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# Does the environmental Phillips curve hypothesis hold within the Ghanaian context?

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ABSTRACT

This study examines the relationship between environmental quality and unemployment in Ghana using annual data spanning the period from 1990 to 2019. It also assesses the impact of gender-segregated unemployment rate on environmental quality. The study employed the Autoregressive Distributive Lag (ARDL) error correction model to estimate the relationship among the variables. In addition, the Fully Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) estimation procedures were employed to check for robustness of the ARDL results. Findings indicate a positive effect of total unemployment rate on environmental quality in Ghana in the long-run and also in the short-run. In the case of the gender-segregated unemployment, the findings reveal that in both short-run and long-run, a rise in female unemployment causes a deterioration in environmental quality in Ghana. The results also validated the Environmental Phillips Curve (EPC) hypothesis in the case of male unemployment. Thus, given that there is no general pattern in the findings, the study concludes that the Environmental Phillips Curve (EPC) hypothesis does not hold within the Ghanaian context.

## Introduction

Environmental degradation is a global problem which has attracted widespread attention in recent times. It is regarded as a global environmental problem because its effects are ubiquitous and trans-boundary [20]. That is, increases in pollution in one country does not only affect that country but also other countries or the rest of the world. As a result, there is a general consensus among policy-makers, researchers, environmental economists and the larger global populace, of the need to improve environmental quality and consequently ensure the achievement of environmental sustainability.

Largely, the continuous pollution and degradation of the environment have been blamed on human activities [24,37]. One such activity is the emission of Green House Gasses (GHGs) [6]. Carbon dioxide ($CO_2$) is estimated to constitute as much as 80% of these gasses in the environment [33]. Statistics from British Petroleum (BP) indicates global carbon dioxide emissions rose to as high as 31, 983.6 million tons in 2020, and in the past decade, it has recorded an annual average growth rate of 1.4%. Rising levels of carbon dioxide emission in the atmosphere is one of the primary causes of global warming and climate change. Climate change impacts are multifaceted, cutting across areas like human health, agricultural productivity and food security, production and consumption activities, biodiversity, tourism, natural disasters, and economic growth amongst others.

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Both the theoretical and the empirical literature indicate a positive relationship between economic growth and carbon dioxide emissions [6,35]. This implies that increases in production and income levels are expected to cause a rise in pollution and vice versa. Given that increases in employment is directly associated with economic growth, it would be logical to infer that employment may also be positively correlated with pollution. Indeed, some empirical studies have confirmed the positive nexus between pollution and employment [7,18]. There are however concerns that reducing pollutions or GHGs emissions may require that countries sacrifice economic growth since the literature has demonstrated that when growth increases, pollution also increases. Most developing countries like Ghana are pursuing higher growth and rely on high carbon-emitting energy resources such as fossil fuels to drive their growth agenda. Therefore, decoupling their resource-hungry economic activities, which create and sustain jobs, from carbon dioxide emissions or pollution may be difficult because these countries lack the technical expertise and financial resources to adopt renewable energy and environmentally friendly technologies. Moreover, the alternative of curbing pollution from a rise in unemployment is a non-starter because it is not feasible. Given that increases in carbon dioxide emissions are largely caused by economic growth, policymakers may be confronted with a trade-off between reducing environmental pollution and sustaining livelihoods. Kashem and Rahman [20] termed this trade-off or nexus between environmental pollution and unemployment as the Environmental Philips Curve (EPC) hypothesis.

Over the past few decades, Ghana has recorded rising levels of emissions, which have been linked to the continuous implementation of policies to expand and transform the economy (Environmental Protection Agency [16] Ghana, 2022). This, coupled with population growth pressures, has resulted in increases in emission generations from road transport, deforestation, thermal energy production, and biomass use for household cooking amongst others [16]. Ghana, just like most developing countries, accounts for a smaller percentage of global $CO_2$ emissions. The fifth national greenhouse gas inventory report prepared by the EPA in 2022 indicated the country's carbon dioxide emissions increased from 0.1629 tnes per capita in 1990 to 0.6029 tnes per capita in 2020. The country's carbon dioxide emission intensity of GDP from 1990 to 2020 also increased from 0.19 kgCO2/GDP to 0.30 kgCO2/GDP, indicating a rise in the amount of carbon dioxide emitted per unit of output produced in the country. The Agriculture, Forestry, and Other Land Use (AFOLU), and energy sectors have been Ghana's dominant source of carbon dioxide emissions. The AFOLU sector was the largest producer of carbon dioxide emissions from 1990 to 2010. The energy sector has taken over the AFOLU sector in recent years [16]. The sector's share of total emissions increased from 2.9 MtCO2 in 1990 to 22.1 MtCO2 in 2019. The sector recorded an increase in net carbon dioxide emissions by about eleven-fold, from 2.5 Mt in 1990 to 26.4 Mt in 2019 at an 8.9% annual growth rate. Over the same period, emissions from stationary combustion increased by more than seven-folds while those from mobile combustion increased by more than four-folds. The rise in carbon dioxide emissions in Ghana's energy sector in recent years has been attributed to road transport and electricity generation, particularly the increasing number of vehicles, growing traffic congestion in major cities, and high carbon-intensive thermal electricity generation [16].

Also, labour statistics from the World Bank's World Development Indicators (WDI) seem to suggest that unemployment in Ghana has not been a major economic problem in the past few decades, given the low average unemployment rate of 5.7% and 4% over the period 1991–2021 and 2011–2021 respectively. The unemployment situation in the country has rather worsened over the years. The high level of informality and vulnerable employment in the country's labour market tends to mask the problem of unemployment [5]. According to the Ghana Living Standards Survey (GLSS) data, over the period from 1991 to 2017, unemployment has been consistently higher for females (from 5.4% to 9.2%) than males (3.7% to 7.5%). The Ghana population and housing census also reveals a similar trend with a rise in female unemployment from 10.7% in 2000 to 15.5% in 2021 as against an increase in male unemployment from 10.1% to 11.6% over the same period. Over the years, the country has witnessed a diversion between economic growth and job creation. This has been attributed largely to the slow growth of high labour-absorbing sectors like the agriculture and manufacturing sectors, and increased growth of sectors with low employment-generating abilities [4]. This development over the years has translated into declining levels of employment elasticity of output from 0.64 in 1992–2000 to 0.52 in 2000–2004, 0.56 in 2005–2008, and then finally to 0.28 in 2009–2017 [4]. The trajectory in the employment-output elasticity reflects the failure of growth in the economy to translate into the creation of jobs. In recent years, the unemployment situation, especially among the youth and graduates with various educational qualifications has worsened and is very endemic in urban areas [1,4]. These worrying developments have been linked to several factors including; the continuous population and labour force growth without a corresponding expansion in productive sectors of the economy; challenges with vulnerable employment; the feeble link between the educational system and the productive sectors of the economy; a mismatch between skills acquired by the youth and what the job market requires; and the inability of the formal sector to absorb graduates with employable skills [5,40].

The empirical literature on Ghana has largely revealed economic growth contributes to upsurges in carbon dioxide emissions [22,29]. The positive relationship between carbon dioxide emissions and economic growth in Ghana is further reinforced by rising population growth, energy consumption, and the structure of the economy [29]. Successive governments have initiated and implemented several policies and strategies to mitigate carbon dioxide emissions in Ghana. The measures have included; a forest plantation development programme to check the degradation of forest lands; a ban on the export of round logs to enhance domestic timber processing; natural gas recovery and utilization; restriction on the flaring of gas in the oil and gas industry; increase in the share of renewable energy in the country's energy mix; adoption of energy efficiency practices in households, organizations, commerce, and industry; encouraging the use of clean cooking and lighting; and adoption of innovative waste management practices like recycling, waste reduction, and reuse [3,16]. Nonetheless, carbon dioxide emission continues to rise in the country. In addition, the decoupling of carbon dioxide emissions from the growth of the Ghanaian economy has remained weak over the years [30]. This development presents a great challenge since the projected growth of the Ghanaian economy is linked with both increasing energy consumption and carbon dioxide emissions [22]. The implication of the weak decoupling status in the country is that any attempts to control emissions may require that other macroeconomic goals like growth and employment be sacrificed.

Extensive studies have been conducted on the economic growth- environmental quality nexus based on the Environmental Kuznets Curve (EKC) hypothesis. However, the literature on the unemployment-environmental quality nexus is quite scanty since the EPC hypothesis is a new concept in the environmental economics literature. To the best of our knowledge, no study has focused on the unemployment rate-environmental quality nexus in Ghana with a primary motive to test the validity of the EPC hypothesis. This study thus offers a novel contribution to the literature by investigating if there is any trade-off between unemployment rate and environmental quality (measured by carbon dioxide emission levels) within the Ghanaian context. The study is also novel as it investigates whether there is a gender dimension to the nexus between environmental quality and unemployment in Ghana. This study conducts the empirical investigation within the context that a weak decoupling status may require countries to sacrifice growth and employment to reduce pollution. Ghana's decoupling status over the years, just like most developing and less developed countries, have been largely weak. The study employs macro-level annual data spanning the period from 1990 to 2019. The choice of the study period is mainly due to data limitations. This study is relevant in the following regard: First, it contributes to the scanty literature on the EPC hypothesis, a finding that speaks to the Ghanaian context. Second, Ghana's rising carbon dioxide emission levels and unemployment rate, and weak decoupling status present an appropriate context to investigate the postulations of the EPC. The findings of the study indicate a positive effect of total unemployment on carbon dioxide emissions in the country. In addition, the results show there is a gender dimension to the nexus between unemployment and carbon dioxide emissions in the country. We found carbon dioxide emission in the country intensifies with increases in female unemployment and declines with rising levels of male unemployment. The study provides an appreciation of the interconnection between the achievement of key macroeconomic objectives like economic growth and employment, and environmental sustainability. In particular, the findings reiterate the need for the country to address its slow and weak growth-pollution decoupling status. The findings also underscore the need to create more green jobs, invest in the production and consumption of renewable energy, and adopt environmentally-friendly technologies and production methods. The study provides valuable insights that could inform the formulation of policies to improve environmental quality in the country, which is key to achieving at least six of the Sustainable Development Goals (SDGs) (Goals 3, 7, 11, 12, 13, and 15)[1]

The rest of the paper is organized as follow. Section 2 presents a review of the existing literature. Section three provides a description of the methodology which comprises the empirical model, data and econometric techniques employed. The empirical results are presented and discussed in section 4 and 5 respectively. Section 6 concludes the study with policy implications.

## Literature review

The EPC hypothesis derives its ideas from both the EKC hypothesis and the Phillips Curve. According to the hypothesis, given the positive nexus between pollution and income as posited by the EKC hypothesis and the negative relationship between unemployment and income, it is expected that as unemployment increases, pollution also decreases. Thus, given that output or income growth is directly linked (positively correlated) to employment generation and pollution, a trade-off between controlling pollution and sustaining livelihoods (jobs) may arise. Kashem and Rahman [20] characterized this trade-off or negative nexus between pollution and unemployment as the Environmental Philips Curve (EPC).

The EPC arises out of concerns regarding the decoupling of environmental degradation from economic growth. The quest to expand production has driven most economies to employ more human, physical and natural resources, which has also in turn left trails of pollutants in the environment. The world's socio-economic ecosystems depend heavily on materials and energy for agriculture, livestock, manufacturing and human activities, all of which emit GHGs and waste. As a result, decoupling growth from the resources it requires or the impacts it has on the environment has become an important policy direction in recent years due to the devastating impacts of climate change. The inability to decouple growth from environmental degradation may require that economies check their growth in order to reduce pollution, which could in turn have a negative effect on employment levels. The goal for delinking environmental pressures from resource-driven economic activities is to create sustainable economic growth and development where the economy can meet the needs of every person, both present and the future, outgrow itself and its own effects.

Empirical studies on the EPC hypothesis have produced mixed results based on different methodologies, time span and cross-sections. Before the introduction of the EPC hypothesis, most studies usually employed micro-level data to investigate the impact of unemployment or employment status on environmental quality. Gough et al. [17] studied the distribution and drivers of total direct and embodied GHGs emissions by households in the UK. The study linked an input-output model of the UK economy to a representative UK expenditure survey data. The findings of the study indicated that workless households emit significantly more GHGs than their counterparts with one or more members in employment. Also, using a representative UK expenditure survey, Büchs and Schnepf [8] investigated whether household characteristics and household carbon emissions in the UK differ in the area of domestic energy use, transport and indirect emissions. The results showed that workless households are less likely to be in the highest emission quartile, but are more likely to have high home energy emissions as compared to the other types of emissions. Also using household level data, Han et al. [18] employed a representative resident survey data collated from urban China to investigate how household characteristics differ in their correlation with household embedded carbon emissions. The study found a negative relationship between unemployment and per capita household embedded carbon emissions.

The introduction of the EPC hypothesis by Kashem and Rahman [20] has popularized macro-level studies on the environmental quality-unemployment nexus. The burgeoning research interest in the area is also attributed to the global call for countries to prioritize

[1] See https://sdgs.un.org/goals# for details on the SDGs.

decoupling of economic growth from pollution due to the devastating impacts of climate change. Kashem and Rahman [20] estimated a panel data on 30 countries spanning the period from 1990 to 2016 using panel random effects, fixed effect technique, and Panel Corrected Standard Error (PCSE) estimation techniques. Their estimation results validated the EPC hypothesis.

Subsequently, a number of studies have also employed macro-level data and based their theoretical foundation on the EPC hypothesis. Liu and Feng [23] examine the potential impacts of unemployment and age dependency ratio on global carbon dioxide emissions by using a panel of 77 countries and regions over the period from 1991 to 2020. The study estimated an STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model, which is an extension of the IPAT (Impacts by Population, Affluence and Technology) model, using the fixed effects, Panel-Corrected Standard Error (PCSE) and the Driscoll–Kraay fixed effects estimation techniques. The study found that at the global level, unemployment and carbon dioxide emissions are negatively correlated. However, at the regional level, the results were mixed. Unemployment was found to have a negative influence on carbon dioxide emissions in Africa, America and Europe. However, the study found no strong effects of unemployment on emissions in the Middle East and the Asia-Pacific. Cui et al. [10] found a positive effect of unemployment on carbon dioixde emissions using data on 30 provinces in Chinese mainland for the period 2004–2019 which was estimated using OLS, Generalized Method of Moments (GMM) and mediating effects estimation approaches. Anser et al. [2] applied the Pooled Mean Group (PMG) Autoregressive Distributive Lag (ARDL) estimation technique to panel data on the BRICST economies (Brazil, Russia, India, China, South Africa, and Turkey) spanning the period from 1992 to 2016 and found that the EPC hypothesis holds in these economies.

Furthermore, focusing on a country-specific analysis, Shastri et al. [36] utilized time series data spanning 30 years (1990 to 2019) to test for the presence of EPC in India. Specifically, the study sought to investigate whether there is a gender dimension to the EPC hypothesis in India. The findings according to the Autoregressive Distributive Lag (ARDL), Fully Modified OLS and Dynamic OLS estimators employed, indicated that male unemployment reduces growth in carbon dioxide emission. The findings also revealed declining levels of female unemployment rather help to improve environmental quality. Similarly, Xin et al. [38] also employed annual data from 1991 to 2020 to investigate the dynamic link between education, unemployment and carbon dioxide emissions in China. Results according to the ARDL estimation indicated that unemployment increases carbon emissions in both the short-run and long-run. Bhowmik et al. [6] employed monthly timeseries data over the period from 1985 to 2018 to test the validity of the EPC hypothesis in the United States. The study adopted a dynamic ARDL model to determine and estimate both short-run and long-run impacts of unemployment and policy uncertainty on carbon emissions. According to the findings, the EPC hypothesis does not hold in the short-run but it is valid in the long-run. Also, Daştan and Együ [11] applied the Augmented-ARDL technique to annual data from 1980 to 2018 on Turkey and confirmed that the EPC hypothesis holds in both the short-run and long-run in the country. Yavuz et al. [39] also employed the Augmented-ARDL method to estimate annual data on Turkiye spanning the period from 1982 to 2022. The study found a negative relationship between environmental quality and unemployment rate which indicates the validity of the EPC hypothesis.

From the existing empirical studies, the following conclusions can be drawn. First, there seem to be quite an extensive literature on the drivers of carbon emissions or environmental quality focusing on developed countries. This is probably because developed countries mostly account for a significant proportion of global carbon dioxide emissions. The literature on developing countries is very scanty. Second, micro-level analysis on the emissions-unemployment nexus is skewed towards developed countries and regions probably due to data availability at the household level. Third, the literature on the unemployment-environmental quality nexus at the macro level still remains a burgeoning research interest considering that the EPC is a new concept in the environmental economics literature. The study is novel in the following regard. First, it contributes to the literature on the EPC hypothesis, a finding specific to Ghana, using macro-level data spanning the period from 1990 to 2019. Second, it investigates whether there is a gender perspective to the nexus between environmental quality and unemployment in the country.

## Methods

### *Data sources*

The study employs annual time series data from 1990 to 2019 to investigate the environmental quality and unemployment nexus in Ghana. The dependent variable is environmental quality and it is measured by level of carbon dioixide emissions. The primary independent variable of interest is unemployment rate (total and gender segregated). The control variables are GDP per capita, energy intensity of GDP, renewable energy consumption, and trade openness. Data on all the variables was sourced from the World Bank's World Development Indicators (WDI).

### *Model specification*

The study specifies two models to conduct the empirical investigation. The first model indicates environmental quality (proxy by level of carbon dioxide emissions) is dependent on total unemployment rate, GDP per capita, energy intensity of GDP, renewable energy consumption, and trade openness. The selection of the control variables was informed by the empirical literature on the drivers of carbon dioxide emissions or environmental quality. The second model incorporates gender dis-aggregated unemployment variables instead of total unemployment, given that studies have shown there are gender disparities in the generation of aggregate carbon dioxide emission levels [9,28].

$$lnCO2_t = \alpha_0 + \alpha_1 unemp_t + \alpha_2 lngdpc_t + \alpha_3 energy_t + \alpha_4 renewable_t + \alpha_5 trade_t + \varepsilon_t \quad (1)$$

$$lnCO2_t = \alpha_0 + \alpha_1 fem\_unemp_t + \alpha_2 mal\_unemp_t + \alpha_3 lngdpc_t + \alpha_4 energy_t + \alpha_5 renewable_t + \alpha_6 trade_t + \varepsilon_t \quad (2)$$

*Description of variables*

The dependent variable is environmental quality. It is measured by the log of carbon dioxide emissions in Kilotonnes (kt) ($lnCO_2$), since there is no indicator that captures the overall level of environmental quality or pollution of a country. The unemployment variable (unemp) is measured by the percentage of the labour force that is without work, but available for and seeking employment. The same definition applies to the female (fem_unemp) and male (mal_unemp) unemployment variables. Energy intensity of GDP variable (energy) is defined as total energy consumption (in kilogram of oil equivalent) per $1000 GDP (constant 2017 PPP), expressed in percentages. The renewable energy variable is defined as the percentage share of renewable energy consumption in total final energy consumption. The GDP per capita variable (lngdpc) is log transformed and it is the total market value of goods and services produced by Ghanaians plus product taxes and minus subsidies (at constant 2015 United States dollars) divided by total population. The trade openness variable (trade) is measured by the sum of exports and imports of goods and services as a percentage of GDP. By incorporating these variables in the study model, we capture both the traditional and non-traditional drivers of carbon dioxide emissions.

*Estimation strategy*

Most time series data are observed to be non-stationary and so using them in any econometric analysis without making the necessary adjustments could lead to spurious regression results. Therefore, it is important to run unit root or stationarity tests on time series data to know how to correct for it, either by differencing or detrending with time-trend regression approach. The study subjected the variables to the Augmented Dickey Fuller (ADF) unit root test developed by Dickey and Fuller [13] and the Kwiatkowski Phillips-Schmidt-Shin (KPSS) stationarity tests proposed by Kwiatkowski et al. [21]. Both tests were conducted at level and first difference of the variables. The next step was to investigate if there is any long-run relationship among the variables in the model by using the ARDL bound test for cointegration technique. The cointegration test relies on the outcome of the unit root tests. Where long-run relationship among the variables is detected, an ARDL model with an error correction component is specified and estimated.

*Pre-estimation diagnostic tests*

*Augmented Dickey-Fuller (ADF) test.* The ADF is an extension of the Dickey-Fuller test which involves fitting a model by Ordinary Least Squares (OLS) specified as;

$$Y_t = \alpha + \rho Y_{t-1} + \delta t + \mu_t \quad (3)$$

Where t is time, $Y_t$ is the variable subjected to the unit root test and $Y_{t-1}$ is its one-period lag, $\delta t$ is the time trend and $\mu_t$ is the error term which is assumed to be free of autocorrelation.

The assumption of no serial correlation in the residuals may not always be the case. The ADF test is therefore seen as a Dickey-Fuller test that has been made robust to autocorrelation. The test adds k lagged-difference terms onto the normal Dickey-Fuller estimation equation.

$$\Delta Y_t = \alpha + \rho Y_{t-1} + \delta t + \sum_{i=1}^{k} \theta_i \Delta Y_{t-i} + \mu_t \quad (4)$$

The test is conducted under the null hypothesis that the variable $Y_t$ follows a unit root process ($\rho = 1$) against the alternative hypothesis that the variable is stationary.

*Kwiatkowski Phillips-Schmidt-Shin (KPSS) stationarity test.* Considering that unit root tests have low power which makes them seldom reject the null hypothesis of a unit root, we employ the KPSS stationarity test as a complementary test to double check the results obtained from the ADF test. The KPSS test decomposes a variable into a sum of three parts: a deterministic trend, a random walk term and a stationary error.

$$Y_t = \delta t + r_t + \varepsilon_t \quad (5)$$

Where the random walk term ($r_t$) is defined as;

$$r_t = r_{t-1} + \mu_t \quad (6)$$

The $\varepsilon_t$ is the stationary error term, $\delta t$ is the deterministic trend and $\mu_t$ is an error term assumed to be independent and identically distributed (0, $\sigma^2$).

The KPSS test, which is a Lagrange Multiplier (LM) test, investigates whether the random walk component or term (defined by Eq. (6)) has zero variance. It is conducted under the null hypothesis that a variable exhibit stationarity process. The test statistic is given as;

$$LM = \sum_{t=0}^{T} S_t^2 \Big/ \sigma_e^2 \tag{7}$$

Where $S_t$ and $\sigma_e^2$ are the sum of residuals and estimated error variance from the regression in Eq. (5). Respectively;

$$S_t = \sum_{i=0}^{t} e_i \tag{8}$$

$$\sigma_e^2 = \sum_{t=0}^{T} e_t^2 \tag{9}$$

*Cointegration test*

The next step investigates if there is any long-run relationship among the series in the model by using the Autoregressive Distributed Lag (ARDL) bound test for cointegration technique, given that the model is made up of a mixture of variables integrated of order zero and one. The test is superior to the Engel and Granger [15] and the Johansen and Juselius [19] cointegration tests in the following regard. First, it accommodates variables with different order of integration. Secondly, the inclusion of an appropriate lag length in the ARDL model corrects for serial correlation and endogeneity. Also, it is a suitable approach for small samples. The test is conducted using an unrestricted version of the ARDL model expressed as;

$$\begin{aligned} lnCO_{2t} = {} & \alpha_0 + \phi_1 lnCO_{2t-1} + \phi_2 unemp_{t-1} + \phi_3 lngdpc_{t-1} + \phi_4 energy_{t-1} + \\ & \phi_5 renewable_{t-1} + \phi_6 trade_{t-1} + \sum_{i=1}^{n} \varphi_i \Delta lnCO_{2t-i} + \sum_{i=1}^{n} \gamma_i \Delta unemp_{t-i} + \\ & \sum_{i=1}^{n} \omega_i \Delta lngdpc_{t-i} + \sum_{i=1}^{n} \partial_i \Delta energy_{t-i} + \sum_{i=1}^{n} \varnothing_i \Delta renewable_{t-i} + \sum_{i=1}^{n} \chi_i \Delta trade_{t-i} + + \epsilon_t \end{aligned} \tag{10}$$

Where t index time and Δ is the difference operator. The parameter $\phi_i$ represent vector of long-run coefficients; the parameters $\varphi_i$, $\gamma_i$, $\omega_i$, $\partial_i$, $\varnothing_i$, $\lambda_i$, and $\chi_i$ are short-run coefficients. The $\alpha_0$ is the constant term and $\epsilon$ is the disturbance term.

Eq. (10) is estimated by OLS. A joint test of significance is conducted on the long-run coefficients using the Wald F-statistic to determine if the series are cointegrated. The test is conducted under the null hypothesis that there is no cointegration. The decision-making rule entails comparing the calculated Wald F-statistic based on the OLS estimated regression with Pesaran et al. [31] computed upper and lower bound critical values. Where the F-statistic is higher than the upper bound critical values, it is concluded that the series have a long-run relationship.

*The autoregressive distributed lag- error correction model (ARDL-ECM)*

The existence of long-run relationship among the series allows for the specification of a re-parametrized ARDL model with an error correction term which captures how much deviations in the dependent variable (emissions) from its long-run equilibrium are corrected through a series of short-run (yearly) adjustments. The long-run and short-run models can be specified respectively as follows;

$$lnCO_{2t} = \alpha_0 + \sum_{i=1}^{q} \phi_1 lnCO_{2t-i} + \sum_{i=1}^{p_1} \phi_2 unemp_{t-i} + \sum_{i=1}^{p_2} \phi_3 lngdpc_{t-1} + \sum_{i=1}^{p_3} \phi_4 energy_{t-1} + \sum_{i=1}^{p_4} \phi_5 renewable_{t-1} + \sum_{i=1}^{p_5} \phi_6 trade_{t-1} + \varepsilon_t \tag{11}$$

$$\Delta lnCO_{2t} = \alpha_0 + \sum_{i=1}^{n} \varphi_i \Delta lnCO_{2t-i} + \sum_{i=1}^{n} \gamma_i \Delta unemp_{t-i} + \sum_{i=1}^{n} \omega_i \Delta lngdpc_{t-i} + \sum_{i=1}^{n} \partial_i \Delta energy_{t-i} + \sum_{i=1}^{n} \varnothing_i \Delta renewable_{t-i} + \sum_{i=1}^{n} \chi_i \Delta trade_{t-i} + ECT_{t-1} + \varepsilon_t \tag{12}$$

The error correction term is denoted by *ECT*. Eq. (10)-12 apply also to the model with gender dis-aggregated unemployment

**Table 1**
Descriptive statistics.

| Variables | Obs | Mean | Std. Dev. | Skew. | Kurt. |
|---|---|---|---|---|---|
| $CO_2$ | 30 | 8130.703 | 4774.114 | 0.538 | 2.039 |
| unemp | 30 | 5.768 | 2.116 | 0.601 | 2.652 |
| fem_unemp | 30 | 6.117 | 2.201 | 0.501 | 2.535 |
| mal_unemp | 30 | 5.412 | 2.075 | 0.684 | 2.682 |
| gdpc | 30 | 1259.638 | 355.572 | 0.658 | 1.980 |
| energy | 30 | 103.656 | 33.187 | 0.384 | 1.375 |
| renewable | 30 | 62.287 | 14.299 | 0.055 | 1.496 |
| trade | 30 | 75.25 | 18.693 | 0.271 | 2.577 |

Source: Authors' computation (2024).

variables. Both Fully Modified OLS (FMOLS) and dynamic OLS (DOLS) estimators were employed to estimate the long-run relationship among the variables to check for robustness of the ARDL results.

## Results

### *Descriptive statistics*

Table 1 presents the summary statistics of the variables incorporated in the model. Average carbon dioxide emissions produced in Ghana over the 30-year period is 8130.703 kt. The standard deviation of 4774.114 of the carbon dioxide emissions data indicates low variability in the observed series over the period. The average annual unemployment rate for the period was at about 5.8% with a standard deviation of 2.116, indicating low variance in the observed unemployment data. On average, unemployment among females (6.1%) was higher than males (5.4%) in Ghana over the 30-year period. Both the male and female unemployment data have low standard deviation which suggests that much of data on the two variables are clustered around the mean of 5.4% and 6.1% respectively. The data on GDP per capita exhibits less variability at an annual average of US$ 1259.638 and a standard deviation of US$ 355.572. Average energy intensity of GDP in Ghana over the period 1990–2019 was US$ 103.656 whereas average renewable energy consumption (as a percentage of final energy consumption) was approximately 62.3%. The standard deviation of the energy intensity of GDP and renewable energy consumption variables indicates low variability in the two series.

The skewness statistic indicates the carbon dioxide emission, total unemployment, female and male unemployment variables are moderately skewed whereas the energy, renewable energy and trade data are approximately symmetric. The relatively low Kurtosis statistics for each variable indicate that, for each variable, fewer values are concentrated around the average. Thus, the tail of the distribution of each variable is lighter than a normal distribution.

### *Unit root/Stationarity tests*

The ADF unit root test and the KPSS stationarity test results as displayed in Table 2 show most of the variables attain stationarity at first difference. This indicates that the model is made up of variables with different order of integration, specifically, a mixture of I(0) and I(1) variables. It is therefore appropriate to employ the ARDL technique to estimate the dynamic relationship among the variables.

### *Cointegration test*

The ARDL bounds test for cointegration estimation results points to the existence of a long-run relationship among the variables included in the two models (refer to Table 3). With both models, the results show the Wald F-statistic is greater than the Pesaran et al. [31] computed upper bound critical values, indicating that the null hypothesis of no cointegration can be rejected at even the 1% significance level.

### *ARDL-ECM estimation*

The existence of a long-run relationship among the variables makes it possible to specify and estimate a re-parametrized ARDL model with an error correction component. Table 4 reports the estimation results of the long-run, short-run, as well as the error correction term coefficients. The findings indicate carbon dioxide emissions in Ghana is sensitive to levels of total unemployment in both the long-run and the short-run. Specifically, total unemployment rate has a positive effect on carbon dioxide emissions in the long-run and short-run at the 1% and 5% significance level respectively. Thus, irrespective of the time period, the results show rising levels of unemployment drive carbon dioxide emissions in Ghana. This finding does not validate the Environment Phillips Curve (EPC) hypothesis within the Ghanaian context, but it is consistent with the findings of Xin et al. [38] and Cui et al. [10]. In the long-run, a one percentage point increase in total unemployment results in about 4.6% increase in carbon dioxide emissions given that all the other variables remain constant. In the short-run, a one percentage point increase in total unemployment triggers approximately 4.1%

**Table 2**
Unit root and stationarity tests (Levels and First Difference of Variables).

| | Level | | First Difference | |
|---|---|---|---|---|
| Variable | ADF | KPSS | ADF | KPSS |
| $lnCO_2$ | −0.980 | 1.550 | −6.644*** | 0.037*** |
| unemp | −2.137 | 0.533*** | −4.369*** | 0.152*** |
| fem_unemp | −1.864 | 0.647 | −4.089*** | 0.148*** |
| mal_unemp | −4.089 | 0.411 | −4.577*** | 0.166*** |
| lngdpc | 0.892 | 1.530 | −2.676* | 0.381*** |
| energy | −0.977 | 1.460 | −3.189** | 0.189*** |
| renewable | −0.362 | 1.570 | −5.02*** | 0.179*** |
| Trade | −2.524 | 0.298*** | −5.113*** | 0.145*** |

Source: Authors' computation (2024).
*, ** and *** denote $p < 0.10$, $p < 0.05$ and $p < 0.01$ respectively. The lag length for each variable in both the ADF and KPSS tests is one.

**Table 3**
ARDL bound test for cointegration.

| | | Critical Values | |
|---|---|---|---|
| F-statistics | Significance level | Lower bound | Upper bound |
| Model 1 = 18.620 | 1% | 3.41 | 4.68 |
| | 5% | 2.62 | 3.79 |
| | 10% | 2.26 | 3.35 |
| Model 2 = 15.182 | 1% | 3.15 | 4.43 |
| (unemp separated into fem_unemp and mal_unemp) | 5% | 2.45 | 3.61 |
| | 10% | 2.12 | 3.23 |

Source: Pesaran et al. [31] ARDL bound test statistics and critical values computed using study data and Stata version 15.1.

**Table 4**
ARDL-ECM estimates of the long-run and short-run coefficients.

| | Coefficient | | | |
|---|---|---|---|---|
| Variable | Long-run | | Short-run | |
| unemp | 0.046*** | | 0.041** | |
| | (0.013) | | (0.015) | |
| fem_unemp | | 0.149*** | | 0.136*** |
| | | (0.053) | | (0.057) |
| mal_unemp | | −0.099** | | −0.091** |
| | | (0.045) | | (0.044) |
| lngdpc | 0.687** | 0.931*** | 1.916** | 0.853*** |
| | (0.269) | (0.296) | (0.709) | (0.381) |
| energy | 0.006** | 0.004 | 0.006*** | 0.003 |
| | (0.002) | (0.003) | (0.002) | (0.002) |
| renewable | −0.046*** | −0.041*** | −0.040*** | −0.037*** |
| | (0.009) | (0.009) | (0.005) | (0.006) |
| trade | 0.002 | 0.003*** | −0.003** | −0.002** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| trade(−1) | | | 0.002** | −0.003** |
| | | | (0.001) | (0.001) |
| ecm | | | −0.888*** | −0.916*** |
| | | | (0.143) | (0.153) |
| Constant | | | 5.082*** | 3.463* |
| | | | (1.578) | (1.942) |

Source: Authors' computation (2024).
Standard errors are reported in parenthesis. *, ** and *** denote $p < 0.10$, $p < 0.05$ and $p < 0.01$ respectively. (−1) denote lag 1. The Bayesian Information Criterion (BIC) specified a lag length for each variable in model 1 as (1 0 1 0 0 2) which corresponds to the variables in the following respective order: $\ln CO_2$, unemp, lngdpc, energy, renewable, and trade. For the model 2, the BIC specified the lag length (1 0 0 0 0 0 2). In both models, the maximum lag order for the BIC estimation is 2. All the short-run variables are first-differenced.

increase carbon dioxide emissions when all the other variables remain unchanged. Thus, the impact of unemployment on carbon dioxide emissions remains somewhat stable across the period. Some reasonable explanations have been posited for the positive effect of unemployment on pollution. Büchs and Schnepf [8] explain that workless households are more likely to have higher emissions due to increased home energy use. Meyer [26] and Duarte et al. [14] also opined that economic issues gained more saliency over environmental issues when one is unemployed. They explained that during times of unemployment, affected individuals do not place value on choices that protect the environment. Thus, unemployment may negatively affect the environment since it reduces income and the ability of individuals to make decisions that promote environmental quality.

When unemployment is dis-aggregated by gender, the results indicate a positive correlation between female unemployment and carbon dioxide emissions at the 1% significance level in both the long-run and short-run. This finding confirms with Shastri et al. [36] and Cui et al. [10]. When all the other variables are held constant, a one percentage point increase in female unemployment in the long-run is expected to increase carbon dioxide emissions by about 14.9%. In the short-run, carbon dioxide emissions rise by about 13.6% for every one percentage point increase in female unemployment, given that all the other variables remain unchanged. The positive effect of female unemployment on carbon dioxide emissions could be explained by the favourable impact that female employment has on population growth. Women who are gainfully employed tend to patronize family planning services and therefore are more likely to defer their decision to have children to later in life. This helps to control population growth and its attendant pressures on the environment [36]. Again, studies have shown that empowering women economically and allowing them to partake in decision-making processes contributes to innovation and increased support for environmental protection [12,27]. This is because women are observed to be sensitive to environmental issues and therefore they are more likely to take pro-environmental decisions.

In both the short-run and the long-run estimation results, the male unemployment variable has the expected negative sign at the 5%

significance level which confirms the EPC hypothesis. This suggests that rising levels of male unemployment has a dampening effect on carbon dioxide emissions in Ghana. Specifically, given that all the other variables remain constant, a 1% increase in male unemployment in the long-run (short-run) results in about 9.9% (9.1%) decline in carbon dioxide emissions. Thus, there exists a trade-off between male unemployment and pollution in the country in both the short-run and the long-run. This finding supports the results of Kashem and Rahman [20], Anser et al. [2] and Shastri et al. [36]. In Ghana, high carbon dioxide-emitting sectors of the economy like the AFOLU (Agriculture, Forestry and Other Land Use) and energy sectors employ a greater chunk of the male labour force. Statistics from the round 7 of the GLSS indicates about 41.7% of the employed in the agricultural sector are males whiles 35.1% are females. The data also shows males (0.3%) were more likely than females (0.1%) to be employed in the energy sector. In addition, findings of the 2021 population and housing census in Ghana revealed a similar outcome which shows the agricultural sector employs more males (36.6%) than females (28.8%). The census data also indicates the energy sector has more male workers (0.9%) than females (0.1%). Therefore, it is reasonable to expect pollution to decline when male unemployment is high in these sectors. In addition, studies have proven that men turn to consume more goods and services with larger environmental footprints (example is fuel) [9,28]. Therefore, it is expected that the negative effect of unemployment on the purchasing power of men may help to check their lifestyle and consumption patterns that contribute to pollution.

Also, in both long-run and short-run, the estimation results of the model with total unemployment variable indicate carbon dioxide emissions in Ghana rise with increases in energy intensity of GDP. The consumption of more renewable energy is also found to reduce carbon dioxide emissions in the long-run and the short-run in both models. We found a positive effect of the GDP per capita variable on carbon dioxide emission levels in both the long-run and the short-run of both models at the 5% significance level. This indicates that economic expansion causes upsurges in carbon dioxide emissions in the country. The trade variable is positive and statistically significant at the 5% level in the long-run estimation with dis-aggregated unemployment variables. However, for both models, the short-run estimation results point to a negative impact of the trade variable on carbon dioxide emissions at the 5% significance level. The coefficient of the error correction term is negative as expected and statistically significant at the 1% level in all two estimations. For the model with total unemployment variable, the results show 88.8% of deviations in carbon dioxide emissions from its long-run equilibrium is corrected every year. However, in the case of the model with gender dis-aggregated unemployment variables, the results indicate an increase in the magnitude of deviations in carbon dioxide emissions from long-run equilibrium that are corrected every year (91.6%). In both models, the coefficient of the error correction term indicates a fast adjustment process towards long-run equilibrium.

*Robustness check*

We estimated the long-run relationship among the variables using the Fully Modified OLS and the Dynamic OLS estimation techniques to check for robustness of the ARDL estimation results. Findings from both estimations as displayed in Table 5 validate the ARDL estimation results. Both the FMOLS and the DOLS estimation results do not validate the EPC hypothesis in the case of total unemployment and female unemployment. Rather, they indicate that increase in total unemployment and female unemployment contribute to rising levels of carbon dioxide emissions and a decline in environmental quality in Ghana. The male unemployment variable is negative and significant at the 1% level in both estimations, which confirms the validity of the EPC hypothesis. All the control variables, with the exception of the trade variable, have the expected sign and are statistically significant at the 1% or 5% level.

*Post-estimation diagnosis*

Table 6 presents the post-estimation tests on autocorrelation, heteroscedasticity, and normality. We test first-order and second-order autocorrelation in the residuals of both model 1 and 2 using the Durbin Watson (DW) test and the Breusch Godfrey LM test respectively. The DW statistic for both model 1 and 2 falls within the acceptable range of 1.5–2.5 which suggests that the residuals of both models do not have first-order autocorrelation. In addition, for both models 1 and 2, the Breusch Godfrey Lagrange Multiplier (LM) test shows there is no second-order autocorrelation in the residuals of different years at the 5% significant level. The two models also passed the White's test for heteroscedasticity at the 5% significance level. With regards to the normality test, the Jaraque-Bera test indicate a failure to reject the null hypothesis of normality at the 5% significant level in the case of model 1. For the model 2, the test shows a rejection of the null hypothesis of normality at the 5% significance level. This may not be indicative of a serious problem especially in relation to parameter estimation and hypothesis testing, if outliers are handled appropriately.[2] The recursive test statistic for both models indicate failure to reject the null hypothesis of no structural break at the 5% significance level.

## Discussion

The study has provided insight into the impact of unemployment on environmental quality within the Ghanaian context. It further investigated the gender dimension to the nexus between unemployment and environmental quality in Ghana. The findings have underscored the need for the government to prioritize job creation to not only sustain livelihoods and improve standard of living, but also to control carbon dioxide emissions in order to improve environmental quality. From the findings, it is expected that the creation

[2] See Ramsey and Schafer [32] and [34].

**Table 5**
FMOLS and DOLS estimates of the long-run coefficients.

| | FMOLS | | DOLS | |
|---|---|---|---|---|
| Variable | Coefficient | | Coefficient | |
| unemp | 0.034*** | | 0.104*** | |
| | (0.008) | | (0.029) | |
| fem_unemp | | 0.037* | | 0.291*** |
| | | (0.020) | | (0.069) |
| mal_unemp | | −0.001*** | | −0.236*** |
| | | (0.018) | | (0.086) |
| lngdpc | 0.386** | 0.416*** | 0.286** | 0.007*** |
| | (0.160) | (0.140) | (0.630) | (0.330) |
| energy | 0.006*** | 0.005*** | 0.008*** | 0.015*** |
| | (0.001) | (0.001) | (0.006) | (0.002) |
| renewable | −0.052*** | −0.051*** | −0.059*** | −0.086*** |
| | (0.005) | (0.004) | (0.023) | (0.011) |
| trade | 0.001* | 0.001 | −0.004* | 0.005* |
| | (0.008) | (0.001) | (0.002) | (0.003) |
| Constant | 8.398*** | 8.200*** | 9.376* | 11.728*** |
| | (1.336) | (1.171) | (5.324) | (2.827) |
| R-squared | 0.9914 | 0.9912 | 0.9914 | 0.9997 |
| Adjusted R-squared | 0.9895 | 0.9888 | 0.9895 | 0.9966 |

Source: Authors' computation (2024).
Standard errors are reported in parenthesis. *, ** and *** denote $p < 0.10$, $p < 0.05$ and $p < 0.01$ respectively. the lag order in both FMOLS and DOLS is one.

**Table 6**
Post estimation diagnostic tests.

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| Diagnostic test | Statistic | Prob/ Critical value | Statistic | Prob/Critical value |
| Durbin Watson (DW) test | 2.3838 | | 2.3107 | |
| Breusch Godfrey LM test | 1.941 | 0.176 | 1.790 | 0.1988 |
| White's test (Homoscedasticity) | 28 | 0.411 | 28 | 0.411 |
| Jaraque-Bera Normality test | 0.2668 | 0.823 | 10.710 | 0.0047 |
| Recursive test | 0.3138 | 0.9479 | 0.5626 | 0.9479 |

Source: Authors' computation (2024).

of jobs will help to reduce emissions of workless households and individuals due to increased home energy use [8]. In addition, the increase in income levels and standard of living arising from the provision of employment opportunities will help to increase willingness to pay for improved environmental quality.

The findings of the study indicated that female unemployment drives carbon dioxide emissions in Ghana. Several studies have highlighted the qualities of women that make them effective agents of change when it comes to tackling the pollution menace and protecting the environment [12,27,36]. The positive effects of these qualities on the environment come to bear when women are economically empowered. For instance, in their study to examine the impact of female political representation on climate change outcomes using data from 91 countries, Mavisakalyan and Tarverdi [25] found female representation in politics encourages the adoption of more stringent climate change policies which results in lower carbon dioxide emissions. Therefore, policies should ensure the economic empowerment of women in Ghana and their involvement in decision-making at all levels in matters concerning the environment to enhance the effectiveness of the country's pollution and climate change mitigation strategies. The United Nations (UN) Women, an entity which focuses on gender equality and women empowerment, advises governments to increase women's access to the right technology and productive resources to engender agricultural productivity and food security, which can reduce pressure to deforest more lands and thus reduce emissions. In addition, the organization advises that more investment should be channelled to sectors like the care sector which supports more women with employment. The organization believes such an initiative provides an effective way to divert efforts towards ensuring collective wellbeing and strengthens economies without necessarily generating more emissions.

Also, the findings suggest the EPC hypothesis holds in the case of male unemployment. It is impractical and unsustainable to reduce carbon dioxide emissions by sacrificing livelihoods considering the adverse socioeconomic effects of unemployment. Moreover, the high carbon-emitting sectors like the agricultural and energy sectors, which employ a greater percentage of the male labour force, are key to the growth of the Ghanaian economy. Therefore, given Ghana's slow decoupling status, sustainable employment policies should be pursued to ensure that jobs created in the country promote economic growth, social inclusion and environmental protection.

## Conclusion

The study investigated the nexus between environmental quality and unemployment in Ghana to ascertain whether the EPC hypothesis holds within the Ghanaian context. It also sought to assess whether the environmental quality-unemployment nexus differs for men and women. The study employed annual data from 1990 to 2019. An ARDL-ECM model was specified and estimated following the unit root tests which confirmed the model is made up of variables integrated of order zero and one, and the cointegration test results which revealed the variables in the model have a long-run relationship. The variables incorporated in the model were carbon dioxide emissions (proxy for level of environmental quality), unemployment rate (total and gender dis-aggregated), GDP per capita, energy intensity of GDP, renewable energy consumption (percentage of total energy consumption) and trade openness. The results indicated that in both the long-run and short-run, carbon dioxide emission in Ghana is sensitive to the general unemployment rate in the country, and particularly to both male and female unemployment rate. We also found that whilst increases in energy intensity of GDP leads to upsurges in carbon dioxide emissions in the country, the consumption of more renewable energy has the opposite effect. The findings also pointed to a positive effect of economic expansion (proxy by GDP per capita) on carbon dioxide emissions.

The study concludes that within the Ghanaian context, there is no general pattern in the findings to validate the EPC hypothesis. We recommend a policy direction that combines employment creation with investment in environmentally-friendly technology, resources and production process. This will help to ensure a balance between the achievement of environmental sustainability and macroeconomic goals of economic growth and employment creation. Policies targeted at creating sustainable employment can go a long way towards checking upsurges in carbon dioxide emissions or declines in environmental quality in the country.

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Not applicable.

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## CRediT authorship contribution statement

**Richmond Addison:** Conceptualization, Writing – original draft, Writing – review & editing, Data curation, Methodology, Resources, Formal analysis, Visualization. **Emmanuel Akutcha:** Writing – review & editing, Methodology, Resources. **Godwin Debrah:** Writing – review & editing, Methodology, Supervision.

## 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.

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