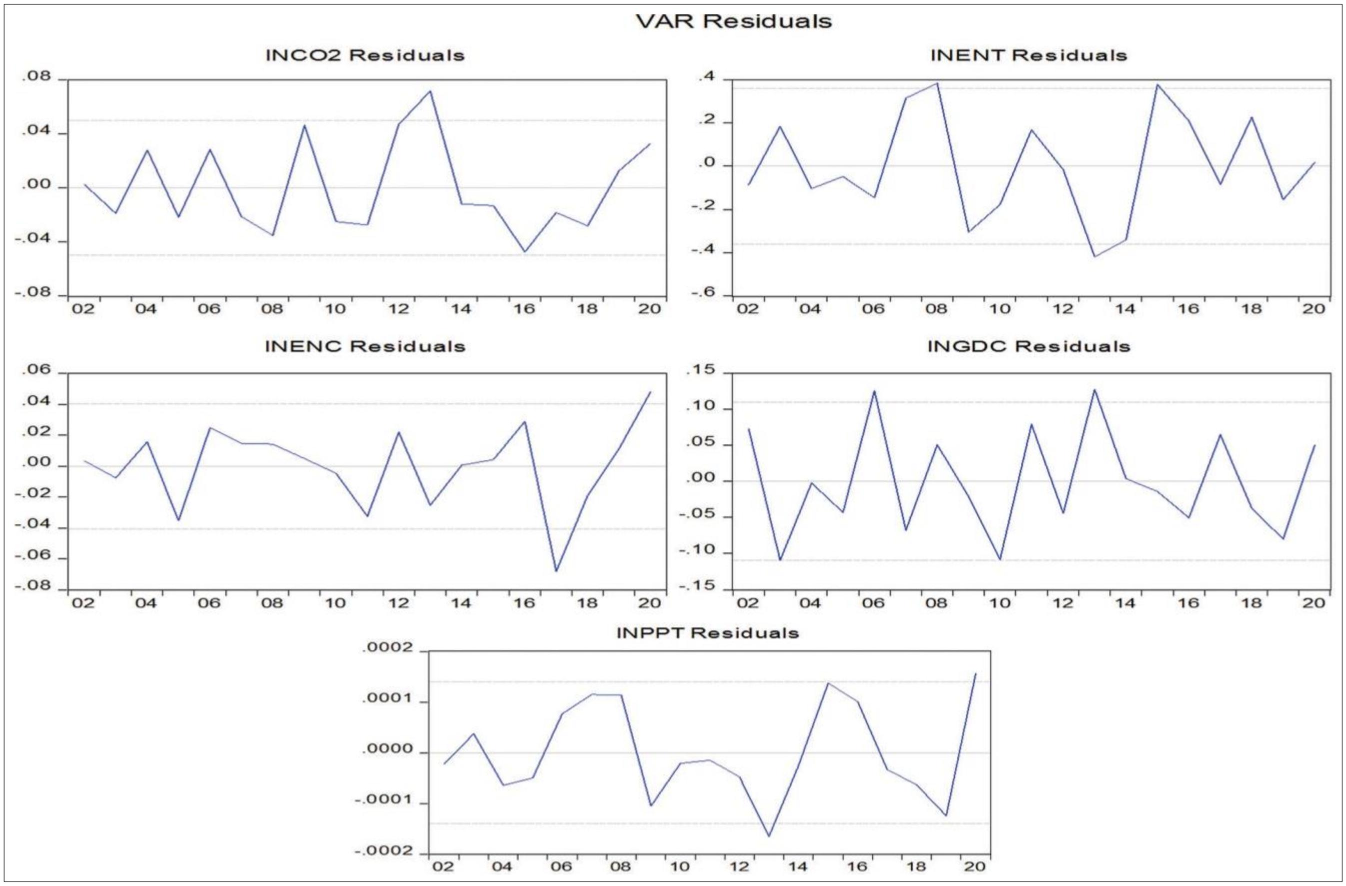
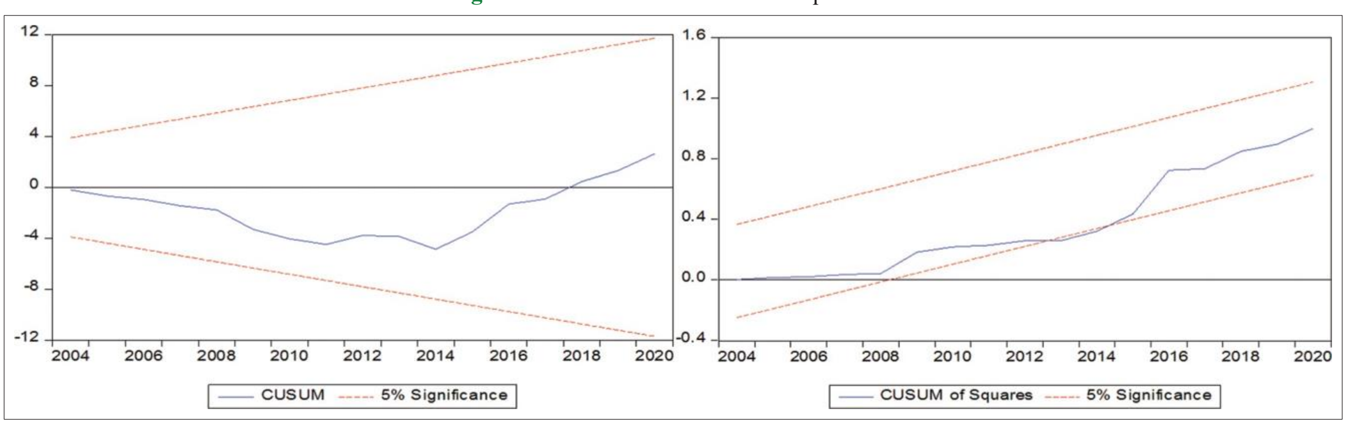


Figure 4: CUSUM and CUSUM of square test



effects of the pointwise derivatives of the regressors in 1st quartile, median, and 3rd quartile under β_{25} , β_{50} , and β_{75} columns correspondingly. Subsequently, we observed an indication of heterogeneous negligible effects across sampled variables. The KRLS results suggest a statistically significant affiliation between dependent variable (i.e.InCO_2) and the explanatory variables, but the average marginal effect estimate of significant predicting variables such as population (InPPT) and economic expansion (InGDC) are somewhat bigger and put forward that a one percent increase in InPPT and InGDC are associated with 1.364 and 0.183 percentage point increase in InCO_2 on average respectively. Hence, both InPPT and InGDC have increasing marginal effects on InCO_2.

One striking result are that of environmental tax and energy intensity were found to be statistically not significant contributor to the emissions level in Ghana. However, environmental tax was found not significant but the parameter shows that 1% change have inverse connection with carbon emissions (InCO_2). That is, the change reduces the emission level by 0.037. This is a clearly demonstrate that environmental taxes cannot be considered as the best strategy that Ghana need to combat environmental degradation (Mardones and Flores, 2018), although its adoption could reduce the ecological degradation. On the other, energy intensity although found insignificant but its coefficient depicts positive value indicating that a

Table 6: Diagnostic test results

Breusch-Godfrey LM test for autocorrelation					
Lags (P)		**F**		**Df**	**Prob>F**
1		1.139		(1, 15)	0.303
2		3.121		(2, 14)	0.076
Cameron and Trivedi's decomposition of IM-test					
Source		χ^2		**Df**	**P-value**
Hetero$_{\kappa}$		12.94		14	0.531
Skew$_{\lambda}$		11.95		4	0.018
Kurt$_{\wp}$		0.39		1	0.530
Ramsey RESET Test					
Total		2.261		(2, 15)	0.139
Skewness/Kurtosis tests for normality					
Variable	**Obs**	**Pr** *(Skew$_{\lambda}$)*	**Pr** *(Kurt$_{\wp}$)*	**Joint adj χ^2 (2)**	**Prob>χ^2**
Residuals	21	0.363	0.999	0.89	0.641

Where *Hetero*$_{\kappa}$, *Skew*$_{\lambda}$, *Kurt*$_{\wp}$, Pr *(Skew$_{\lambda}$)* and Pr *(Kurt$_{\wp}$)* denotes Heteroskedasticity, Skewness, Kurtosis, Pr (Skewness) and Pr (Kurtosis) respectively

Table 7: Estimates of KRLS model

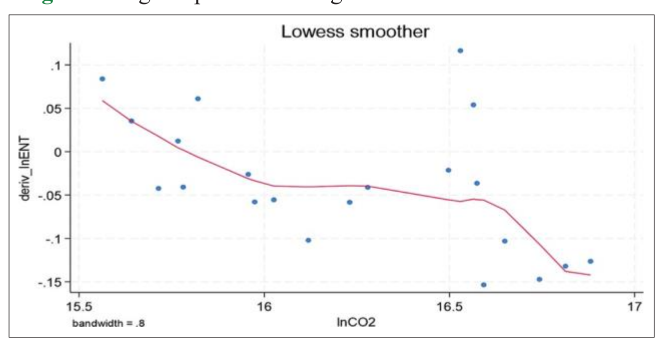
Pointwise derivatives using KRLS							
Dep. InCO2	l_{Avg}	$\hbar_{S\varepsilon}$	**T**	**P > t**	ρ_{25}	ρ_{50}	ρ_{75}
InENT	−0.037196	0.025263	−1.472	0.159	−0.102094	−0.041089	0.012249
InGDC	0.183387	0.029198	6.281	0.000	0.110152	0.174485	0.280097
InPPT	1.36411	0.155899	8.750	0.000	0.779617	1.48549	1.87705
InENC	0.101384	0.176237	0.575	0.573	−0.095402	0.092349	0.321102
Diagnostics							
Lambda	0.06096	Sigma	4	R^2	0.9887	Obs	21
Tolerance	0.021	Eff. DF	9.987	Looloss	0.3264	F-test	

l_{Avg} is the average marginal effect; $\hbar_{S\varepsilon}$ represent the standard error; ρ_{25}, ρ_{50} and ρ_{75} represent percentile of 25th, 50th and 75th respectively. Legend: Dep. InCO$_2$ represents carbon dioxide emissions and as dependent variable, InENT represents Environmental Tax, InGDC denotes the economic expansion, while InPPT connote the population size, and InENC means energy intensity of Ghana

percentage change would cause an increase in emissions by as much as 0.101.

Further exploration divulges that this enhanced model fit results is for the reason that the relation between outcome variable and explanatory variables are not well described by a simple linear relationship instead, the connection is highly non-linear and the KRLS fit accurately learns the shape of this restrictive bated breath function from the data. The existing literature on environmental tax-emissions nexus produced inconclusive results. Some studies in both developed and developing countries have backed our results (Mardones and Flores, 2018). These studies have clinched that environmental taxes are a greasing wheel of reducing ecological destructions. That is, environmental tax although not found statistically significant influencer of the ecosystem destruction. However, its adoption would help to improve the environmental quality since the environmental tax as most scholar on environmental tax-economic growth nexus suggest that environmental tax exacerbates economic expansion. Eventually, the upsurge of the economic development would lead to increase in economic activities at the initial based on EKC theory but subsequently help to address the environmental challenge. Other scholar also holds different view which are contrarily to our findings and classic example is the study by (Tang et al., 2017). Ghana is one of the least emitters in the world due to squat energy concentration and privation of high industrial activities at the current period. Some researchers also had the same results that buttresses our study that shows horrendous effects of economic growth and population on environment obliteration (Abdullah and Morley, 2014). These studies corroborate to our findings.

Figure 5: Sign of pointwise marginal effect of environmental tax



Although the KRLS test results disclosed that, environmental tax is not significant in the analysis but the coefficient explains that it helps to reduce environmental pollution. The question still persists on how phasing out of environmental tax completely in Ghana would affect future environmental degradation. This means that, we are trying to find out the long-run variation in environmental tax and how it would affect environmental emissions and vice versa.

It can be observed in Figure 5 that higher levels of environmental tax decrease ecological pollution at lower levels to a threshold between 15.5 and 16 of the bandwidths where decreasing marginal returns occur, however, declines in environmental tax thereafter causes an upsurge in ecological degradation. Thus, environmental tax has dwindling marginal returns with increasing carbon emissions in Ghana. This infers that government of Ghana need to increase its environmental tax revenue which is a percentage of GDP if it wants to achieve its Sustainable Development Goal targeting environmental sustainability.

5. CONCLUSION

One of the most important challenges currently affecting modern society at large is the environmental one. The environmental sector requires close attention, as well as finding novel and improved approaches, to ensure that it runs effectively. The complexity of climate change and its associated services necessitates the use of a wide range of variables and indicators in this study, which can represent various strategies for climate change adaptation and mitigation. To deal with climate change requires the need to cut CO_2 emissions. Environmental tax is considered as one of the most effective and lowest-cost means. Successful sustainable economic development depends on sustained environmental quality. The role of environmental tax in national strategy to curb environmental degradation has gained increasing attention globally in recent years. Many developing nations are considering environmental levies as a way to raise money and fulfill their obligations in combating climate change and promote sustainable development.

The current government of Ghana for instance turned to the International Monetary Fund (IMF) for loans in July 2022 after severe economic and financial challenges that saw it default on domestic and foreign debts (Abotebuno Akolgo, 2023). One key objective stipulated by the IMF was that Ghanaian government need to introduce new revenue generation measures. Hence, one such measure out of the five new tax interventions is the use of environmental tax. This analysis examined the impact of environmental tax on ecological footprint. Divergent to the previous empirical attempts by other scholars, this study make use of the KRLS estimation modus operandi– a machine learning algorithm that outweighs the traditional econometric methods in a number of perspectives to identify the influence of ecological tax on environmental degradation. Kernel-based Regularized Least Squares (KRLS) technique is designed based on machine learning was created to address regression and classification issues without using additive or linear assumptions. When determining the marginal effects of regressors, its interpretation is comparable to that of the generalized linear model. To investigate the causal-effect relationship and necessary regularization of the coefficients, KRLS applies the pointwise derivatives.

Preliminary results of the R^2 from KRLS test revealed high predictive power of about 99% of the analysis. This implies that the pore over regressors explain 99% of variations in $InCO_2$. The Looloss value of 0.3264 shows the iterations from the cross-validation to find the regularization parameter that minimizes the leave-one-out error (LOOE). Stationarity test results established that variables are integrated at same order. Based on optimal lag selection criterion of selecting lag 2, the cointegration test of PSS bound test and Johansen test uncovered long run relationship among the variables and hence, the variables are cointegrated. Diagnostic test and model validation confirmed that no serial correlation in the series, homoscedasticity in the residuals, normal distribution of the dataset, data model specification is not misspecified and there is stability in the residuals of the model over time without structural breaks.

Based on the scientific findings, there is an evidence of unrelated marginal effects across sampled variables. The KRLS results suggest a statistically significant relationship between dependent variable (i.e.$InCO_2$) and the explanatory variables, but the average marginal effect estimate of significant predicting variables such as population and economic growth are somewhat bigger and suggests that a one percent increase in population and economic development are associated with 1.364 and 0.183 percentage point increase in $InCO_2$ on average respectively. Hence, both population and economic expansion have increasing marginal effects on $InCO_2$. One striking result are that of environmental tax (InENT) and energy intensity (InENC) were found to be statistically not significant contributor to the emissions level in Ghana. However, environmental tax was found not significant but the parameter shows that 1% change have inverse connection with carbon emissions ($InCO_2$). That is, the change reduces the emission level by 0.037. This is a clearly demonstrate that environmental taxes cannot be considered as a strategy need to combat environmental degradation, although its adoption could reduce the ecological degradation. On the other, InENC although found insignificant but its coefficient depicts positive value indicating that a percentage change would cause an increase in emissions by as much as 0.101.

Findings from lowess smoother test to understand the effect of phasing out environmental tax would be on environment of Ghana revealed interesting findings that, a decline in environmental tax revenue would exacerbate ecological degradation. This infers that government of Ghana need to increase its environmental tax revenue which is a percentage of GDP if it wants to achieve its Sustainable Development Goal targeting environmental sustainability.

The empirical findings recommend several policy repercussions. First, with regards to our variable of interest (i.e. InENT), there is the need to sharpen up environmental tax policies to provide stronger incentives for the various sectors especially the industries to adopt much greener habit in their activities. This policy strategy can be achieved through the provision of reducing the environmental rate for industries emitting emission within a certain threshold as well as educating industries on emission reduction strategies especially on how to benefit from carbon trade if they reduce their emission level. Government can as well broaden the tax base by eliminating exemptions and rebates to ensure that all emitting industries are paying for their activities negative effect on environment.

Several literatures that imposition of high environmental tax contribute to the rise of economic growth. However, the end effect of the economic expansion is that, its causes increase in economic activity which leads to environmental degradation. The study findings policy implication on economic growth is that, government of Ghana should look at the various anthropogenic factors within the economy that has detrimental effect on environment as illegal mining although such activities contribute to economy directly or indirectly.

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