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ENVIRONMENTAL TAX, METHANE EMISSIONS, AND FEMALE ECONOMIC INCLUSION

By
Dr. Rabiatu Kamil
University of Skills Training and Entrepreneurial Development (USTED), Department of Accounting Studies Education, Kumasi, Ghana.

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Abstract

This study investigates the double dividend hypothesis by examining whether environmental taxation reduces methane emissions and promotes female employment. The study uses panel data for twenty-three developing economies from 1994 to 2020. The study applies the Method of Moment Quantile Regression (MMQR) to indicate heterogeneous effects across countries. Pooled Mean Group (PMG) and Granger Causality techniques are employed as a robustness check. The study find that environmental tax significantly reduces methane emissions, with stronger effects among high-emitting nations. Also, environmental tax surges female employment in the lowest, low, and middle countries. The study finds evidence to validate the double dividend hypothesis. This finding is confirmed only in the long run. The research find a one-way causal association between environmental tax and methane emissions. However, the findings show that causality between environmental factors and female economic inclusion is bidirectional. The study results suggest that environmental taxation can be an effective tool for achieving environmental objectives while promoting women's participation in the labour market. Policymakers should align environmental tax revenue with gender-responsive employment initiatives. Governments should align environmental policy instruments to gender equality and climate action, thereby contributing to the achievement of Sustainable Development Goals 1, 2, 5, and 13.

Keywords- *Greenhouse gas emissions, non-CO2 emissions, Employment, Double dividend, African economies*

Introduction

The need to lower global temperature due to greenhouse gas emissions, including methane (CH_4) emissions, has made countries pledge during COP26 at the United Nations conference on climate change in Glasgow (2021). This is necessitated after the previous declarations, the Paris Agreement (United Nations, 2015) and the 1997 Kyoto Protocol yielded lower results. Methane (CH_4) emission is a non-CO_2 greenhouse gas emission with a shorter lifetime than CO_2; lowering these emissions provides an extra chance to slow down upcoming climate change (Mar et al., 2022; Montzka, et al., 2011). To mitigate the problem, governments have implemented various environmental policy instruments such as environmental taxes to correct environmental externalities (Fu et al., 2021; Pearce, 1991; Ullah et al., 2023; Schoder, 2023). Environmental tax is a market-based mechanism used to internalize the external costs of environmental deterioration (Fu et al., 2021). It aims to promote the use of renewable energy to reduce pollution, leading to environmental quality (Kamalu & Wan Ibrahim, 2024). In addition to improving the quality of the environment, revenues arising from environmental taxes also have an economic advantage, dubbed the "Double Dividend Hypothesis" (Freire-González, 2018; Pearce, 1991). These revenues offer favorable opportunities for increased economic participation of socially disadvantaged groups, particularly females. Following the above, this study examines the impact of environmental tax on methane emissions and female economic inclusion in Sub-Saharan Africa[1].

Several studies have examined the effectiveness of environmental tax in achieving the double dividend hypothesis in different contexts using varied estimation

[1] South Africa, Burkina Faso, Cote d'Ivoire, Ghana, Mali, Niger, Nigeria, Senegal, Togo, Kenya, Uganda, Botswana, Namibia, Equatorial Guinea, Cameroon, Tunisia, Chad, Congo Democratic, Mauritius, Rwanda, Malawi, Egypt, Mauritania

*Corresponding Author: **Dr. Rabiatu Kamil.**

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techniques. For instance, in China (Yang et al., 2020; Zhou et al., 2020), in Australia (Fraser & Waschik, 2013), Mexico (Rivera et al., 2016), and in the Nordic economies (Alola & Nwulu 2022), Presley et al., (2019) use data from Liberia. Degirmenci & Aydin, (2021) use data from five-African nations and apply Augmented Mean Group (AMG). They observe that environmental tax does not affect environmental quality and unemployment among African economies. Even though they consider employment double dividends, nonetheless, they look at total employment and neglect the female aspect. Additionally, in measuring environmental pollution, they use carbon dioxide emissions (CO_2). However, this study uses Methane, which is 80% more dangerous greenhouse gas emission compared with CO_2 (Mar et al., 2022). Additionally, this study considers female economic inclusion, which refers to the incorporation of women into the economy for decision-making and giving them access to employment opportunities to advance sustainable development goals (World Bank, 2019). Also, women form part of vulnerable people who suffer the most in terms of environmental degradation (Eastin, 2018; Soku et al., 2023). Therefore, the need to target environmental policies towards women.

Further, Soku et al., (2023) apply generalized method of moments (GMM) and consider the role of environmental tax and carbon emissions on female economic inclusion. They find out that both environmental tax and female economic inclusion lower carbon emissions (CO_2). Although they recognize female economic inclusion, they focus on CO_2 emissions at the neglect of methane emissions. Meanwhile removing methane emissions from the atmosphere is faster than CO_2, making action on it important if global temperature is to be reduced below 1.5 $^{\circ}$C (Mar et al., 2022). Additionally, by using GMM estimation technique, they omit the conditional distributional impact of the independent variables on the dependent variable.

This study considers thirty-three African nations. These countries are part of the nations at COP 27 in Egypt that endorse the need for developed countries to provide financial support to assist in lowering emission levels in developing economies. Moreover, they are together facing the cancer of unemployment specifically that of females. Comparable to other continents, 74% of women in Sub-Saharan Africa (SSA) work in the informal sector such as small trading, domestic activities, and small-scale farming (Asongu et al., 2021; Asongu, & Odhiambo 2020). Evidence suggests that the inclusion of a greater number of women in the formal sector promotes dynamics in the labour markets and lowers overall poverty rates (Efobi et al., 2018) , a means through which women can be empowered to engage more in the formal economic sector is through employment. Accordingly, when women are empowered through the use of tax revenues to provide formal employment, this ensures equality, improves poverty and helps in the achievement of SDGs 1, 2, and 5.

Therefore, this study aims to examine the impact of environmental-related taxes on methane emissions and female economic inclusion from 1994 to 2020 among 23 African nations.

The results show that environmental tax decreases methane emissions with a stronger impact among the high-emission countries in Africa. Also, environmental tax surges female employment among the lowest, low, and middle countries only. The study finds evidence to validate the double dividend hypothesis. This finding is confirmed only in the long run. The research find a one-way causal association between environmental tax and methane emissions. However, the findings show that causality between environmental and female economic inclusion is bidirectional.

This study contributes to literature as it uses "double dividend" theory to explain how environmental taxation affects environmental quality and female employment among twenty-three African nations. First, this paper uses methane and female economic inclusion in measuring greenhouse gas emissions and employment. Methane is the second-largest greenhouse gas generated by humans after carbon emissions and constitutes 20% of emissions globally (Mar et al., 2022). Second, the use of female economic inclusion will assist in solving global dilemma of unemployment as women form the largest number in population globally. Further, the study apply the recently developed method of moment quantile regression (MMQR), a non-parametric technique that provides evidence of the conditional distribution of the dependent variables and solves the methodological problems of previous studies. In terms of policy, the study highlights the need to achieve gender equality and promote environmental quality thereby achieving sustainable development goals.

The rest of the study has the following sections. Theoretical and empirical review in section 2. Section 3 contains data and methodology. Results and discussions are in section 4. Section 5 takes care of conclusions and implications for policy.

Theoretical and Empirical reviews

Theoretical review

Pigou (1920), introduced environmental tax concept and proposed that environmental taxes should be used for taxing actions that deteriorate the environment. International organizations such as World Bank, United Nations, and the Organization for Economic Cooperation and Development also support the idea of environmental taxation (Ullah et al., 2023). Apart from taxing environmental polluters, revenues generated from these taxes are also used to solve social and economic issues dubbed "double dividend". "The double dividend" hypothesis suggests that apart from improving the quality of the environment, environmental taxes also provide other economic benefits (Beiser-McGrath & Bernauer, 2019; Freire-González 2018; Kamalu & Wan Ibrahim, 2024). Thus, both environmental (green dividend) and economic benefits (blue dividend) are achieved through environmental tax. Additionally, it involves using environmental tax to reduce current taxes on labour, consumption, and capital so that the government's total tax revenue will not reduce. Thus, governments utilize the money from pollution taxes to lower

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other distortionary taxes. Environmental tax offers twofold benefits: it discourages environmentally damaging activities and reducing the tax system's distortionary costs (Hoang et al., 2025; Goulder, 1995).

Environment tax, environmental quality, and employment

Literature finds the existence of double dividend (Fraser & Waschik 2013; Presley et al., 2019; Rivera et al., 2016; Yang et al., 2020; Kamalu, & Wan Ibrahim, 2024). Others could not validate the double dividend hypothesis (Freire-González, 2018; Zhou et al., 2020). While others think there is nothing like that (Goulder, 2013; Presley et al., 2019). For example, Freire-González, (2018) uses meta-analysis and finds that 55% results confirm the presence of double dividend. Similarly, Zhang et al. (2016), use a computable general equilibrium (CGE) model to examine three Chinese provinces (Hainan, Chongqing, and Fujian) find that imposing an emission tax of 60 yuan per ton significantly reduced CO_2 emissions at the same time enabling reductions in other indirect taxes. This is the result of recycling carbon tax for subsidizing household energy consumption. Using static CGE model, Presley et al., (2019) also confirm the presence of employment double dividend in Liberia when uniform environmental policy is used.

However, by applying CGE in Australia, carbon taxes lower emission but causes reduction in economic growth (Meng et al., 2013). Fakoya, (2014) uses simulation with South African data and realizes that carbon tax reduces economic growth and increases unemployment. Later in South Africa again, environmental tax attenuates CO_2 emissions by 1,900 and 2,300 tons in 2016 and 2035 respectively but lowers GDP (Van Heerden, 2016). Although the above studies confirm or otherwise the presence of double dividend. The use of simulation studies has a lot of weaknesses as it does not use actual data but rather makes use of assumptions.

Empirical evidence from China suggests that environmental taxes incentivize industries to reduce pollution and contribute to improved environmental quality, which could impact positively individual happiness levels (Liu et al., 2019). The use of sulfur dioxide (SO_2) emission as a non-CO_2 greenhouse gas emission is encouraging, yet, they analyze the data with probit model which does not show the conditional distribution of the dependent variable. Yang et al., (2020) apply OLS and difference-in-difference and conduct a study on the double dividend hypothesis of carbon emission policy and employment in China. They observe that policy on carbon emission leads to the reduction in pollution and, at the same time, improves employment. Although they consider employment, little attention is given to female employment. As women are more affected by climate issues Bush & Clayton (2023), promoting female employment improves economic growth and achieves sustainable development (Soku et al., 2023¸ Kamil & Appiah, 2022). Alola & Nwul, (2022) use MMQR and document that energy tax lowers carbon emissions and energy intensity among Nordic nations. Although they use non-parametric quantile regression to document the double dividend hypothesis of environmental tax, the use of an index in measuring greenhouse gas emissions hides a lot of information about the variable. It does not allow us to understand the variable better instead of specific measures like methane emissions.

Based on the above, the study hypothesizes the relation between environmental tax, methane emissions, and female economic inclusion as follows:

H1: Environmental tax is negatively related to methane emissions.

H2: The relationship between environmental tax and female economic inclusion is positive.

Data and Method

This study investigates the role of environmental tax in lowering methane emissions and improving employment among females in twenty-three (23) nations in Africa for the period 1994 to 2020. The study uses twenty-three countries from 1994 to 2020 due to data availability. Following Danish et al., (2019), the study uses interpolation to ensure balanced data. This approach is simple to use as compared with the cubic method (Sarpong & Bein, 2020).

The data set for the study includes Methane emissions (measured as kilotons of CO_2 equivalent), emissions from agricultural and industrial activities. Female economic inclusion (measured as female employment in industry), environmental taxes (total environmental taxes as a % of GDP), import (Imports of goods and services % of GDP), export (Exports of goods and services % of GDP), and Gross Domestic Product (measured in constant 2015 United States Dollars). Table 1 provides meaning and sources of these variables. The research anticipates a negative impact of environmental tax on methane emissions. The study expects environmental tax to impact positively on female economic inclusion. Export, import, and Gross Domestic Product could be positive or negative depending on the model.

Exports boost economic activities, but it can also lead to increased consumption of fossil fuels due to higher energy demand. This, in turn, is associated with a rise in emissions. Imports associated with durable goods can improve energy productivity and lower long-term emissions. Economic expansion due to manufacturing and industrial activities leads to energy demand resulting in increased carbon emissions.

The study takes into account several diagnostic and statistical tests, including cross-sectional dependence, unit root test, and Westerlund cointegration test, to check the long-term cointegrating relationship and method of moments quantile regression (MMQR). As a robustness check, the study uses pooled mean group (PMG) and Granger Causality tests to validate the MMQR results. Because traditional estimation techniques use mean values to determine the coefficients, this study uses method-of-moments quantile regression (MMQR), which estimates coefficients across different distributions of the dependent variable. Hence, offering more detailed extreme information about the dependent variables. The study also uses PMG to estimate both the long and short-run coefficients as robustness. The research apply PMG as it uses ARDL

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model, or autoregressive distributive lag, to generate accurate and reliable estimates for a long-run relationship. In the PMG, the coefficients are averaged and pooled (Pesaran et al., 1999). The study further uses second-generation Granger causality as an additional robustness test (Dumitrescu & Hurlin, 2012). Although the MMQR and PMG estimator results provide detailed and consistent estimates, they do not determine the causal links between the variables, which is vital for policy recommendations.

The results in Table 2 indicate descriptive statistics of the variables under study. The results show that while some correlation exists among the variables, none of the correlation coefficients exceed the 80% threshold, indicating no significant concerns about multicollinearity. The results further indicate that environmental tax has a mean of 0.999%. The methane emissions and female economic inclusions have, on average, 9.250 and 11.180, respectively. The means of import, export, and gross domestic products are 36.342, 30.805, and 4.873, respectively. Additionally, the significant value of the Shapiro-Wilk, normality test suggests that the data is non-normally distributed. This informs our selection of MMQR, which takes care of such data.

The findings in Table 2 reject the null hypothesis that data is normally distributed as the p-values are significant. The study further considers the cross-sectional dependence of the variables. The result shows that interdependence exists among the variables of developing economies due to economic integrations, as the p-values are significant except for environmental taxation. The study checks the stationarity of the variables due to the cross-sectional dependence. Except for cross domestic product, which is stationary at a level, all the variables become stationary at the first difference when the study applies CIPS. Regarding the CADF stationarity test, all the variables are stationary at levels except cross-domestic product, urbanization, and population. Thus, the variables have mixed integration order. The study analyses co-integration of the variables using Westerlund, (2007). The result is statistically significant, which shows that the variables are cointegrated.

Model specification

Based on prior studies Naqvi, (2020), He et al., (2021) our baseline equation of whether environment-related tax impacts methane emissions and female economic inclusion are as follows:

$$Ln\ \text{Methane emissions} = \beta 0 + \beta_1 Environmental\ Tax_{it} + \beta_2 Import_{it} + \beta_3 Export_{it} + \beta_4 Economic\ growth_{it} + \nu_{it}$$

equation 1

$$\text{Ln Female economic inclusion} = \lambda_0 + \lambda Environmental\ Tax_{it} + \lambda_2 Import_{it} + \lambda_3 Export_{it} + \lambda Economic\ growth_{it} + \omega_{it}$$

equation 2

To examine the conditional distribution of methane and female economic inclusion which the traditional regression methods are not able to provide, the research employs the recently developed and estimation technique of Method of Moments Quantile Regression (MMQR) (Machado & Santos Silva, 2019). The MMQR provides explanations for tail dynamics of the effects of environmental tax on methane emissions and female economic inclusion with the African sample.

MMQR ensures accurate and reliable estimates when the dataset is non-parametric, specifically when there are outliers, data is not normal, and there is no correlation. In addition, MMQR calculates the distribution across different quantile values. It permits individual fixed effects throughout the quantiles to allow the predictors to include the functions of the location and scale (Alhassan et al., 2020). The research uses MMQR with fixed effects model (Amegavi, 2022; Ike et al., 2020; Wolde-Rufael & Mulat-Weldemeskel, 2022). The addition of fixed effects makes MMQR take care of distributional heterogeneity across various quantile distributions of the dependent variable (Ike et al., 2020; Machado & Silva, 2019). The study specifies the conditional $Q_{yit(\wp|x_{it})}$ quantile as follows:

$$Y_{it} = \alpha_i + x'_{it}\beta + (\theta_i + V'_{it}\Omega)s_{it}$$

eq. 3

Where Y_{it} represents the dependent variable, X_{it} is independently $(\alpha_i, \beta, \theta, \Omega)$ are the parameters to be estimated. Following prior study (Amengavi, 2022), the study further specifies Equation (2) as follows:

$$Q_{y(\mu|x_{it})} = \left(\alpha_i + \Omega_i q(\mu)\right) + x'_{it}\beta + V'_{it}\theta q(\mu)$$

eq 4

The quantile distribution of the outcome variable is $Q_{y(\mu|x_{it})}$. $\alpha_i(\mu) = \alpha_i + q(\mu)$ shows the coefficient of scalar and μ^{th} is the sample quantile. V represents a *k*- k-vector.

To capture all the variables, the following MMQR model is used:

$$Q\ methane\ emission_{it}(\mu_k|a_i, x_{it}) = \alpha_{it} + \beta_{1\mu} environmental\ tax_{it} + \beta_{2\mu} gross\ domestic\ product_{it} + \beta_{3\mu} export_{it} + \beta_{4\mu} import + \beta_{5\mu} gross\ domestic\ product_{it}$$

eq. 5

$$Q\ female\ economic\ inclusion_{it}(\mu_k|a_i, x_{it}) = \alpha_{it} + \wp_{1\mu} environmental\ tax_{it} + \wp_{2\mu} gross\ domestic\ product_{it} + \wp_{3\mu} export_{it} + \wp_{4\mu} import + \wp_{5\mu} gross\ domestic\ product_{it}$$

eq. 6

Results and discussions

The study uses Pesaran, (2004) to address the issue of cross-sectional dependence (CD), which is the most commonly issue in panel data and may be due to unobserved shocks that may bias the results. The results in Table 3 rejects the null hypothesis for cross-section independence. The result shows that interdependence exists among the variables of developing economies due to economic integrations, as the p-values are significant except for environmental taxation. The study checks the stationarity of the variables due to the cross-sectional dependence. Table 4 shows that except for gross domestic product and import, which are stationary at level, all

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the variables become stationary at the first difference when the study applies CIPS and ADF stationarity tests. Thus, the variables have mixed integration order. This confirms the need to determine the long run relationship.

This paper uses Westerlund, (2007) panel cointegration due to the cross-sectional dependence among the variables. The test result in Table 5 shows that there is cointegration and therefore the variables have long run relationship.

INSERT TABLE 1 HERE

INSERT TABLE 2 HERE

INSERT TABLE 3 HERE

INSERT TABLE 4 HERE

INSERT TABLE 5 HERE

Method of moment quantile regression results

This section contains the findings of the method of moment quantile regression (MMQR). The results for the robustness tests comprise the Pooled Mean Group (PMG) for both long and short runs, and finally, the result of the Granger causality estimates for the two models.

Tables 6 and 7 indicate the findings of the quantile regression estimation. The results show the conditional methane distribution for the 10th to 90th quantiles. The 10th, 20th, 30th, and 40th quantiles are countries with fairly low methane emissions (such as, Uganda, Rwanda, Mauritius, and Kenya) and low female economic inclusion (example, Botsuwana, senegal, Rwanda, Uganda, Democratic Republic of Congo). The higher quantiles (60th, 70th, 80th, and 90^{th}) show economies with relatively high methane emissions (For example Nigeria, South Africa, Egypt, Tunisia, and Ghana) and high employed females (see Tunisia, Muritius, Ghana, Burkina Faso).

Table 6 indicates the heterogeneous results of environmental-related tax on methane (CH4) emissions among the 23 African nations. Although across all quantiles the impact is negative, there are some significant differences across different quantiles in the conditional distribution of methane emissions. In *H1*, the study projects that environmental tax should be negatively related to methane emissions. This is confirmed. The coefficient of environmental tax is highly significant at various quantiles except for the tenth (10th) quantile. The level of significance and the impact of the coefficients of environmental tax on the conditional distribution of methane increase from the twentieth (20th) to the ninetieth (90th) quantiles. Specifically, the impact increases from 0.089 to 0.098 at 10 percent level of significance to 0.106, 0.117, 0.125, 0.137, 0.148, and 0.159 at 1 percent level of significance. The result indicates that the effect of an increase in environmental tax in decreasing methane is strongest among the most emission economies. By implication, high tax levies among African countries with high emission levels could potentially attenuate methane emissions levels in those countries. Furthermore, the findings regarding the negative effect of taxes on environment on could be attributed to the conscious efforts African government made at COP 27 in Sharm el-Sheikh, Egypt to mobilize more funds from the developed world to improve climate conditions and the need to lower greenhouse gas emissions by 45% by the end of 2030 (United Nations General Assembly on Africa 2023).

INSERT TABLE 6 HERE

INSERT TABLE 7 HERE

This shows the effectiveness of environmental taxes in improving quality of the environment. This corroborates the studies of Alola & Nwulu, (2022) who observe that energy tax reduces emissions among Nordic nations. The lack of using methane as a measure of emission instead of an index of greenhouse gas emissions justifies the need for further empirical studies. This is also consistent with recent work by Soku et al., (2023), which shows that environmental tax negatively affects emissions. Their study is limited to the fact that GMM approach ignores the whole conditional distribution of the outcome variable, which this study considers.

Off the control variable, the result in Table 5 shows that the importation of goods and services declines methane emissions in our panel data. Specifically, a 1% increase in import lessens emissions across all the quantiles, ranging from 0.049 to 0.061 units. This can be because foreign companies have enough incentives from their governments to use recycled materials during production. On the other hand, export upsurges methane emissions in African economies throughout the conditional distribution of the panel. Firms in these countries fail to use renewable energies such as solar energy and proper waste management processes at the time of production. The study finds no link between these countries' economic growth and methane emissions, as the impact is not statistically significant. Figure 1 confirms the above results, representing the graphical presentation of variables under study.

INSERT FIGURE 1 HERE

INSERT FIGURE 2 HERE

The findings in Table 7 shows a heterogeneous effect of environmental-related tax on female economic inclusion. This is because, on one hand the effect of environmental tax on females is significantly positive from the 10th to 60th quantiles. A percentage increase in environmental tax surges female employment ranging from 1.184 to 0.590. This could be because revenues generated from these taxes could be redistributed to social programs that empower more women into economic emancipation. However, from the 70th and 80th quantiles, the result shows positive but insignificant effect. On the other hand, the impact turns to negative at the

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90th quantile even though insignificant. This means that environmental tax surges female economic inclusion in countries with the lowest to the medium levels of female economic inclusion. Additionally, in countries with high levels of female inclusion, the impact increases but not significant. Meanwhile, in countries with the highest levels of female economic inclusion, environmental tax lowers the inclusion of female even though not significant.

Moreover, the trend of the relationship shows a decreasing effect (1.184 - 0.590) of environmental tax on female economic inclusion in African countries within the period 1994 to 2020 as seen in Figure 2. This means that in African environmental tax policy is a strategic tool for improving female economic inclusion, especially for those countries with low to medium female economic inclusion. African countries where female economic inclusion ranges from high to the highest level, the implementation of the tax should not be radical, otherwise it becomes counter-productive. The positive impact of these taxes on female employment may be due to conscious efforts made by these countries to increase the low participation of women in the formal sector (Asongu et al., 2021).

In general, the results support the double dividend hypothesis. This result is similar to Yang et al., (2020) who observe that carbon emission trading policy surges the scale of employment and lowers emissions among China. However, this contradicts the findings of Degirmenci & Aydin, (2021) who could not validate the double dividend hypothesis among five nations in Africa.

Regarding the control variable, the result in Table 7 shows that imports decline female economic inclusion in quantiles 10th to 30th our panel data, as it shows a significant negative relationship. In the 40th to 70th quantiles, the results turn insignificant. It then become significantly positive at the 80th and 90th quantiles. Contrary, environmental tax upsurges export throughout the conditional distribution of the panel. Indicating that African countries avoid the use of energy-intensive products and use alternative sources of energy to produce goods meant for export. The results show that environmental taxes negatively influence gross domestic product across all the quantiles. The above results support the graphical trend in Figure 2.

Robustness check (Pooled Mean Group) (PMG) and panel causality tests

The research uses Pooled Mean Group (PMG-ARDL) estimation to validate the findings of MMQR. Table 8 provides outcome of the PMG which supports the results for MMQR. The findings indicate that environmental tax statistically and significantly lessons methane emissions and it also increases female economic inclusion significantly in the long run. In the short run, the results are insignificant.

The study tests the panel causality in order to verify the direction between environmental tax on methane emissions and female economic inclusion. Table 9 shows that there is a one - way causal association between environmental tax-methane emissions. However, the findings show that causality between environmental tax-female economic inclusion is bidirectional. Suggesting that any policy shocks in environmental tax will have an impact on methane emissions but not the other way round. In addition, any policy restricting for environmental tax will impact female economic inclusion and vice versa.

INSERT TABLE 8 HERE

INSERT TABLE 9 HERE

Conclusion and implication

What is the role environment-related tax on methane emissions and female economic inclusion? With the use of MMQR, PMG-ARDL, and granger causality estimation methods, this study finds answers to the above questions using twenty-three (23) African nations from the period 1994 to 2020. First, the study observe that environmental taxes attenuate methane emissions, but the effect is more significant among high-emissions economies. Second, taxes on environment upsurge female employment in nations that emit low to medium emissions only. The study therefore validate the double dividend hypothesis of female economic inclusion. The above heterogenous results indicate that the analysis could have misleading implications if they are not examined across the conditional distribution of methane and female economic inclusion.

In addition, the study finds a one-way causal association between environmental tax and methane emissions. However, the findings show that causality between environmental and female economic inclusion is bidirectional.

These findings are essential to policymakers for different reasons, among others: Landfills are leading sources of methane emissions. Environmental taxes can assist governments to increase investment in landfill gas recovery systems. Methane emissions can be found in livestock farming. These taxes can motivate the use of improved manure management practices and enhanced animal feed to reduce methane emissions. In terms of implication for consumers, environmental taxes can raise awareness about the sources and impacts of methane emissions, encouraging consumers to support businesses and products that are environmentally friendly. For instance, consumers should not patronize goods and services that use plastic bags. This will support the ban on plastic bags imposed by Kenyan government. Governments can reinvest in other environmental initiatives and also use the revenue to lower female unemployment in the former sectors. Due to the heterogeneous nature of the results, governments must consider the industry's emission levels before imposing the tax. Through the reduction in emissions and increase the number of females in employment, these developing nations will achieve SDG 13 for climate action, SDGs 1, 2, and 5 for no poverty, no hunger, and gender equality.

This study does not consider disaggregation of environmental tax. Further studies may consider examining the impact of

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other aspects of environmental taxes, such as energy tax and pollution tax, on other non-C2 emissions like Nitrogenous gas emissions.

Data Availability Statement: The data supporting this study will be made available upon request.

ENVIRONMENTAL TAX, METHANE EMISSIONS, AND FEMALE ECONOMIC INCLUSION

Table 1. Definition of variables

Variable	Description	Source
Methane emissions	Methane emissions are those from human activities like agriculture and industry	WDI
Female Economic inclusion	Female Employment in industry, female (% of female employment) (modelled ILO estimate)	WDI
Environmental tax	Total environmental tax as a % of GDP	OECD
Import	The value of products and services received from other countries in the world	WDI
Export	The value of goods and services offered to the rest of the world.	WDI
Economic growth	GDP (constant US dollars) stands for gross domestic product. The annual percentage growth rate of the GDP is calculated using market prices in constant local currency. The aggregate is calculated using constant 2015 prices stated in US dollars.	WDI

Table 2: Descriptive statistics

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) Environmental tax	1.000					
(2)Methane emissions	-0.052	1.000				
(3) Female economic inclusion	0.090	-0.195	1.000			
(4) impt1	0.131	-0.506	0.315	1.000		
(5) expt1	0.013	-0.318	0.362	0.770	1.000	
(6) gdpg1	-0.021	-0.102	-0.039	0.267	0.378	1.000
Mean	0.999	9.250	11.180	36.342	30.805	4.873

Table 3: Normality and Cross-sectional dependence test

Variable	Methane	Female economic employment	Environmental tax	Export	Import	Gross domestic product
Normality (Shapiro-Wilk)	4.663*** 0.000	9.701*** 0.000	10.839*** 0.000	10.353*** 0.000	8.904*** 0.000	13.069*** 0.000
Pasaran CD test	38.633***	14.639 ***	2.369*	6.888***	9.388***	13.401***
Prob value	0.000	0.000	0.018	0.000	0.000	0.000

Table 4: Panel unit root test

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Variable	Level	1st Difference	Level	1st Difference
	CIPS		ADF	
Methane	-1.527	-4.760***	1.068	-14.408***
Female economic inclusion	-1.488	-3.877***	1.183	-6.586 ***
Environmental tax	-1.996	-4.399 ***	-0.664	-5.907 ***
Import	-2.614***	-5.037 ***	--2.085 **	-10.343 ***
Export	-1.757	-4.557 ***	-1.885	-3.635 ***
Gross domestic product	-3.883***	-5.845***	-2.787***	-4.686 ***

***, **, * 1%, 5%, and 10% significance levels respectively

Table 5: Cointegration test

Westerlund	Model 1		Model 2	
	Statistics	P-value	Statistics	P-value
	7.733	0.000	5.407	0.000

Table 6: environmental tax and Methane emissions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
VARIABLES	location	scale	qtile__1	qtile__2	qtile__3	qtile__4	qtile__5	qtile__6	qtile__7	qtile__8	qtile__9
Environmental tax	-0.116***	-0.028	-0.066	-0.089**	-0.098**	-0.106***	-0.117***	-0.125***	-0.137***	-0.148***	-0.159***
	(0.036)	(0.021)	(0.055)	(0.044)	(0.040)	(0.038)	(0.036)	(0.036)	(0.038)	(0.041)	(0.045)
Import	-0.056***	-0.004	-0.049***	-0.052***	-0.053***	-0.054***	-0.056***	-0.057***	-0.059***	-0.060***	-0.061***
	(0.005)	(0.003)	(0.007)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
Export	0.017***	-0.001	0.019***	0.018***	0.018***	0.018***	0.017***	0.017***	0.017***	0.016***	0.016***
	(0.004)	(0.002)	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Gross Domestic Product	-0.005	0.005	-0.014	-0.010	-0.008	-0.007	-0.005	-0.003	-0.001	0.001	0.003
	(0.007)	(0.004)	(0.010)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
Constant	10.789***	0.930***	9.167***	9.905***	10.217***	10.466***	10.830***	11.084***	11.495***	11.842***	12.217***
	(0.123)	(0.072)	(0.199)	(0.157)	(0.136)	(0.135)	(0.133)	(0.131)	(0.140)	(0.143)	(0.156)
Observations	526	526	526	526	526	526	526	526	526	526	526

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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