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Women empowerment and environmental sustainability in Africa

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Abstract

This study examines the effect of women's socioeconomic empowerment on environmental sustainability in Africa over the 1996-2019 period. Results of the system Generalised method of Moments (GMM) estimator reveal that women's socioeconomic empowerment is environment enhancing. Moreover, the findings reveal that the environmental impact of women's socioeconomic empowerment is modulated through GDP per capita and Foreign Direct Investments (FDI), leading to respective net effects of 0.002055 and 0.003478. These positive net effects are offset beyond respective threshold values of 9.513889 and 9.611398. These thresholds of GDP and FDI are critical for complementary policies relating to the link between women empowerment and environmental sustainability. Consequently, for women empowerment to effectively contribute to environmental sustainability in Africa, various governments, either through individual or concerted efforts should endeavour to create enabling business environments capable of attracting substantial FDI necessary to propel sustainable growth. Moreover, the nexus is not linear and hence, governments should also be aware of critical levels of FDI and GDP per capita at which, complementary policies are needed for women's socioeconomic empowerment to maintain a positive influence on environmental sustainability.

Key words: Women empowerment, Environmental sustainability, Ecofeminism, Africa.

JEL Classification: B54, J16, O55, Q56

1. Introduction

The question whether female socioeconomic empowerment is environment enhancing has not been given considerable attention in scholarly literature. However, in the recent past, the quest for gender equality and the need for a clean and safe environment have aroused research interest among scholars in understanding the underlying relation between women empowerment and environmental conservation. Thus, women empowerment and environmental sustainability are among the major contemporary challenges faced by governments across the world. Women empowerment is generally concerned with the promotion of women's social, economic and political status in the society (Ghasemi *et al*., 2021; Mukhopadhyay *et al*., 2019; Sinha et al., 2019; Duflo, 2012). Specifically, women empowerment consists in building a conducive socio-political environment capable of ensuring the security of women, so that that they carry out their activities void of fear of vindictiveness, maltreatment, disquietude, discrimination, and the overall feeling of harassment attendant with being a woman in a male subjugated world (Ghasemi *et al*., 2021; Rani, 2017). The importance of women empowerment has been emphasised in the recent Sustainable Development Goals (SDG) defining the global development agenda for the 2015-2030 horizon (United Nations, 2015).

As outlined in SDG5, women empowerment encompasses the elimination of all forms of discrimination, violence and harmful practices against women; ensuring equal opportunities and the full and effective participation of women in the socioeconomic and political decision-making process; as well as undertaking reforms allowing women equal rights of access to land ownership, economic and financial resources (United Nations, 2015). The quest for women empowerment is further consolidated in SDG16 concerned with the promotion of peaceful and inclusive societies with reduced violence of all forms. These considerations make women empowerment an important component of socioeconomic development. However, besides the socioeconomic dimensions of development, the modern development agenda identifies environmental sustainability as paramount for the attainment of sustainable development.

Nevertheless, environmental concerns are multidimensional and constitute about 20percent of the SDGs as evidenced through SDG13 to SDG15. Specifically, world leaders in 2015 pledged to ensure environmental sustainability by incorporating climate change actions into national development strategies (SDG13); significantly abating all forms of marine pollution through sustainable use of oceans, sea and marine resources (SDG14); halting deforestation and boosting afforestation; halting biodiversity loss and fighting desertification (SDG15). Whence,

given that environmental sustainability is closely associated with socioeconomic sustenance, Morelli (2011) contends that environmental sustainability is concerned with the "provision of clean air, clean water, and clean and productive land" to ensure socioeconomic sustainability. Specifically, Morelli (2011) defines environmental sustainability as "a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity". Thus, Sturgeon (2009) contends that the highly desired environmental sustenance is attainable through abatements in greenhouse gas (GHG) emissions. Hence, modern economies can mitigate GHG emissions by substantially reducing the use of non-renewable energy and the adoption of environment-friendly policies.

However, several studies have argued that environmental problems greatly depend on existing social systems. For instance, Gaard (1993) believes that feminist concerns can be addressed in the perspective of environmental problems. In this context, Ghasemi *et al*. (2021) opine that the socioeconomic empowerment of women is likely to have enormous effects on environmental sustainability due to the key role played by women in shaping social systems. Although the correlation between women and nature had long been established since the early 1970s following the advent of ecofeminism (Allison, 2017), research pertaining to the socioeconomic contribution of women towards environmental sustainability has remained barren (Mahour, 2016). Moreover, no consensus has been found among the few existing studies. Besides, extant studies have been largely concerned with the contribution of women's political empowerment to economic development in the confines of European and Asian countries.

It is against this backdrop that the present study seeks to analyse the effect of women's socioeconomic empowerment on environmental sustainability in the context of African countries. Consequently, the contribution of this study is threefold. Firstly, the study attempts to enhance extant scholarly literature on ecofeminism in Africa. Hence, while extant studies often focus on the environmental effects of women political empowerment, this study provides empirical evidence of the connection between the women's social and economic empowerment on environmental preservation. Secondly, besides exploring the direct linkages between women's economic empowerment and environmental sustainability, the current study explores some indirect channels through which women's socioeconomic empowerment can influence

environmental sustenance. Thirdly, unlike extant studies that employ classical measures of women economic empowerment, this study employs the composite indicator, known as the "Women, Business and the Law Index". This index, developed by the World Bank is aimed at informing policymakers on strategies capable of abating legal restrictions on women, as well as promoting research on the enhancement of women's economic inclusion.

Employing the system Generalised Method of Moments estimation technique, this study empirically examines the effect of women's socioeconomic empowerment on environmental sustainability for a panel of 50 African countries over the period 1996 – 2019. Specifically, the panel analysis reveals that women's socioeconomic empowerment contributes to environmental sustainability. Moreover, the findings reveal that the environmental impact of women empowerment is modulated through GDP per capita and Foreign Direct Investments (FDI), leading to positive net effects which are offset beyond respective threshold values of 9.513889 and 9.611398. The net effects and thresholds computed in this study are indeed relevant to policymakers as they provide them with critical levels of the modulating variables that when reached, women empowerment and corresponding modulating variables become necessary but not sufficient conditions for environmental preservation. Beyond the established thresholds, complementary policies are thus worthwhile to promote environmental sustainability.

Having provided a brief introduction, the rest of the paper is organised as follows. A synopsis of salient theoretical and empirical literature is contained in section 2. Section 3 presents the methodological strategy. The empirical results and robustness checks are discussed in section 4. Section 5 presents the concluding remarks and policy implications.

2. Synopsis of salient theoretical and empirical literature

The theoretical basis of the link between women empowerment and the environment can be traced to ecofeminist theories that emerged in the 1970s. Although a distinction is made between four principal feminist theories (liberal feminism, traditional Marxist feminism, radical feminism and socialist feminism), it is important to highlight the interconnectedness between these theories and the environment. Thus, according to Sturgeon (2009), ecological feminism (ecofeminism) refers to any theory and political practice that associate feminism (women empowerment) to environmentalism (environmental conservation). However, Rao (2012) considers ecofeminism as a "value system, a social movement, and a practice", capable

of providing a political analysis that highlights the connection between androcentrism and environmental degradation. Hence, ecofeminism is construed on the hypothesis that a significant relationship exist between the subjugation of women and the environment, thereby necessitating the inclusion of an ecological dimension in every feminist theory (Warren, 1987; Gaard, 1993). It is thus believed that any meaningful development strategy ought to prioritise women empowerment and environmental conservancy.

It is widely acclaimed in extant literature that women constitute an essential component of sustainable development. For instance, Niaghi (2019) concludes that the quest for environmental sustainability may remain farfetched if women's economic and managerial capacities, as well as their social participation are not improved. Moreover, a number of studies argue that environmental problems greatly depend on existing social systems that have a bearing on women's socioeconomic involvement. Consequently, Ghasemi *et al*. (2021) contend that women empowerment has a significant positive impact on environmental sustainability. This view corroborates the findings of Rao (2012) who argues that women significantly contribute to environmental protection and regeneration. Conversely, Karamidehkordi (2012) contends that women's livelihoods depend greatly on natural resources, thereby making women vulnerable to environmental degradation. Consequently, women's socioeconomic empowerment should be prioritised by policymakers in order to enhance environmental sustainability.

While several studies have explored the nexuses between women empowerment and economic development, the relation between women empowerment and environmental sustainability remains greatly unexplored. However, the link between women and the environment saw the limelight around the early 1970s thanks to birth of ecofeminism advocating the need to empower women on environmental issues (Rao, 2012). A number of recent studies have been concerned with women's political empowerment and industrialisation (Nchofoung *et al.*, 2021a) and vulnerability to climate change (Ergas and York, 2012; Asongu *et al.*, 2021). With regard to female economic empowerment, emphasis has been on its nexus with globalisation (Tselioni*et al.*, 2011; Asongu *et al.*, 2020a), inequality, financial access and government revenue (Asongu *et al.*, 2020b, 2021a). Thus, very few studies have ventured into the nexus between women's economic empowerment and environmental sustainability. Nevertheless, Ergas and York (2012) argue that highly politically empowered women contribute to environmental sustainability through abatements in CO2 emissions.

Likewise, Asongu *et al*. (2021b) assert that vulnerability to climate change can be mitigated through women's political empowerment. These authors further state that governance effectiveness, education, and public expenditures on education are the main channels through which women's political empowerment affects climate change. Moreover, although Ahmed *et al*. (2021) do not dissociate female from male labour force participation, they conclude that education (human capital) is environment degrading. Furthermore, in a study on the economic empowerment of rural women in Nigeria, Achudume (2009) found that routine domestic tasks carried out by predominantly less educated women (assembling fuel woods and biomass for cooking) have a negative effect on their contribution to environmental preservation and development.

Besides the few extant studies that establish a direct link between women empowerment and environmental sustenance, a number of scholars have delved into the indirect linkages. For instance, several studies have shown that women economic empowerment can be achieved through entrepreneurial activities (Alkhaled and Berglund, 2018). Proponents of this ideology argue that entrepreneurship is likely to render women entrepreneurs autonomous, thereby liberating them from male domination in economic life. Entrepreneurship helps in the liberation of women from labour market discrimination (Datta and Gailey, 2012; Sadi and Al-Ghazali, 2012). Moreover, self-employment through entrepreneurship leads to poverty mitigation (Scott *et al*., 2012). However, situational constraints encountered by women entrepreneurs may actually result to limited or bounded empowerment (Gill and Ganesh, 2007). Nevertheless, contrary to the believe that entrepreneurship brings about women empowerment, a number of scholars posit that entrepreneurial activities undertaken by women are responsible for the eventual subjugation of women in the society (Jennings *et al*., 2016; Verduijn *et al*., 2014).

These controversies regarding the contribution of women entrepreneurs to women empowerment are believed to result from institutional frameworks which regulate the business world (Azmat and Fujimoto, 2016; Xheneti, 2017). Therefore, government trade policy may play a great role in empowering women economically. Equally, an enabling business environment can act as an incentive to foreign investors thereby attracting Foreign Direct Investments (FDI) which have proven to be growth enhancing in sub-Saharan Africa (Miamo and Achuo, 2022). Moreover, enhanced growth is likely going to improve the livelihoods of the population, although with some attendant environmental concerns. Therefore, a proper

understanding of the effects of women empowerment on environmental sustainability requires an analysis of the indirect role played by FDI and economic growth.

Apparently, the preceding literature has been devoted to the entrepreneurial component of women's economic empowerment. Therefore the sparse literature on the nexus between women's socioeconomic empowerment and environmental sustainability necessitates a critical investigation. Moreover, it is important to explore other channels through which the socioeconomic empowerment of women can impact the environment.

3. Econometric strategy

3.1. Model specification

Cognisant of the extant theoretical and empirical literature, and in order to capture the underlying effects of women's socioeconomic empowerment on environmental sustainability in Africa, the following econometric model is specified:

$$\mathrm{ENS}_{it} = \lambda_0 + \lambda_1 \mathrm{WEM}_{it} + \lambda_2 \mathrm{X}_{it} + \varepsilon_{it} \qquad (1)$$

Where ENS denotes environmental sustainability; subscripts i and t associated with environment represent individual and time dimensions of the panel; λ_0 is the intercept; $\lambda_1$and λ_2 are slope coefficients; WEM denotes women's socioeconomic empowerment, X is a vector of control variables; and ε is the random error term.

The dependent variable is environmental sustainability, proxied by "Total greenhouse gas (GHG) emissions", which are composed of carbon dioxide (CO2) emissions and various human-induced (anthropogenic) GHGs, notably: methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and Sulphur hexafluoride (SF6). The use of GHGs emissions in this study is due to the fact that most women in Africa are subjected to traditional routine tasks (water, fuelwoods and biomass collectors for cooking; subsistence food producers) and these activities result in the release of anthropogenic GHGs which together with CO2 emissions negatively impact the environment (Achudume, 2009; Ergas and York, 2012). However, given that most environmental studies employ CO2 as a proxy for environmental quality (Nchofoung et al., 2021b), CO2 emissions is later introduced as an alternative dependent variable in order to check the robustness of the total GHGs emissions employed in this study as a proxy for environmental sustainability.

The main explanatory variable in this study is women socioeconomic empowerment, proxied by the "Women Business and Law Index" (henceforth denoted WBLI). This index examines laws and regulations affecting women's prospects as entrepreneurs and employees (World Bank, 2020). The WBLI is aimed at informing policymakers on strategies likely to abate legal restrictions on women, as well as promoting research on the enhancement of women's economic inclusion. This index is constructed on the basis of eight indicators[†], computed on a scale of 1-100, where the scores are calculated by taking the average of each indicator, with 100 indicating the highest possible score (World Bank, 2020). Intuitively, the broad scope covered by the various indicators of this index makes it more appealing as a proxy over classical socioeconomic indicators of women empowerment. Consequently, the WBLI is expected to be environment enhancing, implying that higher scores will reduce environmental degradation.

In order to control for omitted variables bias in our specified model, several control variables are used besides the independent variable of interest (WBLI). Other control variables used include: female labour force participation, GDP per capita, women in parliament, resources rents, Foreign Direct Investment, trade, population density, rule of law and female employment. The inclusion of these variables is consistent with extant literature (Asongu *et al*., 2021a; Nchofoung *et al*., 2021a).

However, it is believed that improved economic growth increases the wellbeing of a country's population, although this may equally be environment-unfriendly. Furthermore, increased net inflows of Foreign Direct Investment (FDI) may stimulate home production, leading to increased job opportunities, resulting to a reduction in the level of unemployment, poverty and income inequalities. In addition, increased job opportunities implies increased pay and thus increased household income which may be used to finance women's education, leading to their intellectual emancipation. Moreover, given that a long standing relationship has been established between economic growth (GDP), FDI and environmental quality (Dinga et al., 2021), it is intuitively believed that GDP and FDI are the principal channels through which women's socioeconomic empowerment affects environmental sustainability.

[†] According to the World Bank (2020), the eight indicators included in the construction of the Women, Business and the Law index are: (i) Mobility – which examines constraints on freedom of movement; (ii) Workplace – which analysis laws affecting women's decisions to work; (iii) Pay – which measures laws and regulations affecting women's pay; (iv) Marriage – that assesses legal constraints related to marriage; (v) Parenthood – which examines laws affecting women's work after having children; (vi) Entrepreneurship – concerned with analysing the constraints on women's starting and running businesses; (vii) Assets – which takes into consideration gender differences in property and inheritance; (viii) Pension – which assesses laws affecting the magnitude of a woman's pension.

Consequently, consistent with Nchofoung et al. (2021b), in order to account for the transmission channels we introduce a multiplicative interaction term of economic growth (GDP) and Foreign Direct Investment (FDI) into equation (1) as follows:

$$\begin{aligned} \mathrm{ENS}_{it} = \lambda_0 + \lambda_1 WEM_{it} + \lambda_2 GDP_{it} + \lambda_3 FDI_{it} + \lambda_j X_{it} + \beta_1 (GDP_{it} \times WEM_{it}) \\ + \beta_2 (FDI_{it} \times WEM_{it}) + \varepsilon_{it} \end{aligned} \quad (2)$$

Where $\lambda_1, \lambda_2, \ldots, \lambda_j$ are parameter coefficients of the variables that capture the direct effects of the determinants of environmental sustainability. Conversely, β_1 *and* β_2 are coefficients of variables that capture the indirect effects of the modulating factors (GDP and FDI) through which women empowerment (WEM) affect environmental sustainability? Hence, when we differentiate equation (2) with respect to WEM, the following equation is obtained.

$$\frac{\partial \mathrm{ENS}_{\mathrm{it}}}{\partial \mathrm{WEM}_{\mathrm{it}}} = \lambda_1 + \beta_1 \mathrm{GDP}_{\mathrm{it}} + \beta_2 \mathrm{FDI}_{\mathrm{it}} \quad (3)$$

Where ∂ denotes the partial derivative operator. However, a unit change in environmental sustainability is contingent on the sign and size of the interactive variables (GDP and FDI). The interactive effect may result to a net effect, depending on the sign and significance of λ_1 and β_i (where i=1 or 2, for GDP or FDI respectively). Explicitly, a net effect only occurs when λ_1 and β_i are both significant but have opposite signs. Conversely, there is no net effect in a situation where both λ_1 and β_i have the same sign or at least one of them is insignificant. Therefore, the alternation in sign between λ_1 and β_i is a rule of thumb for the existence of net effects. From what precedes, we calculate the net effects of the aforementioned modulating variables as follows:

$$\text{Net effect} = \begin{cases} \lambda_1 + (\gamma \times \beta_i) & \text{if } \lambda_1 \text{ and } \beta_i \text{ have opposite signs but both significant} \\ \text{N.A} & \text{if } \lambda_1 \text{ and } \beta_i \text{ have the same sign} \\ & \text{or atleast } \lambda_1 \text{ or } \beta_i \text{ is insignificant} \end{cases} \quad (4)$$

Where β_i is the size of the indirect effect; γ is the mean value of the policy modulating variable; and N.A implies "not applicable" and as such, the net effect cannot be calculated.

Once the existence of net effects is established, it is necessary to determine the threshold beyond which the effects of the explanatory variable will be truly impactful on the dependent variable. The thresholds in this case are obtained by taking the absolute value of the ratio of the direct effect to the indirect effect as follows:

$$\text{Threshold} = \left|\frac{\text{unconditional impact}}{\text{Conditional impact}}\right| = \left|\frac{\lambda_1}{\beta_i}\right| \qquad (5)$$

The determination of this threshold is important as it informs policymakers on the actions to be taken when the critical values are attained by the modulating variables.

3.2. Data

This study employs data sourced from the World Development Indicators of the World Bank (World Bank, 2021) and the World Governance Indicators (WGI, 2021) for a panel of 50 African countries[‡] over the 1996 – 2019 period. The choice of the study period and countries included in the sample is constrained by the availability of data for the various variables of interest. Moreover, the choice of the retained variables is consistent with theoretical underpinnings and extant literature relating to ecofeminist studies. A comprehensive description and definition of the variables is provided in appendix A1. While all variables are used as defined in appendix A1, the natural logarithms of GDP per capita and GHG emissions are employed. Likewise, a summary of descriptive statistics and correlation analysis of the variables are presented in Table 1 and appendix A2 respectively.

[‡]Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Cameroon, Central African Republic, Chad, Comoros, Congo (Democratic Republic), Congo (Republic), Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Environmental Sustainability	1150	9.811	1.517	5.704	13.171
Women Business & Law Index	1200	59.533	14.602	23.75	91.875
Female labour force participation	1200	56.964	18.349	11.8	87.68
Female employment	1200	52.136	19.548	8.36	86.02
Women in parliament	1070	16.054	11.214	0	63.75
Natural resources rents	1182	11.709	11.948	.001	67.918
Foreign Direct Investment	979	.6	5.463	-32.233	89.233
Trade openness	1139	72.342	39.651	16.141	347.997
Population density	1233	83.107	113.323	2.02	623.503
Rule of law	1200	-.68	.626	-2.13	1.077
CO2 emissions	1150	1.094	1.892	.016	11.676
Female self-employed	1200	73.936	24.501	11.82	99.38
Female wage & salaried workers	1200	26.065	24.501	.62	88.18
GDP per capita (log)	1176	8.087	.944	6.227	10.627

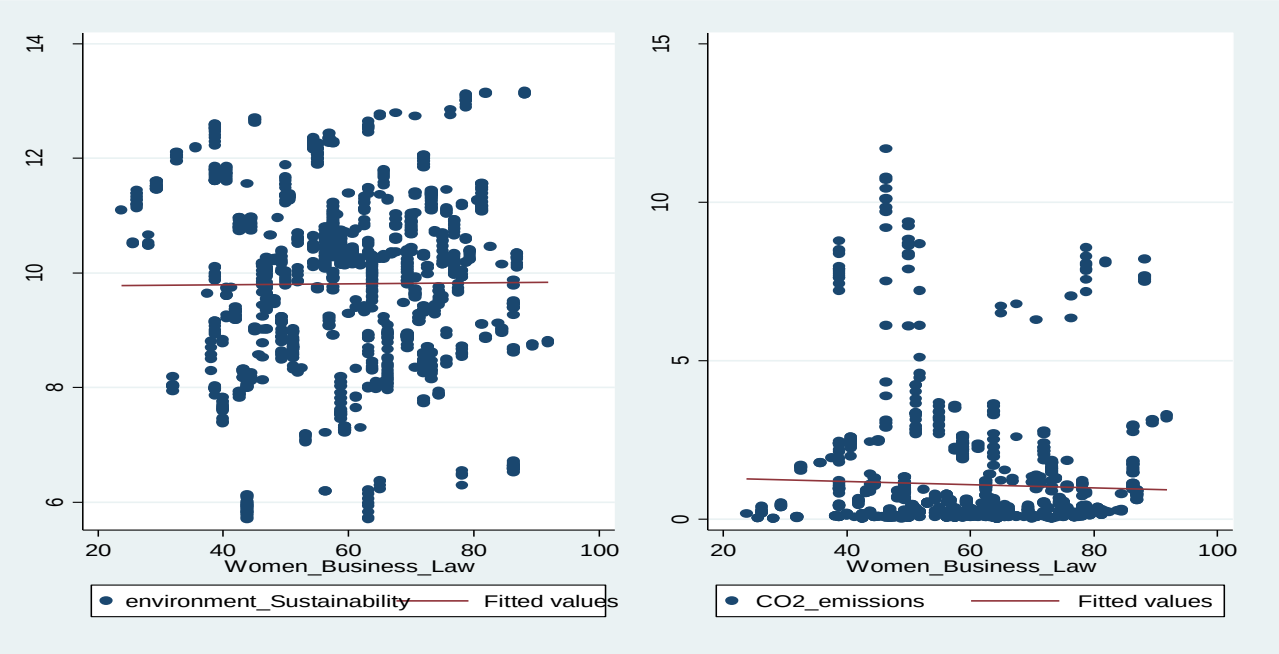
Notes: Obs=observations; Std. Dev=standard deviation; Min=minimum; Max=maximum; CO2=Carbon dioxide; GDI=Gross Domestic Product

The mean and standard deviation values in Table 1 reveal that there is overall moderate variability of the modelled variables. For instance, the respective mean and standard deviation values of the dependent variable, environmental sustainability (captured through GHG emissions) are 9.811 and 1.517. However, there seem to be relatively great variability exhibited by most of the indicators of women economic empowerment. For example, the main explanatory variable, women empowerment (captured by the Women Business and Law Index) has respective mean and standard deviation values of 59.533 and 14.602. This trend is consistent with other women's economic empowerment indicators like female labour force participation and female employment. The least variability is observed with CO2 emissions, Foreign Direct Investment and the rule of law.

However, looking at the correlation between environmental sustainability and women empowerment, a negative relation is perceived, as revealed by Figure 1. This perceived nexus is consistent irrespective of the proxy (total GHG emissions or CO2 emissions) used in measuring environmental sustainability. This implies that a highly empowered female

population is an asset to an economy as this will reduce GHG emissions thereby enhancing environmental quality.

Figure 1: Relationship between women's socioeconomic empowerment and environmental sustainability



Source: Authors

3.3. Estimation technique

The empirical examination of the relationship between the socioeconomic empowerment of women and environmental sustainability is established with the help of the Generalised method of Moments (GMM) estimator. This is consistent with extant studies providing justifications for the adoption of this approach (Asongu & Odhiambo, 2019; Tchamyou, 2020). Firstly, the number of cross sections exceeds the number of time periods. Specifically, this study is based on 50 African countries (N=50) over the period 1996-2019 (T=24). Moreover, the GMM estimator is consistent when there is a high degree of correlation between the present and lagged values of the dependent variable. Thus, the high correlation coefficient (see appendix A2) between environmental sustainability and its lagged value (0.999) makes the adoption of this technique appropriate. Furthermore, by employing internal instruments and accounting for time invariant omitted variables, the GMM approach controls for double causality and unobserved heterogeneity, which are dimensions of endogeneity.

Thus, this study adopts the system GMM technique by Roodman (2009) which is a refinement of the earlier works of Holtz-Eakin *et al.* (1988) and Arellano and Bover (1995), due to its

ability to account for cross-sectional dependence and instrument proliferation (Jacob and Osang, 2020). Hence, the ability of the system GMM to combine a level equation and a difference equation ensures the robustness of the GMM estimator. Consequently, we specify the following standard system GMM procedure captured by equations (6) and (7) in levels and difference respectively.

$$ENS_{it} = \lambda_0 + \lambda_1 EN擫_{i(t-□)} + \lambda_2 WEM_{it} + \sum_{h=1}^{k} \gamma_h X_{h,i(t-□)} + \psi_t + \Omega_i + \varepsilon_{it} \quad (6)$$

$$ENS_{it} - ENS_{i(t-□)} = \lambda_1(ENS_{i(t-□)} - ENS_{i(t-2□)}) + \lambda_2(WEM_{it} - WEM_{i(t-□)}) +$$
$$\Sigma_{h=1}^{k} \gamma_h(X_{h,i(t-□)} - X_{h,i(t-2□)})\ (\psi_t - \psi_{t-□})\ + \varepsilon_{i(t-□)} \quad (7)$$

While most variables are defined as before, γ is the time invariant constant, $\boldsymbol{\Omega}$ represents the country fixed effects, ∪ is the degree of auto-regression. This parameter (∪) can assume the value one (1) because the past information of the modelled variables can be captured by such a one period lag. Consequently, the above specified system GMM equations can conveniently be written as:

$$ENS_{it} = \lambda_0 + \lambda_1 ENS_{i(t-1)} + \lambda_2 WE\langle_{it} + \sum_{h=1}^{k} \gamma_h X_{h,i(t-1)} + \psi_t + \Omega_i + \varepsilon_{it} \quad (8)$$

$$ENS_{it} - ENS_{i(t-1)} = \lambda_1(ENS_{i(t-1)} - ENS_{i(t-2)}) + \lambda_2(WEM_{it} - WEM_{i(t-1)}) +$$
$$\Sigma_{h=1}^{k} \gamma_h(X_{h,i(t-1)} - X_{h,i(t-2)})\ (\psi_t - \psi_{t-1})\ + \varepsilon_{i(t-1)} \quad (9)$$

However, extant literature on GMM estimation (Nchofoung et al., 2021c; Tchamyou, 2021) holds that all explanatory variables are suspected of endogeneity resulting from the identification, simultaneity and restriction problems. In this light, we employ period dummies to ensure strict exogeneity of our instruments.

4. Discussion of empirical findings

The findings of this study will be presented in two sections. Firstly, the unconditional effects of women's socioeconomic empowerment on environmental sustainability are presented. Then, the indirect effects through various modulating variables are discussed.

4.1. Unconditional effects

In presenting the direct environmental impacts of women empowerment in Africa, we commence with baseline results and then verify the robustness of the findings by employing various proxies of women's socioeconomic empowerment as evident in extant literature.

Table 2 presents the baseline results for both the Ordinary Least Squares (OLS) and system Generalised Method of Moments (GMM) estimators. Results of the OLS estimator (column 2) indicate that women's socioeconomic empowerment (proxied by "Women Business and Law Index") leads to environmental degradation, as depicted by the significant positive coefficient of 0.0132 at the 1% level of significance. The OLS results further reveal, while GDP per capita and natural resources rents equally lead to environmental degradation, environmental sustainability is enhanced by other control variables like the rule of law, population density and trade openness. However, given the high correlation between the lagged dependent variable and the dependent variable, as well as other independent variables, it is necessary for this term to be included in the empirical model (Nchofoung et al., 2021b). This necessitates the adoption of a more robust estimation technique since the OLS estimators become biased in the presence of the lag dependent variable.

Consequently, we focus on the results of the system GMM estimator (column 3) based on its inherent advantages as earlier highlighted. The system GMM results reveal that environmental sustainability is greatly affected by its past values. The negative coefficient (-0.000159) of the "Women Business and Law Index" implies that women empowerment significantly enhances environmental sustainability. GDP per capita and Foreign Direct Investment (FDI) are equally seen to be environment enhancing. Nevertheless, the results further reveal that natural resources, population density and the rule of law are environment-unfriendly, as evidenced by their significant positive coefficients. This environment degrading nature of natural resources is consistent with recent findings by Miamo and Achuo (2022) in the context of sub-Saharan African countries. Moreover, although trade openness equally leads to environmental degradation, its effect is however insignificant.

Table 2: Baseline results of the environmental impacts of women empowerment

	(1)	(2)
	OLS	System GMM
Variables	Dependent variable: Environmental Sustainability	
Environmental Sustainability (-1)		0.999***
		(0.00124)
Women Business & Law Index	0.0132***	-0.000159*
	(0.00330)	(8.56e-05)
Natural resources rents	0.0132***	0.000428***
	(0.00439)	(0.000101)
GDP per capita (log)	0.480***	-0.00873***
	(0.0573)	(0.00148)
Rule of law	-0.293***	0.00939***
	(0.0873)	(0.00268)
Foreign Direct Investment (FDI)	0.00533	-0.000105**
	(0.00765)	(4.32e-05)
Population density	-0.00363***	2.03e-05**
	(0.000392)	(8.55e-06)
Trade openness	-0.0170***	3.45e-05
	(0.00135)	(2.66e-05)
Constant	6.409***	0.117***
	(0.545)	(0.0186)
Observations	849	711
R-squared	0.266	
Fisher	43.59***	142014***
Number of Countries		44
Instruments		33
AR(1)_ Prob		0.117
AR(2)_ Prob		0.548
Hansen_Prob		0.299

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Besides the baseline results employing the "Women Business and Law Index" as the main variable of interest, we employ other key measures of women's socioeconomic empowerment in order to check for the robustness of our findings. This study equally employs a classical measure of environmental quality (CO2 emissions) unlike the GHG emissions proxy used in our baseline model. The ensuing results are presented in Table 3.

The results in Table 3 reveal that the employment of other socio-politico-economic indicators of women empowerment remains consistent with our baseline results, indicating that women empowerment is environment enhancing. Specifically, models 1, 2 and 5 (respectively in columns 2, 3 and 6) reveal that respective economic indicators notably female employment, female wage and salaried workers and female labour force participation are all environment enhancing. It should be noted that the nature of female employment plays a great role in

environmental sustainability. This is because, of all the employment indicators employed, only female self-employment is environment degrading as evidenced by its positive coefficient in column 4.

Given that most ecofeminist studies have been concerned with women's political empowerment, we equally included a political indicator of women empowerment (contained in model 4 of the penultimate column in Table 3). The results indicate that women empowerment brings about environmental sustainability. These findings are consistent with the results of Asongu et al. (2021) who examine the effect of women political empowerment on climate change vulnerability in developing countries.

Equally, the last column in Table 3 shows the system GMM results of the CO2 model. Given that this study employs the GHG emissions as a proxy for environmental quality unlike other recent studies (Asongu et al., 2021; Dinga et al., 2021; Miamo and Achuo, 2022) that use CO2 emissions as a proxy for environmental quality, it was necessary for us to estimate another model to check for the robustness of our results. Consequently, the results from the CO2 emissions model remain consistent with our baseline results.

Table 3: System GMM estimations for alternative measures of women empowerment and environmental sustainability

	(1)	(2)	(3)	(4)	(5)	(6)
			Dependent Variable			
Variables			Environmental Sustainability			CO2 Emissions
Environmental Sustainability (-1)	1.001***	0.999***	0.999***	1.001***	1.000***	
	(0.00142)	(0.00118)	(0.00117)	(0.00153)	(0.00138)	
Female employment	-0.000179					
	(0.000134)					
Natural resources rents	0.00102***	0.000724***	0.000761***	0.000737*	0.000998***	0.00211***
	(0.000269)	(0.000212)	(0.000206)	(0.000414)	(0.000251)	(0.000295)
GDP per capita	-0.0163***	-0.0120***	-0.0128***	-0.0113***	-0.0169***	0.00891**
	(0.00297)	(0.00256)	(0.00253)	(0.00377)	(0.00270)	(0.00373)
Rule of law	0.0149***	0.0146***	0.0147***	0.0114*	0.0145***	0.0304***
	(0.00493)	(0.00432)	(0.00425)	(0.00619)	(0.00455)	(0.00712)
Foreign direct Investment (FDI)	-0.000400**	-0.000278***	-0.000308***	-0.000498	-0.000413**	0.000725***
	(0.000169)	(9.28e-05)	(9.51e-05)	(0.000644)	(0.000162)	(9.34e-05)
Population density	3.93e-05***	2.87e-05***	3.16e-05***	4.66e-05***	3.85e-05***	2.53e-05
	(1.11e-05)	(8.59e-06)	(8.62e-06)	(1.16e-05)	(1.06e-05)	(2.63e-05)
Trade openness	0.000124*	0.000159***	0.000158***	0.000116	0.000138*	-0.000235***
	(7.28e-05)	(4.09e-05)	(4.08e-05)	(7.17e-05)	(7.07e-05)	(5.35e-05)
Female wage & salaried workers		-0.000163**				
		(7.86e-05)				
Female self-employed			0.000149*			
			(7.97e-05)			
Women in parliament				-0.000308**		
				(0.000148)		
Female labour force participation					-0.000276**	
					(0.000130)	
CO2 emissions (-1)						0.994***
						(0.00115)
Women Business & Law Index						-0.000437**

						(0.000191)
Constant	0.149***	0.122***	0.114***	0.102***	0.161***	-0.0687*
	(0.0286)	(0.0240)	(0.0240)	(0.0305)	(0.0275)	(0.0382)
Observations	711	711	711	632	711	711
Number of Countries	44	44	44	44	44	44
Instruments	17	25	25	17	17	25
AR(1)_Prob>	0.118	0.118	0.118	0.143	0.118	0.243
AR(2)_Prob>	0.560	0.561	0.561	0.511	0.562	0.360
Hansen_ Prob>	0.800	0.261	0.307	0.139	0.833	0.242
Fisher	83683.12***	115736.19***	115786.32***	63297.70***	90342.74***	219425.52***

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2. Conditional effects

In accounting for the conditional effects of women empowerment on environmental quality, we explore the key transmission channels through which women empowerment impacts environmental sustenance. The ensuing findings are contained in Table 4.

Table 4: The modulating role of GDP and FDI on the nexus between women empowerment and environmental sustainability

Variables	(1) Dependent variable: Environmental sustainability	(2) Dependent variable: Environmental sustainability
Environment Sustainability (-1)	0.870***	0.724***
	(0.0228)	(0.0449)
Women Business & Law Index (**A**)	**0.0137*** **	**0.00371*** **
	(0.00329)	(0.000726)
Natural resources rents	0.000234	5.48e-05
	(0.00103)	(0.000269)
GDP per capita	0.115*	0.117***
	(0.0616)	(0.0251)
Rule law	0.000814	-0.0110
	(0.0201)	(0.0161)
Foreign Direct Investment (FDI)	-0.00260*	0.0241***
	(0.00137)	(0.00393)
Population density	0.000599***	0.00104***
	(0.000141)	(0.000252)
Trade openness	0.000435	0.000261
	(0.000286)	(0.000166)
GDP per capita × **A**	**-0.00144*** **	
	(0.000383)	
Foreign Direct Investment × **A**		**-0.000386*** **
		(6.18e-05)
Net effect of A	**0.002055**	**0.003478**
Thresholds of GDP per capita and FDI	**9.513889**	**9.611399**
Constant	0.162	1.470***
	(0.369)	(0.316)
Observations	815	815
Number of countries	44	44
AR(1)_Prob	0.110	0.109
AR(2)_Prob	0.674	0.595
Instruments	19	28
Hansen_Prob	0.165	0.476
Fisher	2614***	3113***

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; The respective net effects of the "Women Business & Law Index" (**A**) in columns 2 and 3 are computed thus: $0.002055 = [0.0137 + (8.087) \times (-0.00144)]$; and $0.003478 = [0.00371 + (0.6) \times (-0.000386)]$. Likewise, the respective thresholds in columns 2 and 3 are computed thus: $9.513889 = \left|\frac{0.0137}{-0.00144}\right|$; and $9.611399 = \left|\frac{0.00371}{-0.000386}\right|$. Details about net effect and threshold computations are provided in section 3.1.

Table 4 reveals two principal channels through which the environmental impact of women's socioeconomic empowerment can be felt. First and foremost, as revealed by the first model (column 2) regarding the interaction of GDP per capita and women empowerment (captured through "Women Business and Law Index"), we find that women empowerment is environment enhancing as revealed by the significant negative coefficient of -0.00144. Given the significance and alternation in signs between the direct and interactive effects, it is therefore imperative to calculate the net effect of women empowerment on environmental sustainability.

Accordingly, following the methodological procedure outlined supra for the determination of net effects which is consistent with current studies on interactive regressions (Achuo *et al*., 2021; Nchofoung *et al*., 2021b; Tchamyou *et al*., 2019), a positive net effect of 0.002055 is computed for GDP per capita. This result reveals that women empowerment can only be environment enhancing below certain threshold of GDP. Consequently, a threshold value of 9.513889 is obtained following the relevant computations. This threshold value implies that for women empowerment to be environment enhancing, GDP per capita must be below 9.513889. Beyond the established threshold, complementary policies are required to maintain the positive net effect on environmental sustainability. This result therefore implies that the Environmental Kuznets Curve (EKC) hypothesis is not applicable in the African context, since environmental quality is only improved below a certain level of GDP per capita growth (Grossman and Krueger, 1991).

Furthermore, a similar situation is observed when women empowerment is modulated through Foreign Direct Investment (FDI). That is, the net effect and threshold values are respectively 0.003478 and 9.611398, implying that women empowerment will lead to environmental sustainability when the value of net FDI inflows is below 9.611398. Beyond the established threshold, complementary policies are imperative to maintain the positive net effect on environmental sustainability. In this light, our findings therefore support the Pollution Haven Hypothesis (Yoon and Heshmati, 2021) for FDI values above the established threshold. Therefore, beyond this threshold, our findings are not consistent with recent literature invalidating the pollution Haven Hypothesis (Nadeem*et al*., 2020), in favour of the Pollution Halo hypothesis (Bulus and Koc, 2021) of a negative nexus between FDI and environmental degradation. Nevertheless, both the Pollution Haven and Pollution Halo hypotheses have been invalidated in favour of the neutrality hypothesis of no long-run relation between environmental pollution and FDI in a recent study for developing countries (Çelik *et al*., 2021).

Consistent with existing relevant literature (Brambor et al, 2006; Asongu and Odhiambo, 2021), the net effects and thresholds computed in this study are indeed relevant to policymakers as they provide them with critical levels of the modulating variables (notably GDP per capita and FDI) that when reached,women empowerment and corresponding modulating variables become necessary but not sufficient conditions for environmental preservation. Beyond the established thresholds, complementary policies are thus worthwhile to promote environmental sustainability

5. Concluding remarks and policy implications

This paper aimed at empirically analysing the effect of women's socioeconomic empowerment on environmental sustainability of 50 African countries from 1996 – 2019. To achieve this, we use the "Women Business and the Law Index" developed by the World Bank as a proxy for women's socioeconomic empowerment, besides other classical indicators. The empirical findings from the Generalised Method of Moments (GMM) estimator reveal that women empowerment contributes to environmental preservation in Africa. Moreover, the findings reveal that the environmental impact of women's socioeconomic empowerment is modulated through GDP per capita and Foreign Direct Investments (FDI), leading to respective positive net effects of 0.002055 and 0.003478. These positive net effects are offset beyond respective threshold values of 9.513889 and 9.611398. These thresholds of GDP and FDI are critical for complementary policies relating to the link between women empowerment and environmental sustainability.

Consequently, in order to ensure that women empowerment effectively contributes to environmental sustainability, various African governments, either through individual or concerted efforts should endeavour to create enabling business environments capable of attracting substantial FDI necessary for achieving sustainable growth across the continent. In other words, while governments in the African continent should concert efforts to exceed per capita GDP of 9.513889 (log) and foreign direct investments inflows of 9.611398 (%GDP), respectively for a sustainable environment, the attendant governments should also be aware of critical levels of FDI and GDP per capita at which, complementary policies are needed for women's socioeconomic empowerment to maintain a positive influence on environmental sustainability. These complementary policies can be feasibly engaged not least, because in the real world, FDI, GDP per capita and women's socioeconomic empowerment do not interact in isolation to influence environmental sustainability. Evidently, a plethora of macroeconomic

indicators interact in the real world to influence environmental sustainability. Moreover, the complementary policies should be informed by robust empirical evidence as opposed to blanket suggestions that are not underpinned on data behaviour.

Apparently, this article leaves room for future research particularly with regard to other potentially modulating variables through which women's socioeconomic empowerment can enhance environmental sustainability in Africa. In addition, in order to design individual country-specific policies regarding the nexus between women's socioeconomic empowerment and environmental preservation, it is necessary for future research to employ appropriate empirical methodologies for country-specific studies.

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Appendixes

Appendix A1: Definitions and sources of variables

Variable	Definition	Source
Environmental Sustainability	Total greenhouse gas emissions (kt of CO2 equivalent)	WDI
Women Business & Law Index	Women Business and the Law Index Score (scale 1-100)	WDI
Female labour force participation	Labor force participation rate, female (% of female population ages 15+) (modeled ILO estimate)	WDI
Female employment	Employment to population ratio, 15+, female (%) (modeled ILO estimate)	WDI
Women in parliament	Proportion of seats held by women in national parliaments (%)	WDI
Natural resources rents	Total natural resources rents (% of GDP)	WDI
Foreign Direct Investment	Foreign direct investment, net inflows (% of GDP)	WDI
Trade openness	Trade (% of GDP)	WDI
Population density	Population density (people per sq. km of land area)	WDI
Rule of law	Rule of Law: Estimate	WGI
CO2 emissions	CO2 emissions (metric tons per capita)	WDI
Female self-employed	Self-employed, female (% of female employment) (modeled ILO estimate)	WDI
Female wage & salaried workers	Wage and salaried workers, female (% of female employment) (modeled ILO estimate)	WDI
GDP per capita	GDP per capita, PPP (constant 2017 international $)	WDI

Notes: WDI = World Development Indicators; WGI = World Governance Indicators; CO2 = Carbon dioxide; GDI = Gross Domestic Product

Appendix A2: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Environmental sustainability	1.000														
(2) Environmental sustainability (-1)	0.999	1.000													
(3) Women Business & Law Index	-0.099	-0.099	1.000												
(4) Female labour force participation	-0.160	-0.160	0.318	1.000											
(5) Female employment	-0.138	-0.138	0.304	0.979	1.000										
(6) Women in parliament	0.048	0.048	0.372	0.198	0.175	1.000									
(7) Natural resources rents	0.147	0.147	-0.253	0.068	0.058	-0.029	1.000								
(8) Foreign Direct Investment	-0.059	-0.058	0.039	0.061	0.073	-0.008	0.092	1.000							
(9) Trade openness	-0.303	-0.302	0.039	0.013	-0.053	-0.010	0.221	0.211	1.000						
(10) Population density	-0.314	-0.313	0.319	0.046	0.080	0.166	-0.241	-0.033	0.039	1.000					
(11) Rule of law	-0.186	-0.185	0.321	-0.259	-0.308	0.105	-0.488	-0.078	0.105	0.279	1.000				
(12) CO2 emissions	0.296	0.294	0.004	-0.450	-0.520	0.054	0.279	-0.015	0.088	-0.026	0.226	1.000			
(13) Female self-employed	-0.027	-0.026	-0.014	0.609	0.684	-0.048	0.099	0.040	-0.128	-0.179	-0.536	-0.715	1.000		
(14) Female wage & salaried workers	0.027	0.026	0.014	-0.609	-0.684	0.048	-0.099	-0.040	0.128	0.179	0.536	0.715	-1.000	1.000	
(15) GDP per capita	0.043	0.040	-0.169	-0.499	-0.555	-0.147	0.103	-0.069	0.432	0.077	0.272	0.413	-0.542	0.542	1.000