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The nexus between labour force participation and environmental sustainability: Global comparative evidence

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ABSTRACT

The pursuit of environmental sustainability and decent employment are among the fundamental macroeconomic priorities of the 21st century. Extant studies reveal that labour market dynamics have a bearing on global greenhouse gas (GHG) emissions. Thus, this study empirically examines the effect of labour force participation on environmental sustainability from a global perspective. Employing the Driscoll-Kraay fixed effects (DKFE) and system Generalised Method of Moments (GMM) estimators for a panel of 173 countries from 1996 to 2020, we find that labour force participation (LFP) enhances environmental quality. When controlled for income differences, the study reveals that while LFP significantly reduces environmental pollution in Low-income and High-income countries, it is environment-degrading in Upper-middle-income countries. Furthermore, with regard to level of development and geographical region, rising LFP significantly reduces GHG emissions in developing countries, whereas the effect is insignificant in developed economies. Likewise, the effect of LFP is divergent across geographical regions. However, when LFP is disaggregated into the male and female components, the results show that male-LFP is environment degrading while female-LFP is environmental augmenting. Contingent on these findings, practical policy implications are discussed.

1. Introduction

While the importance of human capital in spurring sustainable development cannot be overemphasised [1], the question whether labour force participation deters or enhances environmental sustainability has not been given enough attention in contemporary literature. However, environmental quality has continued degrading over the years as a result of the persistent upsurges in global greenhouse gas (GHG) emissions. This rising GHG emissions results to climate change and other socioeconomic challenges with regard to labour market dynamics. Development agencies and policymakers have become increasingly concerned with the design of policies aimed at improving environmental quality and ensuring social equity through decent job creation. Hence, the pursuit of environmental sustainability and decent employment are among the fundamental macroeconomic priorities of the 21st century [2]. This is particularly visible through national and international debates and conferences focusing on environmental targets and labour market

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indicators contained in the Sustainable Development Goals (SDGs), guiding the 2015–2030 global development agenda [3,4].

Although recent decades have been characterised by great disparities between the male and female labour force participation rates, very few studies have endeavoured to explore the underlying determinants of such disparities. However, Horrell and Humphries [5] argue that these disparities are largely due to the continuous economic dependence of women on men especially in developing countries where women are subjected to domestic chores. Equally, the health [6,7] and educational status [8] constitute important determinants of labour force participation between males and females across the globe. Thus, Osundina [9] concludes that improved health conditions and higher educational attainment increases female labour force participation, which in turn greatly impacts on environmental sustainability. Thus, Wang et al. [10] affirm that while rising female labour force participation reduces CO2 emissions across all economic sectors in developing countries, the emissions reduction effect of growing female labour share is visible only in the service sector in the context of developed economies.

In recent years, despite the multiplicity of studies devoted to the investigation of the underlying determinants of environmental degradation, very little has been done with respect to the labour force-environmental quality nexus. For instance, while several studies have found economic growth as a principal source of environmental pollution [11–13], others reveal that urbanisation, energy consumption, population dynamics, information and communication technologies [2,14–18], institutional quality, industrialisation, globalisation, and foreign direct investments [19–21] equally contribute to the deterioration of environmental quality. Studies focusing on the growth-pollution nexus often make reference to the inverted U-shaped environmental Kuznets curve hypothesis, according to which environmental degradation initially worsens at the early stages of economic development and then improves beyond a certain development threshold [22].

However, a proper understanding of the environmental effects of economic growth cannot be feasible without exploring some key determinants of growth such as labour market dynamics. Thus, the sustainable development challenges faced by world economies today seem to have further compounded following a persistent slowdown in macroeconomic activities that have particularly affected the business, educational and health sectors [23]. These socioeconomic challenges are believed to have a great bearing on labour force participation and environmental sustainability. As established by extant literature, labour force participation depends to a greater extent on the quality of education and health outcomes.

For instance, from a gender-inclusive perspective, Osundina [9] contends that female labour force participation improves with higher educational attainment and better health conditions. Equally, female labour force participation has the potential to catalyze the attainment of several SDGs. Moreover, increased female labour force participation inevitably leads to abatements in gender inequality, with its inherent potential of catalysing sustainable development. While the existence of a U-shaped relationship is found between female labour force participation and economic development in the European Union [24], an inverted U-shaped relationship is revealed in Africa [25]. These opposing findings may be justified by different levels of educational attainment of the population and health care coverage across regions. These health and educational outcomes however have a bearing on the environment. Thus, some studies have attempted to analyse the environmental impacts of the educational level of the labour force. For example, Naseer et al. [26] contend that a highly educated labour force leads to CO2 emission abatements. These views corroborate the findings of Yin et al. [18] who opine that higher educational attainment reduces CO2 emissions levels in China.

Furthermore, some academics focus on the role of women empowerment and environmental sustainability. These ecofeminists studies reveal that women are more concerned with environmental protection than men. For instance, Achuo et al. [21] found that women socioeconomic empowerment is negatively correlated with greenhouse gas (GHG) emissions, implying that gender inclusion enhances environmental quality. Generally, ecofeminists studies focused either on economic or political empowerment of women are assertive of the fact that women empowerment is environment enhancing [27–29].

Despite the existence of a vast body of literature on environmental pollution, studies on the nexus between labour force participation and environmental sustainability remain sparse or almost inexistent. Due to the sparseness of literature exploring the environmental impacts of labour force participation, the objective of this study is to empirically examine the effect of labour force participation on environmental sustainability from a global perspective.

The present study is important for several reasons. Firstly, this study fills an important gap in literature by examining the direct environmental impacts of labour force participation. The study abstracts from extant studies that predominantly examine the indirect effects of labour market dynamics on environmental quality. To the best of our knowledge, this study is the first attempt to examine the environmental effects of labour force participation at a global scale. Secondly, besides exploring the links between total labour force participation and greenhouse gas (GHG) emissions, the study goes further to explore the gender dimensions of labour force participation. In addition, with the help of the Driscoll-Kraay Fixed Effects (DKFE) and the system GMM estimators, the study reveals the existence of a negative effect of total labour force participation (LFP) on GHG emissions. However, this effect is divergent for alternative measures of LFP. Moreover, we show evidence of the divergence of the environmental effects of LFP across regional groupings, income groups and level of development. Consequently, the results of this study provide fresh evidence for policymakers to reduce greenhouse gas emissions by improving labour market conditions to enhance labour force participation as well as encouraging the socioeconomic empowerment of women.

The rest of the paper is structured as follows. Section 2 reviews extant literature. The methodological strategy is outlined in section 3 whilst section 4 discusses empirical findings. Section 5 concludes with policy implications.

2. Synoptic review of literature

A proper understanding of the environmental impacts of labour force participations requires ample knowledge of the dynamics of the determinants of human capital. Thus, Becker [1] asserts that private or public spending on education, training and healthcare constitute investments in human capital since labour is inseparable from their knowledge, skills and health. Quality health and education are fundamental for the enhancement of human capital and access to educational facilities enables the acquisition of knowledge and skills. Improved human capital not only increases the individual's skills, but also enhances his productivity, earnings and quality of life [1,30]. However, the role of human capital in the determination of sustainable development can be traced to the initial neoclassical growth theory developed in 1956 by Robert Solow. Even though Solow's theory [31] does not lay emphasis on various components of human capital, it makes use of physical capital and labour as vital inputs to production. Thus, given the interconnectedness between production and economic growth, as well as economic growth and environmental pollution as evidenced in the EKC hypothesis [13] and the STIRPAT model [32], it becomes imperative to examine whether labour force participation deters or enhances environmental sustainability.

Although studies examining the direct linkages among labour force participation and environmental quality are almost inexistent, several extant environmental studies have however explored related aspects of labour force participation. For instance, while some studies have examined the environmental impacts of women empowerment and economic development [21,28,29,33,34], education [18,26], income inequality [14,15,35,36], infrastructural development [37–40], and demographic characteristics of countries [41,42], very few studies have delved into the direct links between labour force participation and environmental quality [10,43,44].

On the direct linkage between labour force and pollution emissions, Wang et al. [10] contend that female labour force contributes to improvements in environmental sustainability. However, this contribution varies across sectors and level of development [44]. Thus, Wang et al. [10] further argue that increased female labour force participation (FLFP) reduces pollution emissions in the service sector in the context of developed economies, while in developing countries FLFP enhances environmental quality in both the industrial and service sectors. Moreover, Zhong and Su [43] reveal that reductions in pollution emissions are associated with structural changes in the labour market especially relating to the participation of the labour force in value chains. However, the authors argue that labour productivity is exacerbates environmental degradation. Similarly, Wang et al. [41] conclude that environmental pollution increases with increased labour income share in developing countries. These authors argue that the associated embodied carbon emissions in foreign trade can be mitigated by increasing investments in green technologies.

On the women empowerment and environmental pollution nexus, Achuo et al. [21] contend that women socioeconomic empowerment enhances environmental sustainability in Africa. Similarly, Asongu et al. [34] conclude that environmental degradation improves with increasing political empowerment of women in developing countries. However, from the economic, social and political fronts, several ecofeminists studies have confirmed the environmentally enhancing role of women empowerment [27–29]. Nevertheless, the environmental effects of women's economic empowerment are believed to be transmitted through their involvement in entrepreneurship. Women's entrepreneurial undertakings reduce the male dominance and gender discrimination in the labour market [45,46]. In a related study, Zhong and Su [43] analyse the linkages between labour market dynamics and environmental pollution and conclude that labour market changes (notably labour productivity and job creation) improves environmental quality. These findings indicate the need for policymakers to consider women's socioeconomic empowerment in the design of environmental policies.

Regarding the environmental impacts of income inequalities, Ridzuan [36] authenticate the EKC hypothesis from a global perspective, arguing that rising income inequality is harmful to the environment. Similarly, Wang et al. [15] reveal the existence of an N-shaped curve between income inequality and environmental degradation. Contrarily, Grunewald et al. [47] opine that environmental quality improves with rising income inequalities in the context of Low and Middle-Income countries. From a global perspective, Wang et al. [14] argue that the environmental effects of human capital are heterogeneous, while confirming the validity of the EKC hypothesis. Although similar results are reported by Wencong et al. [35], their findings invalidate the applicability of the EKC hypothesis in the context of transition economies.

With regard to the infrastructure-environmental pollution relationship, a number of studies conclude that infrastructural development is detrimental to environmental sustainability. However, the environmental effects depend to a greater extent on the type of infrastructure [38]. Recently, Nchofoung and Asongu [37] argued that increased infrastructural development (notably in the domains of ICTs, transport, electricity, water and sanitation) accentuates environmental degradation in Africa. This result corroborates the findings of Lin and Omoju [40] who showed that rapid infrastructural development in the road sector was responsible for growing CO2 emissions across Asian countries. These findings are consistent in the context of country-specific studies as evidenced in recent empirical studies for Cameroon [39] and France [48] indicating that infrastructural investments are environmentally unfriendly across respective economies.

Conversely, several studies have focused on the relationship among education and environmental sustainability. In this light, Lan et al. [49] conclude that education enhances technological innovation which in turn ameliorates environmental quality through the adoption of green technologies. Furthermore, it is believed that environmental regulations are likely to be respected by a more educated and skilled labour force [50,51]. Consequently, human capital development through innovative and improved education could catalyze efforts towards environmental sustainability. The importance of innovation in extenuating environmental degradation is equally stressed by Bekun [52].

Another variant of literature has been devoted to the examination of the linkages between demographic characteristics of the labour force and environmental sustainability. Several studies in this perspective suggest that while rising CO2 emissions are consistent with a growing population size. For instance, Balezentis [53] reveals that the fall in CO2 emissions in Eastern Europe is consistent with declines in population size. However, the author opines that this effect was offset due to the vicissitudes in the behaviour of the population such as dwelling area and household size. Increasing household size is likely to increase energy consumption, which in turn raises the level of CO2 emissions, thereby leading to environmental degradation. Equally, Yu et al. [42] showed that lifestyle and structural changes towards small household size and aging populations increase energy consumption and CO2 emissions in China. These results have been corroborated by Wang et al. [41]. Concordantly, in a related study for Brazil, Carvalho et al. [54] contend that

CO_2 emissions increase less proportionately compared to the growth in population.

Despite the fact that environmental sustainability and labour market dynamics constitute key priorities among the sustainable development goals (SDGs) pursued by world economies, extant literature on the direct links between labour force participation and environmental sustainability remain sparse. Moreover, the few existing studies have been largely confined to country-specific analyses in developed countries. Thus, this study fills an important research gap and extends existing literature by examining the global dynamics of the environmental impacts of labour force participation. Moreover, comparisons are made with regard to the environmental impacts of labour force participation across different income groups, geographical regions, as well as developed and developing countries.

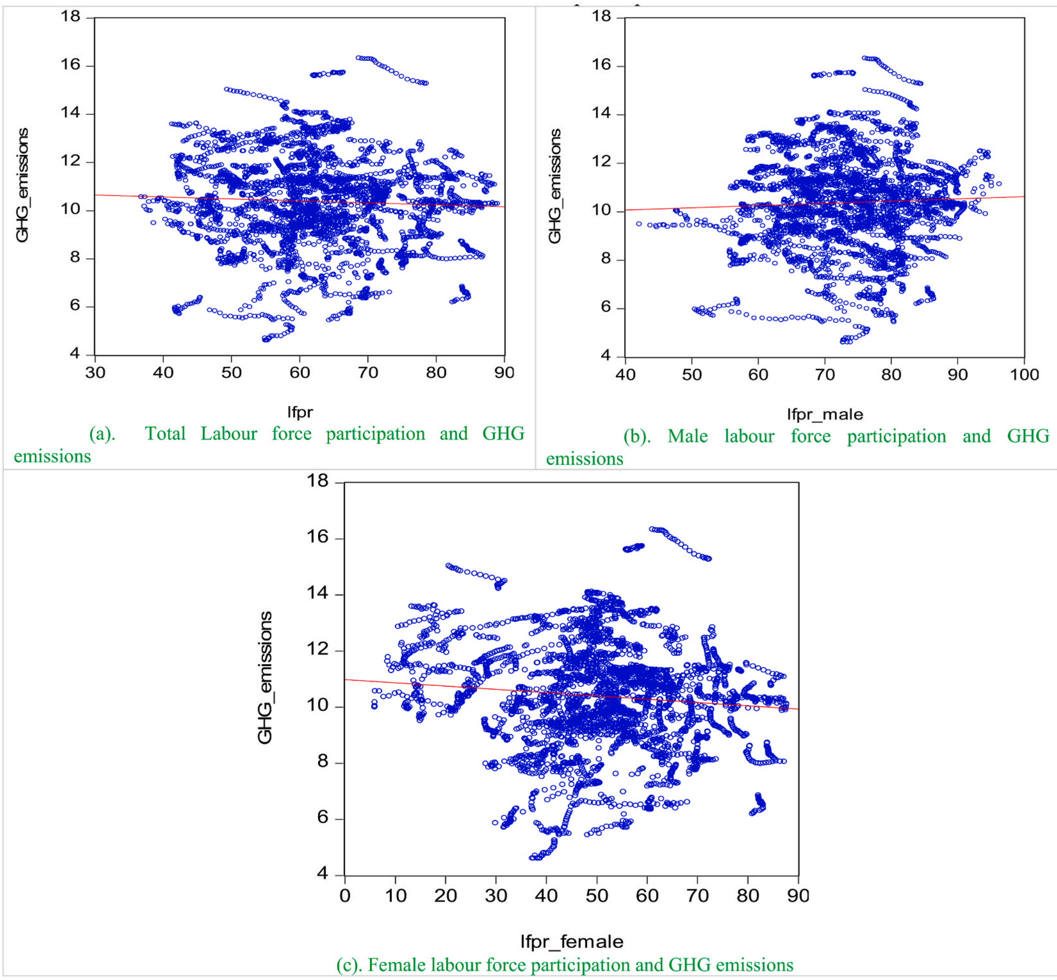
3. Empirical strategy

3.1. Data and description of variables

The data for this study is collected for a global panel of 173 countries (see appendix A3) between 1996 and 2020. The data is collected from the World Bank database. Specifically, while the institutional quality variables were gotten from the Worldwide Governance Indicators of the World Bank, the rest of the variables were gotten from the World Development indicators. The choice of countries and period is conditioned by the availability of data for modelled variables of interest.

3.2. Dependent variable

The dependent variable in this study is environmental sustainability proxied by the logarithm of total greenhouse gas (GHG)



(a). Total Labour force participation and GHG emissions

(b). Male labour force participation and GHG emissions

(c). Female labour force participation and GHG emissions

Fig. 1. Correlation between labour force participation and GHG emissions, (a). Total Labour force participation and GHG emissions, 1(b). Male labour force participation and GHG emissions, (c). Female labour force participation and GHG emissions.

emissions. A Similar measure for environmental sustainability has been recently adopted by Achuo et al. [2]. This measure is preferable because it combines all the gases that are potentially harmful to the environment.

3.3. Independent variable of interest

The independent variable of interest used here is the labour force participation (% population). Robustness is further carried out with male labour force participation (% male population) and female labour force participation (%female population). Similar measures have been used in literature by Efobi et al. [55]. Achuo et al. [21] argue that female labour force participation enhances environmental sustainability in Africa. A similar result is expected in this study. Thus, Fig. 1 reveals an apparent negative relationship between labour force participation (LFP) and GHG emissions, though the relationship is not quite apparent. However, unlike the perceived link between female LFP and GHG emissions which is significantly negative, a positive relationship is depicted between male LFP and GHG emissions. This suggests that female labour force participation mitigates environmental degradation while male labour force participation exacerbates pollution emissions. However, the combined effect of male and female labour participation has the potential of mitigating environmental deterioration.

3.4. Control variables

The first control variable is ICT infrastructures proxy by number of mobile telephone users per 100. Nchofoung and Asongu [37] argue that infrastructures exacerbate environmental quality in Africa. A similar result is expected in this study. Also, trade openness is used in accordance with the study of Halicioglu and Ketenci [56], who argue that the effect of trade on the environment varies from one economy to another. A positive or negative sign is thus expected from this variable. Another control variable is foreign direct investment inflows (%GDP), which is expected to negatively impact GHG emissions, in accordance with Opoku and Boachie [57]. Besides, financial development is used as a control variable and proxied by the domestic credit to the private sector (%GDP). The next control variable is urbanization which is expected to have a positive sign in line with a recent study by Mignamissi and Djeufack [58]. Equally, institutional quality is used as a control variable, proxied by the average of the six governance indexes of Kaufmann [59]. A similar approach of measuring institutional quality has been recently used in literature by Ngouhouo et al. [60]. This variable is expected to enhance environmental quality. Women political empowerment (proxied by women in parliament) is also employed in accordance with the study of Asongu and Salahodjaev [61] and is expected to improve environmental quality. The last but not the least variable is natural resources endowment. It is used at first place as the total natural resource rents (%GDP), then oil rents (%GDP), coal rents (%GDP), mineral rents (%GDP), gas rents (%GDP), and forest rents (%GDP). Baloch et al. [62] argue that natural resources have a heterogeneous effect on CO2 emission. The sign of these variables can therefore be negative or positive. The correlations between these variables and descriptive statistics are respectively presented in appendix A1 and A2.

3.5. Model specification and estimation method

The empirical modelling of the environmental impacts of labour force participation is inspired by the STIRPAT model advocated by Dietz and Rosa [32]. This model is expressed in equation [1] as follows:

$$I_{it} = \eta P_{it}^{\gamma} A_{it}^{\delta} T_{it}^{\vartheta} \varepsilon_{it} \tag{1}$$

where I, P, A and T respectively represent environmental impact, population size, per capita GDP, and technological change; η is the intercept; γ, δ and ϑ respectively represent the exponents of P, A and T to be estimated; ε is the random error term; subscripts i and t respectively denote the country and time dimensions.

After ensuring a logarithmic transformation of the STIRPAT model, and congruent with contemporary literature [17,37,63], the following empirical model is specified in equation [2].

$$Environment_{it} = \mu_0 + \mu_1 LFP_{it} + \mu_j Y_{it} + \varepsilon_{it} \tag{2}$$

where *Environment* represents environmental quality (captured by GHG emissions), LFP denotes labour force participation; Y is a vector of control variables; μ_0 is the intercept; μ_1 and μ_j are slope coefficients; j is the number of control variables; and the rest of the variables are defined as before.

Given the integration of different economies due to globalization, the co-movement of macroeconomic variables across countries is inevitable. In this respect, the presence of cross-sectional dependence among these variables is worth considering [2,64]. Thus, Driscoll and Kraay [65] proposed a standard error correction regressor that takes care of cross-sectional dependence between panels. Driscoll and Kraay's approach applies a Newey-West–type correction to the sequence of cross-sectional averages of the moment conditions. This adjusts the standard error ensuring that the covariance matrix estimator is consistent, independently of the cross-sectional dimension [2,66]. The error structure is assumed to be heteroscedastic and auto correlated up to a given lag.

4. Results and discussions

Before carrying out the empirical analysis, we provided descriptive statistics (appendix A2) and carried out preliminary tests.

Specifically, we tested for cross-sectional dependence (CD) with the help of the Pesaran CD test in order to choose between first- and second-generation unit root tests. The Pesaran CD tests (see appendix A4) authenticated the existence of cross-section dependence, thus necessitating the employment of the Pesaran CADF second generation unit root test (see appendix A4), which is suitable in large panels where the number of cross-sections exceed the time periods. Besides the preliminary tests, this section discusses the empirical results of the effects of labour force participation on environmental sustainability for a global panel of developed and developing countries. We begin by presenting the baseline results for the global sample, before providing robustness checks by disaggregating the global panel into different income groups, regional groupings, as well as developed and developing countries.

4.1. Baseline analysis

The baseline estimation results of the environmental effects of labour force participation (LFP) are presented in Table 1. Employing the Driscoll-Kraay Fixed Effects (DKFE) technique, the results (model 1) reveal a negative effect of LFP on greenhouse gas (GHG) emissions. This implies that environmental pollution decreases with rising LFP. This result is however inconsistent with the findings of Jung et al. [67] who assert that labour force participation positively drives CO_2 emissions through economic development. However, after disaggregating the LFP into the male and female components, the results (model 2) show that male LFP is environment degrading as evidenced by the significantly positive coefficient of male LFP. Conversely, results from model 3 reveal that female LFP has a significant negative effect on GHG emissions, implying that rising female LFP is environmentally friendly. These findings corroborate the works of Wang et al. [10] who contend that female labour force participation improves environmental sustainability across developing countries. Moreover, this result confirms the ecofeminists claims that the socioeconomic empowerment of women has the ability to enhance environmental quality [21,28,29].

Besides the environmental effects of LFP, other control variables are believed to play a key role in determining environmental quality. For instance, Table 1 (model 1) indicates that while foreign direct investment (FDI), trade openness and institutional quality significantly enhance environmental quality, urbanisation, financial development and political empowerment of women lead to environmental degradation. These findings are in accordance with extant studies with regard to the environmental impacts of women's political empowerment [34] and urbanisation [68].

4.2. Robustness checks and sensitivity analysis

The robustness of the baseline results is verified with the help of other competent econometric techniques, notably the system Generalised Method of Moments (GMM) approach proposed by Roodman [69]. The system GMM approach is believed to be more robust than other approaches as it controls for various dimensions of endogeneity (notably simultaneity bias and unobserved heterogeneity), instrument proliferation and cross-sectional dependence which are econometric problems inherent with large panel

Table 1
DKFE estimates of the effect of labour force participation on environmental sustainability.

Variables	(1)	(2)	(3)
	Dependent variable: Greenhouse gas (GHG) emissions		
Labour force participation rate (LFP)	−0.00646**		
	(0.00294)		
Foreign direct investment (FDI)	−0.0109***	0.000612**	−0.0107***
	(0.00252)	(0.000221)	(0.00229)
ICT	0.000266	0.00183***	−4.19e-05
	(0.000787)	(0.000251)	(0.000698)
Trade openness	−0.0109***	−0.000462	−0.0109***
	(0.000539)	(0.000333)	(0.000553)
Urbanisation	0.0294***	0.0193***	0.0271***
	(0.00144)	(0.00344)	(0.00145)
Financial development	0.0151***	0.000278	0.0151***
	(0.00104)	(0.000489)	(0.00102)
Institutional quality	−0.421***	0.0443**	−0.396***
	(0.0985)	(0.0195)	(0.0937)
Women political empowerment	0.0141***	0.00153*	0.0183***
	(0.00131)	(0.000827)	(0.00129)
Male LFP		0.00482***	
		(0.00164)	
Female LFP			−0.0127***
			(0.00121)
Constant	9.246***	8.957***	9.575***
	(0.326)	(0.235)	(0.211)
Observations	2709	2709	2709
R-squared	0.313		0.321
Number of groups	162	162	162
Fisher	2000**	1921***	1364***

Notes: ICT denotes Information and communication technologies; Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

datasets [70,71]. The system GMM results in Table 2 largely corroborate the baseline findings for our main variables of interest, thereby confirming the robustness of our findings. The absence of multicollinearity (see Appendix A5) further confirms the reliability of the empirical findings.

Nevertheless, we further present the sensitivity analysis of the baseline results in Table 1 by splitting the global panel into different geographical regions, income groups, and level of development. With regard to various income groups, the environmental effects of labour force participation (LFP) are conflicting. Specifically, Table 3 indicates that labour force participation has a significantly negative effect on environmental pollution across Low-income and High-income countries, while the effect is significantly positive for Upper-middle-income countries. The effect is however insignificant for Lower-middle-income countries. These findings may be partly due to the high unemployment rates that characterize Low-income countries with an insufficient labour force to propel economic growth, which is believed to be at the genesis pollution emissions [2], while the High-income countries are capable of investing in green technologies and meeting with the high cost associated with financing the of training of human capital in green technologies.

Regarding the level of development and various geographical regions, Table 4 reveals that, while labour force participation significantly reduces GHG emissions in developing countries, the effect is insignificant in developed economies. This result for developing countries corroborates the findings of previous studies [10,41] asserting that upsurges in female labour force participation bring about diminutions in CO_2 emissions levels, thereby contributing to environmental sustainability.

Furthermore, Table 4 reveals that the effect of LFP is divergent across geographical regions. For instance, while LFP has a significantly negative effect on environmental sustainability in Europe and Central Asia, Latin America and the Caribbean, North America, South Asia, and Sub-Saharan Africa, its effect is insignificant across East Asia Pacific as well as Middle East and North African countries. The significantly negative effect observed across European and Central Asian countries may be attributed to the improved health and educational facilities in these regions. These results are therefore in conformity with extant studies emphasizing the role of health [6,7] and educational attainment [8] influencing labour force participation outcomes.

Having verified the sensitivity of the environmental effects of labour force participation with regard to income groups, geographical regions and level of development, we now consider the role of natural resources as a key determinant of environmental sustainability. Consequently, Table 5 reveals that natural resources rents (model 1) lead to environmental pollution. Thus, the significantly positive coefficient of resources rents is consistent with the findings of a recent study in Africa [21]. These results are largely consistent with the employment of alternative measures of natural resources. For instance, besides forest rents (model 6) which have a significantly negative effect on greenhouse gas emissions, the effects of mineral rents (model 3), oil rents (model 4) and gas rents (model 5) are significantly contribute to environmental degradation, as depicted by the positive coefficients. However, the environmental effect of coal rents (model 2) is insignificant.

The environmentally enhancing role of forest rents may be attributed to the continuous awareness creation and adoption of carbon

Table 2
System GMM estimates of the environmental effects of labour force participation.

Variables	(1)	(2)	(3)
	Dependent variable: GHG emissions		
Labour force participation rate (LFP)	−0.00788***		
	(0.00190)		
Foreign direct investment (FDI)	−0.0148***	0.00913	−0.0112***
	(0.00319)	(0.00820)	(0.00321)
ICT	0.00174***	−0.000991	0.00164***
	(0.000263)	(0.00109)	(0.000252)
Trade openness	−0.0109***	−0.0523***	−0.0115***
	(0.000216)	(0.00300)	(0.000266)
Urbanisation	0.0295***	0.0340***	0.0276***
	(0.000716)	(0.00393)	(0.000645)
Financial development	0.0166***	0.0550***	0.0149***
	(0.000490)	(0.00284)	(0.000679)
Institutional quality	−0.575***	−2.003***	−0.499***
	(0.0407)	(0.193)	(0.0421)
Women political empowerment	0.0109***	0.0820***	0.0163***
	(0.00107)	(0.00667)	(0.00159)
Male LFP		0.153***	
		(0.0151)	
Female LFP			−0.0151***
			(0.00112)
Constant	9.080***	3.414**	9.551***
	(0.178)	(1.518)	(0.124)
Observations	1977	1977	1977
Instruments	28	19	28
AR(1)_proba.	1.67e-05	4.41e-05	1.79e-05
AR(2)_proba.	0.218	0.527	0.677
Hansen_proba.	0.244	0.135	0.242
Fisher	1.389e+06***	18995***	960192***

Notes: The lagged dependent variables are considered in the GMM estimations, Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 3
Environmental effects of labour force participation across income groups.

Variables	(1) Low-income	(2) Lower-middle-income	(3) Upper-middle-income	(4) High-income
	Dependent variable: Greenhouse gas (GHG) emissions			
Labour force participation rate (LFP)	−0.0205***	−0.00735	0.0646***	−0.104***
	(0.00432)	(0.00502)	(0.00563)	(0.0121)
Foreign direct investment (FDI)	−1.50e-05	−0.0149*	−0.101***	−0.0138***
	(0.00116)	(0.00772)	(0.0207)	(0.00184)
ICT	0.00432***	−0.000588	−0.00319**	0.00240**
	(0.000487)	(0.00171)	(0.00140)	(0.00114)
Trade openness	0.000318	−0.0207***	−0.0124***	−0.00923***
	(0.000666)	(0.000934)	(0.00107)	(0.000293)
Urbanisation	8.99e-05	0.0180***	0.0491***	0.0333***
	(0.00538)	(0.00189)	(0.00439)	(0.00174)
Financial development	0.00469**	0.0237***	0.0281***	0.0104***
	(0.00222)	(0.00259)	(0.00140)	(0.00153)
Institutional quality	0.110**	−1.005***	−1.159***	0.233***
	(0.0395)	(0.229)	(0.133)	(0.0664)
Women political empowerment	0.00206*	0.0294***	0.0360***	−0.0278***
	(0.00109)	(0.00618)	(0.00731)	(0.00335)
Constant	10.91***	9.852***	3.358***	15.37***
	(0.408)	(0.575)	(0.544)	(0.717)
Observations	357	862	661	829
R-squared		0.321	0.581	0.423
Fisher	1177***	320.9***	17223***	3166***
Number of groups	20	50	44	48

Notes: ICT denotes Information and communication technologies; Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

emission reduction strategies across the globe. For instance, the local and international forest-based carbon emission reduction initiatives commonly referred to as REDD+ (Reduced Emissions from Deforestation and Forest Degradation) initiatives have become increasingly adopted across the globe. Several environmental studies reveal that the inclusion of REDD + initiatives in the local development plans of especially developing countries have greatly contributed to abatements in CO2 emissions [72–76].

5. Conclusion and policy recommendations

This paper empirically examined the effects of labour force participation on environmental sustainability for a global panel of 173 countries for the 1996–2020 period. To achieve this objective, the study employed the Driscoll-Kraay Fixed Effects (DKFE) and system Generalised Method of Moments (GMM) estimators and the following key findings were revealed.

First, there is a negative relationship between labour force participation (LFP) and greenhouse gas (GHG) emissions. This implies that environmental pollution decreases with rising LFP. Second, after disaggregating LFP into the male and female components, the results show that male LFP is environment degrading while female LFP is environment augmenting through reduced GHG emissions. Moreover, while a significantly negative effect of LFP on environmental pollution is observed across Low-income and High-income countries, the effect is significantly positive for Upper-middle-income countries. In addition, although rising LFP significantly reduces GHG emissions in developing countries, the effect is insignificant in developed economies. Likewise, the effect of LFP is divergent across geographical regions.

Moreover, the environmentally enhancing role of female labour force participation is in conformity with ecofeminists claims and reawakens debates on the need for policymakers to consider labour market dynamics and women's political and socioeconomic empowerment in the design of employment and environmental policies. However, policymakers should design holistic policies capable of comprehensively bettering the working conditions of the populace without compromising environmental quality. Thus, there is need for various governments either through individual or concerted efforts to encourage the creation of "green jobs". Thus, modern training programs should be tailored towards green technologies, which are likely to enhance environmental sustainability. Moreover, a certain proportion of the proceeds of development, especially in Upper-Middle Income countries should be used to finance eco-innovations and related training workshops should be organised empower the labour force in these environment-friendly technologies.

Given that this study is a novel attempt in modelling the nexus between labour force participation and environmental sustainability at a global scale, the findings thus leave room for future research opportunities. As the findings are limited to the direct effects of labour force participation on environmental quality, future research could explore the potential indirect channels through which labour force participation could impact the environment. Likewise, individual country studies could be conducted so as to suggest country-specific policies with regard to the environmental impacts of labour force participation. Besides, future studies could consider extending the timeframe to re-examine the established relationships and integrate recent dynamics in the labour force-environment relationship once more recent data becomes available.

Table 4
Environmental effects of labour force participation across geographical regions and level of development.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Developed economies	Developing economies	East Asia Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle east and North Africa	North America	South Asia	Sub-Saharan Africa
	Dependent variable: Greenhouse gas (GHG) emissions								
Labour force participation rate (LFP)	−0.00185	−0.0474**	−0.00250	−0.0563***	−0.0610***	0.000107	−0.110***	−0.0179***	−0.00922**
	(0.00185)	(0.0175)	(0.00352)	(0.0135)	(0.0143)	(0.00518)	(0.0188)	(0.00433)	(0.00384)
Foreign direct investment (FDI)	0.00144	−0.0117***	−0.00227	−0.00573**	−0.0880***	0.00106*	−0.00844	0.00543	0.00175
	(0.00111)	(0.00163)	(0.00132)	(0.00218)	(0.0172)	(0.000553)	(0.0134)	(0.0106)	(0.00140)
ICT	0.00173***	−0.00229	0.00156***	−9.33e-05	−0.00342**	0.0108***	−0.00176	0.00204***	0.00249***
	(0.000156)	(0.00195)	(0.000205)	(0.000876)	(0.00148)	(0.000886)	(0.00877)	(0.000367)	(0.000170)
Trade openness	0.000425	−0.0104***	0.000769***	−0.0104***	−0.0289***	−0.0163***	−0.0342***	−0.00134	0.00123**
	(0.000301)	(0.000541)	(0.000205)	(0.000968)	(0.00511)	(0.00105)	(0.00541)	(0.000874)	(0.000587)
Urbanisation	0.0197***	0.0296***	0.0251***	0.0326***	0.0255***	−0.0141***	−0.0634	0.0177***	0.0103***
	(0.00243)	(0.00433)	(0.00206)	(0.00319)	(0.00315)	(0.00273)	(0.197)	(0.00532)	(0.00224)
Financial development	0.00250***	0.00559**	0.00257***	−0.00145	0.0117	−0.00978***	0.00568***	0.00324*	0.00360**
	(0.000558)	(0.00210)	(0.000224)	(0.00174)	(0.00705)	(0.00226)	(0.00188)	(0.00156)	(0.00128)
Institutional quality	0.0352	0.182**	−0.0850**	0.239***	−0.444***	−0.179	−0.152	−0.0346	0.129***
	(0.0264)	(0.0645)	(0.0330)	(0.0636)	(0.154)	(0.122)	(0.710)	(0.0677)	(0.0407)
Women political empowerment	0.00235***	−0.0390***	0.00269	−0.0113***	0.0296***	−0.0220***	−0.0212	−0.00108	0.00237**
	(0.000600)	(0.00354)	(0.00197)	(0.00278)	(0.00386)	(0.00525)	(0.0366)	(0.00138)	(0.000890)
Constant	9.121***	13.74***	9.446***	13.37***	14.23***	13.62***	28.40*	11.24***	9.628***
	(0.190)	(0.799)	(0.277)	(0.921)	(0.730)	(0.293)	(14.73)	(0.307)	(0.279)
Observations	2068	641	374	691	451	293	32	116	752
R-squared		0.415		0.264	0.537	0.769	0.993		
Number of groups	124	38	22	45	25	19	2	7	42
Fisher	743.4***	699.6***	946.1***	290.0***	813.8***	406.5***	1241***	1582***	421.8***

Notes: ICT denotes Information and communication technologies; Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5
Sensitivity of environmental sustainability indicators taking into account natural resources.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Greenhouse gas (GHG) emissions					
Labour force participation rate	−0.00155	−0.00176	−0.00191	−0.00132	−0.00173	−0.00148
	(0.00201)	(0.00201)	(0.00194)	(0.00209)	(0.00203)	(0.00210)
Foreign direct investment	0.000545**	0.000563**	0.000550**	0.000559**	0.000564**	0.000582**
	(0.000214)	(0.000215)	(0.000213)	(0.000216)	(0.000217)	(0.000225)
ICT	0.00180***	0.00182***	0.00178***	0.00181***	0.00181***	0.00179***
	(0.000268)	(0.000253)	(0.000251)	(0.000270)	(0.000257)	(0.000251)
Trade openness	−0.000634*	−0.000569	−0.000494	−0.000649*	−0.000551	−0.000415
	(0.000330)	(0.000362)	(0.000337)	(0.000338)	(0.000359)	(0.000361)
Urbanisation	0.0187***	0.0184***	0.0182***	0.0189***	0.0184***	0.0180***
	(0.00321)	(0.00328)	(0.00312)	(0.00330)	(0.00324)	(0.00311)
Financial development	0.000325	0.000280	0.000320	0.000349	0.000290	0.000326
	(0.000496)	(0.000508)	(0.000516)	(0.000489)	(0.000506)	(0.000512)
Institutional quality	0.0450**	0.0445**	0.0435**	0.0447**	0.0445**	0.0418**
	(0.0198)	(0.0197)	(0.0194)	(0.0193)	(0.0197)	(0.0178)
Women political empowerment	0.00130	0.00123	0.00124	0.00130	0.00122	0.00119
	(0.000849)	(0.000810)	(0.000807)	(0.000842)	(0.000824)	(0.000782)
Resources rents	0.00189*					
	(0.00108)					
Coal rents		0.00238				
		(0.00498)				
Mineral rents			0.00543**			
			(0.00239)			
Oil rents				0.00319*		
				(0.00170)		
Gas rents					0.00511**	
					(0.00242)	
Forest rents						−0.0126***
						(0.00339)
Constant	9.456***	9.490***	9.500***	9.430***	9.486***	9.506***
	(0.235)	(0.237)	(0.216)	(0.248)	(0.237)	(0.226)
Observations	2698	2698	2709	2698	2695	2709
R-squared	0.400	0.398	0.396	0.401	0.398	0.402
Fisher	4868***	1061***	1204***	1434***	1207***	974.7***
Number of groups	162	162	162	162	162	162

Notes: ICT denotes Information and communication technologies; Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Data availability statement

The data associated with this study has not been deposited into a publicly available repository. However, data will be made available upon reasonable request from the corresponding author.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Elvis D. Achuo: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. **Tii N. Nchofoung:** Conceptualization, Validation, Writing – original draft, Writing – review & editing. **Linda Julie Tiague Zanfack:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing. **Clovis Ekwelle Epoge:** Conceptualization, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

A1
Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1 Greenhouse gas (GHG) emissions	1.000																
(2) Labour force participation (LFP)	−0.111	1.000															
(3) Male LFP	−0.166	0.751	1.000														
(4) Female LFP	0.011	0.900	0.410	1.000													
(5) Foreign direct investment (FDI)	−0.104	−0.034	−0.056	−0.011	1.000												
(6) ICT	0.205	−0.198	−0.271	−0.141	0.091	1.000											
(7) Trade openness	−0.216	−0.085	−0.135	−0.055	0.273	0.271	1.000										
(8) Urbanisation	0.360	−0.279	−0.234	−0.281	0.112	0.492	0.250	1.000									
(9) Financial development	0.343	−0.094	−0.148	−0.047	0.186	0.446	0.201	0.495	1.000								
(10) Institutional quality	0.152	−0.095	−0.215	−0.008	0.129	0.384	0.293	0.544	0.657	1.000							
(11) Women political empowerment	0.184	0.095	−0.115	0.227	−0.016	0.345	0.022	0.204	0.269	0.300	1.000						
(12) Resources rents	0.017	0.034	0.101	−0.081	−0.044	−0.078	−0.045	0.006	−0.304	−0.387	−0.184	1.000					
(13) Coal rents	0.128	−0.022	−0.075	0.016	0.034	0.042	0.005	0.006	0.055	−0.018	0.014	0.093	1.000				
(14) Mineral rents	−0.017	0.016	−0.010	0.036	0.014	0.000	−0.027	−0.027	−0.116	−0.132	0.021	0.202	0.300	1.000			
(15) Oil rents	0.126	−0.140	0.026	−0.280	−0.048	0.040	0.003	0.200	−0.162	−0.223	−0.186	0.870	−0.041	−0.074	1.000		
(16) Gas rents	0.053	0.017	0.046	−0.042	−0.019	0.080	−0.013	0.041	−0.036	−0.054	0.018	0.355	−0.011	−0.028	0.225	1.000	
(17) Forest rents	−0.296	0.401	0.205	0.435	−0.010	−0.348	−0.106	−0.456	−0.355	−0.395	−0.075	0.302	−0.049	0.091	−0.093	−0.061	1.000

A2
Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Greenhouse gas (GHG) emissions (log)	3979	10.385	1.917	4.605	16.33
Labour force participation	4322	62.623	10.539	36.83	89.05
Labour force participation (male)	4152	73.743	8.703	42.13	96.28
Labour force participation (female)	4152	51.4	15.896	6	87.68
Foreign direct investment	4020	5.244	15.777	−58.323	449.083
ICT	4221	63.133	51.591	0	212.639
Trade openness	3937	85.052	49.942	.027	437.327
Urbanization	4313	55.241	22.791	7.412	100
Financial development	3501	48.22	43.344	0	304.575
Institutional quality	4322	−.077	.925	−2.1	12.768
Women political empowerment	3885	17.46	11.346	0	63.75
Resources rents	4053	7.401	11.399	0	87.459
Coal rents	4034	.145	.788	0	25.965
Mineral rents	4070	.761	2.225	0	25.163
Oil rents	4053	3.823	9.803	0	66.713
Gas rents	4046	.618	3.017	0	68.564
Forest rents	4070	2.049	4.226	0	40.408

A3
List of Countries

Afghanistan, Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Comoros Congo Dem. Rep., Congo Rep., Costa Rica, Cote d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Djibouti, Dominican Republic Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Eswatini, Ethiopia, Fiji, Finland, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea Dem. People's Rep., Korea, Rep., Kuwait, Kyrgyz Republic, Lao PDR, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Rwanda, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Sierra Leone, Singapore, Slovak Republic, Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sudan, Suriname, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan. Vanuatu, Vietnam, Yemen, Rep., Zambia, Zimbabwe.

A4
Cross-section dependence and unit root tests

Variable	Pesaran CD test for cross-section dependence		Pesaran CADF test for unit root	
	CD test	*P*-value	Z[t-bar] statistic	*P*-value
GHG emissions	207.084	0.000	−6.440*	0.000
Labour Force Participation (LFP)	216.578	0.000	−9.255**	0.000
Male LFP	204.891	0.000	−10.168**	0.000
Female LFP	211.674	0.000	−7.689**	0.000
ICT	149.709	0.000	−2.734*	0.003
Trade openness	189.013	0.000	−16.028**	0.000
Urbanisation	224.702	0.000	−3.525*	0.000
Financial development	170.52	0.000	−18.592**	0.000
Institutional quality	212.323	0.000	−4.808**	0.000
Women political empowerment	168.058	0.000	−2.009*	0.022
Foreign direct investment	63.581	0.000	−5.646*	0.000
Resources rents	188.726	0.000	−4.115*	0.000
Coal rents	176.926	0.000	−8.168**	0.000
Mineral rents	145.968	0.000	−3.023**	0.000
Oil rents	201.647	0.000	−8.029**	0.000
Gas rents	180.039	0.000	−10.982**	0.000
Forest rents	197.562	0.000	−4.352*	0.000

Notes: * and ** denote stationarity at levels and first difference respectively.

A5
VIF test for multicollinearity

Variable	Model 1		Model 2		Model 3	
	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
Labour force participation rate (LFP)	1.14	0.880855				
Foreign direct investment (FDI)	1.11	0.901928	1.11	0.901622	1.11	0.901475
ICT	1.59	0.627254	1.61	0.621640	1.59	0.629961
Trade openness	1.22	0.820239	1.22	0.819389	1.22	0.819972
Urbanisation	1.77	0.565523	1.69	0.591473	1.84	0.542933
Financial development	2.00	0.500989	2.00	0.499500	1.99	0.501402
Institutional quality	2.11	0.474441	2.12	0.470827	2.13	0.470224
Women political empowerment	1.23	0.809910	1.20	0.835746	1.31	0.764540
Male LFP			1.11	0.903167		
Female LFP					1.23	0.813768
Mean VIF	1.52		1.51		1.55	

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