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Studying the relationship between women and the environment in developing countries

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Abstract

Purpose – The purpose of this study is to examine whether there is a unidirectional or a bidirectional relationship between women and the environment, and to further study the effect of women on environmental quality.

Design/methodology/approach – To achieve this purpose, a Granger causality test and a random effects panel data model are used to study women–environment relationship in developing countries. Error correction model (ECM) is the chosen estimation technique. A Granger causality test is used because of its frequent use in examining the existence of a unidirectional or a bidirectional relationship between two or more variables. A random effects panel data model is used as it has proven to be more efficient than the fixed-effects panel data model.

Findings – Women Granger-cause environmental quality while the opposite is not true in developing countries in the long run. This indicates the existence of a unidirectional relationship between women and the environment when the long-run relationship is considered. However, when considering the long- and short-run relationship together, the results indicate the presence of a bidirectional relationship. The empirical results of the random effects panel data model through ECM estimation indicate the positive effect of women on improving environmental quality as illustrated by the coefficient of the current change of women. This shows that women are concerned about environmental degradation. In addition, the empirical results highlight the persistence of CO_2 emissions. Results also confirm that foreign direct investment inflows lead to further environmental degradation. However, education and trade openness coefficients are found insignificant at the current period.

Research limitations/implications – The research results have great implications on women empowerment, the reduction of gender bias and the increase in government expenditure on women's education and health because of women's positive effect in improving environmental quality.

Originality/value – To the best of the author's knowledge, this is the first paper that examines the two-way relationship between women and the environment and, hence, it fills the gap present in the literature.

Keywords Women, Environmental quality, Granger causality test, Error correction model, Developing countries, Random effects panel data model

Paper type Research paper

1. Introduction

Nowadays there is a growing concern about environmental quality. People all over the world are starting to not only see but feel the hazards of environmental degradation. Environmental issues have been accumulating for a long period of time. Industrialization, economic growth, foreign direct investment (FDI), heavy use of fossil fuels and wrong consumption patterns carry most of the blame. In sum, global environmental issues such as global warming, rise in pollution emissions level, ozone depletion and loss of biodiversity are mainly anthropogenic, a result of wrong production and consumption patterns of humans. Substantial research has been conducted to study the factors affecting environmental quality. A relatively recent development in environmental economics is the

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focus on the effect of women on environmental quality. The interest in studying this relationship was evident earlier in other disciplines such as sociology and psychology but it is considered relatively new in environmental economics. A considerable strand in the literature discusses the positive impact of women on the environment. This is usually attributed to women's sense of responsibility towards their children as caregivers, their experience and/or their multiplier effect on their children (McStay and Dunlap,1983; and Todaro and Smith, 2020). On the other hand, there is an opposing view stating that men are more environmentally concerned because of being more aware and financially capable of demanding expensive green goods (Eisler *et al.*, 2003; Xiao and Hong, 2010). Hence, women–environment relationship is a debatable issue. As a step towards settling this debate, the main objective of the research is to study the relationship of women and the environment, its nature and its direction from an economic perspective to have a better understanding of this relationship.

To reach this end, several research questions are addressed such as:

RQ1. Is there a relationship between women and the environment in developing countries?

RQ2. If so, is it a unidirectional or a bidirectional relationship?

And what is the nature of women and environment relationship? To answer these questions, a Granger causality test and a random effects panel data model are used (Granger, 1969). This is applied in a sample of 33 developing countries in the period 1980–2018 for Granger causality test and a sample of 18 developing countries in the period 1987–2018 for the random effects panel data model because of data availability. A Granger causality test is used because of its ease in examining the existence of a unidirectional or a bidirectional relationship between two or more variables. It can be used through several estimation techniques such as ordinary least squares or error correction model (ECM; Hassaballa, 2014). It has been commonly used in several environmental economics research work such as that of Hoffmann *et al.* (2005), Lee (2009) and Hassaballa (2014). Developing countries are chosen to be studied because of the dire environmental condition in many developing countries because of poor water quality, sanitation, high pollution emissions level and toxic chemicals which have great health impact. As mentioned in the World Health Organization [The World Health Organization (WHO) Report, 2021] report on "Environment and Health in Developing Countries", the poor environmental quality in developing countries is the main reason behind spread of diseases and increase in the number of deaths and disabilities. "The resulting impacts are estimated to cause about 25% of death and disease globally, reaching nearly 35% in regions such as sub-Saharan Africa" [The World Health Organization (WHO) Report, 2021] [1]. Hence, it is of vital importance to study women and environment relationship specifically, and to study the determinants of environmental quality generally so as to reduce further environmental degradation in developing countries.

The rest of the paper is organized as follows: Section 2 reviews the literature in which theoretical and empirical reviews are given. Section 3 explains Granger causality test and the model used. Section 4 displays the empirical results. Section 5 provides conclusion and policy implications.

2. Literature review

Many theories have been developed to explain the relationship between women and the environment. Because of the diversity and the richness of women–environment relationship, sociological, psychological and economic theories were formulated. These theories can be

grouped under three different views, namely, the Western view, the oriental view and the neutral view (Chileshe, 2020).

Under the Western view, socialization theory, ecofeminism approach and gender identity maintenance theory are discussed. For instance, McStay and Dunlap (1983) and Strapko *et al.* (2016) argue that gendered difference with respect to the environment can be explained through the socialization theory. During socialization, children acquire their gendered identities, which in return affect their attitude and/or concern regarding environmental quality. Pavco-Giaccia *et al.* (2019), Barbour (1980), Gray (1979), Merchant (1979) and Reuther (1975) highlight that men are socialized to be responsible for technological change, rationality and competitiveness – traits that do not incorporate the environmental dimension. On the other hand, women are socialized to be mothers or caregivers and, hence, they become more concerned of preserving environmental quality in which their children are living. Not only this, but also assigned men roles make men view nature as the main provider for raw materials to achieve economic growth. Hence, men acquire a "marketplace mentality", which is mainly concerned about economic growth (McStay and Dunlap, 1983). However, because women have little power in controlling political, social and economic institutions in their societies, they become less dedicated to achieving these institutions' objectives and even more skeptical and concerned of the inability of these institutions to promote economic growth without resulting in environmental degradation (Cowan, 1979; Passino and Lounsbury, 1976; Reed and Wilkes, 1980). This explanation illustrates the institutional trust hypothesis in which women usually have trust issues when it comes to government institutions and science than men. This can be attributed to the socialization theory. Accordingly, it can be concluded from this discussion that women are more concerned about environmental quality than men.

Furthermore, ecofeminism approach reaches the same conclusion but from a different perspective. Ecofeminism asserts the existence of a strong link between women and the environment (Hosseinnezhad, 2017; Mukherjee, 2013; Shiva, 1989). This approach even extends further to acknowledge the presence of a very unique relationship between women and the environment. The reason of this unique relationship can be attributed to different factors such as women's role as mothers and caregivers (moving in line with the socialization theory in this respect), and women's biological function related to pregnancy, childbirth and lactation (Rico, 1998). All this give women a special mentality and attitude towards the environment. Having this, together with their better knowledge of the environment stemming from their experience, women not only become more concerned about environmental quality, but they are also better rescuers of the environment (Shiva, 1989). Ecofeminism approach is criticized for treating all women alike in spite of their age, ethnic, education or social class differences (Rico, 1998). In addition, Leach (1992) stated that ecofeminism grant women the right to be the rescuers of the environment without bearing in mind the presence of the complementary factors to achieve this result. Nevertheless, there is one interesting analogy given by the ecofeminist approach that is still worthy of discussion. That is, ecofeminism illustrates the dominance of patriarchal and dualistic societies through comparing the inferiority of women to men with that of the environment to culture (Rico, 1998). In this respect, both women and nature share sufferings; women as being oppressed, and nature as being exploited. In addition, the gender identity maintenance theory states that women are more environmentally friendly because "an eco-friendly person" is stereotyped by the society as being feminine, a trait that men will normally do not wish to be described as (Brough *et al.*, 2016; Jerndahl and Næss, 2018: Chileshe, 2020). Hence, men will have the motive and tendency to refrain from showing any environmentally friendly concerns or acts.

From an economic perspective, women have a major impact in improving environmental quality. This is mainly because of their multiplier effect. This multiplier effect is realized

through the influence of a mother on her children (Lepeley, 2019; Todaro and Smith, 2020). For instance, there is a strong tendency for educated mothers to have educated children. Likewise, environmentally friendly mothers will transmit their environmentally friendly concerns and attitude to their children resulting into a multiplier effect. Hence, strategies that target women's empowerment and/or improvement of women's education and income in general are encouraged because of their influence on preserving environmental quality. Both factors are represented via a multiplier effect of women on their children.

Opposite to this, the second view is more of an oriental view that states that men are more concerned about the environment than women (Arcury *et al.*, 1987; Arcury and Christianson, 1990; Aoyogi-Usui *et al.*, 2003; Eisler *et al.*, 2003; Xiao and Hong, 2010). This can be because of having more access to education, especially in developing countries, which results in gaining more awareness of environmental hazards. Another possible explanation can be that because in many developing countries men are getting higher income than women, this makes them afford relatively more expensive green products.

The third explanation is the neutral view that states that there is no major difference between men and women's attitude regarding environmental quality and this mainly because of that the fact that gender differences have decreased massively (Blocker and Eckberg, 1989; Berenguer *et al.*, 2005; Chileshe, 2018).

All the above theories and hypotheses assert that the nature of the relationship between women and the environment exhibits a unidirectional relationship: from women to the environment. Nevertheless, environmental quality can affect women, too. Thus, the relationship between women and the environment is more complex than it may seem because it can be expressed through a bidirectional relationship.

The effect of environment quality on women is mainly illustrated through the link between environmental degradation and poverty. The poor are more affected by environmental degradation than the rich. This is mainly because of lack of resources to mitigate environmental damage or the lack of appropriate infrastructure to cope with environmental threats [2]. Furthermore, most of the poor are women and children, especially in developing countries (Todaro and Smith, 2020). Hence, women are more affected by environmental hazards than men. This was best described by Bedri and Osama (1992): "When environmental deterioration occurs, women are the first to suffer; when economic gains occur, women are the last to receive the benefits". In addition, according to the United Nations data, 80% of relocated people, as a result of climate change, are women [3].

Hence, theoretically, there is an ongoing debate on the direction and nature of women–environment relationship. It will be interesting then to provide a quick empirical review of this relationship to examine whether this debate is also present on the empirical level or not. This will be through reviewing the effect of women on the environment first and then the effect of the deterioration of environmental quality on women.

As early as 1972, McEvoy showed that men have more environmental concerns than women. Opposite to this, the research conducted by Passino and Lounsbury (1976) and Reed and Wilkes (1980) indicated that women are more environmentally concerned than men. Furthermore, subsequent research such as the work of Baldassare and Katz (1992), Roberts (1993); Steel (1996), Stern *et al.* (1995); and Widegren (1998) show that women have more environmentally friendly behaviour than men. In contrast, Mohai (1992) indicated that men are more environmentally proactive. In addition, Arcury and Chriatianson (1993) and Blocker and Eckberg (1997) indicated the presence of insignificant difference between men and women with respect to environmental proactive behaviour. More up-to-date research as that conducted by Sundström and McCright (2014); Xiao and McCright (2015), Brough *et al.* (2016) and Al Ayouty *et al.* (2021) showed that women are more environmentally aware.

Moving in line with this but from a different perspective, Fredriksson and Wang (2011) and Fraune (2016) have shown in their research work on the US congress that congress women prefer stringent environmental laws than men. Nevertheless, other studies such as that of Eisler *et al.* (2003) and Xiao and Hong (2010) have shown that men are more active in participating in environmentally friendly behaviour than women. In addition, Ramstetter and Habersack (2020) have shown in their research that both men and women are concerned about the environment; however, when it comes to legislation, men are more in control.

On examining the effect of environmental degradation on women, Bedri and Osama (1992) showed that women are more affected by environmental crisis than men. Furthermore, Clougherty (2010) indicated in her research work that there is evidence for the greater effect of high pollution emissions level on women than men in spite of the fact that the results can vary sometimes. This can be attributed to cultural or biological differences (Clougherty, 2010). Furthermore, Gu *et al.* (2020) studied the effect of pollution emissions level on female labour participation in China using two-stage least square estimation technique. Their results showed that pollution emissions level as instrumented by the maximum wind speed has a negative and significant effect on female labour force participation (Gu *et al.*, 2020).

The debate is thus not restricted to the theoretical level, but extends also to the also to empirical level. It is therefore essential then to further analyse the women–environment relationship to have a better understanding of this complex relationship. To the best of the author's knowledge, this is the first paper that examines the two-way relationship between women and the environment and, hence, it fills the gap present in the literature. Furthermore, it is important to highlight that there is a shortage in the literature with respect to empirical research papers conducted to study the relationship between women and the environment in developing countries. This is evident from the review of previous research work as most of them focused on examining this relationship in developed countries. For instance, among the reviewed papers, only Bedri and Osama (1992), Xiao and Hong (2010), Gu *et al.* (2020) and Al Ayouty *et al.* (2021) studied this relationship in developing countries, particularly in Sudan, China and Egypt. Clougherty (2010) studied this relationship in developed and developing countries. Thus, there is a gap in the literature in studying women–environment relationship in developing countries. For that, this research paper focuses on developing countries to have a better understanding of women–environment relationship in general and to fill the gap present in the literature in developing countries in particular.

3. Granger causality test and model estimation

3.1 Granger causality test

To examine the existence of a two-way relationship between women and the environment, a Granger causality test is used. This is conducted through identifying how much of the current values of variable Y is explained by the preceding values of variable Y and the preceding values of variable X (Granger, 1969). Hence, we are testing if previous values of variable X improve the estimation of variable Y. The variables are assumed to be stationary over time. The Granger causality test in an autoregressive distributed lag, in its simplest form, is illustrated as follows:

$$Y_{i,t} = \alpha + \varphi Y_{i,t-1} + B_1 X_{i,t-1} + B_2 X_{i,t-2} + \ldots + B_K X_{i,t-K} + e_t \quad (1)$$

The null hypothesis to be tested is X does not Granger-cause Y, that is, $B_1 = B_2 = \ldots = B_k = 0$. The F statistic is used to examine the joint hypothesis at a chosen level of significance. If we reject the null hypothesis, then, the past values of X Granger-cause Y. Similarly, another

equation is formed to test the other direction of the relationship in which we test whether the past value of variable X and past values of variable Y explain the current value of variable X. The null hypothesis is Y does not Granger-cause X and is verified using the same statistics explained above:

$$X_{i,t} = \rho + \lambda X_{i,t-1} + \Omega_1 Y_{i,t-1} + \Omega_2 Y_{i,t-2} + \ldots + \Omega_K Y_{i,t-K} + \upsilon_t \quad (2)$$

3.2 Model estimation

Applying these Granger causality tests will identify the direction of the relationship between women and the environment. After doing so, it will be interesting to identify the nature of the relationship between women and the environment. To do so, a random effects panel data model is used as illustrated below:

$$Y_{it} = \alpha + \sum_{j=1}^{k} \beta_j X_{jit} + c_i + e_{it} \quad (3)$$

where Y_{it} is the dependent variable for country i at time t. X_{it} is the vector of explanatory variables for country i at time t, c_i represents the random variation between the cross-sectional units and e_{it} is the idiosyncratic error which is independent of the cross-sectional units and time periods.

The advantage of using panel data model is that panel data model increases the sample size, which results in better estimation and increases the power of the test statistics. In addition, it allows for more degrees of freedom.

The decision to use random effects panel data model has been reached after conducting Hausman test. The null hypothesis is that the preferred model is random. The results of Hausman test indicated that we cannot reject the null hypothesis and, hence, the random effects model is more appropriate because of being more efficient and consistent than the fixed-effects panel data model.

3.3 Variable used and data sources

There are two main variables used in this empirical investigation, namely, carbon dioxide emissions per capita (measured in metric tons per capita) and females as a percentage of population to account for environmental quality and women, respectively.

In addition, traditional determinants of environmental quality such as FDI, education level and trade openness are used.

Hence, the chosen variables and their expected signs are as follows:

Carbon dioxide per capita $(CO)_2$ is the *dependent vari*able and measures environmental quality. This is because carbon dioxide is one of the greenhouse gases which results in higher air pollution level and global warming, thereby contributing to the deterioration of environmental quality. Accordingly, reducing carbon dioxide emissions level will result into less pollution and, hence, a better environmental quality. In addition, it is commonly used to reflect environmental quality by other researchers such as Shahbaz *et al.* (2017), Cialani (2007) and Malik (2021).

3.3.1 Explanatory variables. CO_2 *per capita is regressed on the lag of carbon dioxide per capita* $(CO_2)_{t-1}$ to measure whether there is persistence in carbon dioxide emissions level or

there is correction, in this respect. Hence, the expected sign is positive, indicating persistence and negative indicating correction.

Women (FEM) is the percentage of females in the total population as residents in a country. This is the main explanatory variable, and the expected coefficient sign is indistinct. It can be positive if women are not environmentally friendly. Women can be a reason for pollution if they do not incorporate the environmental dimension in their decision. This can be because of lack of awareness, lack of affordability or simply being more engaged in solving the rather "pressing" economic problems such as poverty or unemployment. Accordingly, preserving environmental quality will be a luxury good that women cannot simply afford or think of. It can be negative to indicate an environmentally friendly behaviour of women as explained in the theoretical review.

It is important to highlight that the relationship between environmental quality and population was tested before through Granger causality test whether in its aggregate form as tested by Sulaiman and Abdul Rahim (2018) in their paper entitled "Population Growth and CO_2 Emission in Nigeria: A Recursive ARDL Approach", or through the sub-aggregates form as tested by Boamah *et al.* (2018) in their papers entitled: "A Study on Causal Effect of Urban Population Growth and International Trade on Environmental Pollution: Evidence from China" [4]. Hence, testing for Granger causality between environmental quality and female percentage in the population is a slight modification to what has been done previously by other researchers because females are sub-aggregates of the population as well.

Furthermore, women participation in the labour force has been used before in the literature as an indicator for women; however, women participation in the labour force does not include all women. Following the discussion in the literature review, women whether working or not may have a positive effect on the environment, and this is the rationale that the paper adopts. It is more of a general study of women relationship with the environment rather than focusing only on women in the labour force. The literature highlighted that woman in general cares about the environment because of being caregivers or because of their sense of responsibility or their biological characteristics, for instance. Hence, the percentage of women in the labour force excludes housewives for example, who may be pro-environment than many women engaged in the labour force. Following the same logic, the effect of environmental degradation does not necessarily differentiate between housewives and working women [5]. Accordingly, the percentage of females in the population is used instead.

Education (EDU) is the total enrolment that corresponds to a successful completion of secondary school education. This is obtained through dividing the number of students registered in the tertiary education at any age by the population of the age group, which officially represents tertiary education and multiplying by 100. The expected coefficient sign is negative as with higher education level, students become more environmentally aware which will be reflected in improving environmental quality. Hence, lower carbon dioxide emissions per capita.

FDI inflows is measured as net inflows of investment (10% or more of voting stock) in a firm operating in a different country of origin divided by gross domestic product (GDP). The expected sign of the coefficient is indefinite. It is positive if FDI is concentrated in polluting industries as explained by the pollution havens hypothesis. On the other hand, the coefficient of FDI can be negative, indicating the FDI is improving environmental quality as stated by the pollution haloes hypothesis (Hassaballa, 2011).

Trade openness (TO) is measured as the sum of exports and imports of goods and services divided by GDP. The expected coefficient sign is positive if trade is concentrated in

illegal goods and services, and is negative if trade promotes the exchange of environmentally friendly goods and services.

Data sources: Data is obtained from the World Development Indicators database of the World Bank [6].

The sample used: A total of 33 middle-income developing countries in the period 1980–2018 for Granger causality test and a sample of 18 middle-income developing countries in the period 1987–2018 for the random effect panel data model because of data availability [7].

4. Empirical results

To apply this on studying the relationship between women and the environment, it will be more interesting to look first at the summary statistics of CO_2 and FEM displayed in Figures 1 and 2.

To perform the Granger causality test, stationarity of the variable should be examined first. To do so, the augmented Dicky–Fuller and Philips–Peron tests of CO_2 and FEM are used, and their results are shown in Tables 1–4.

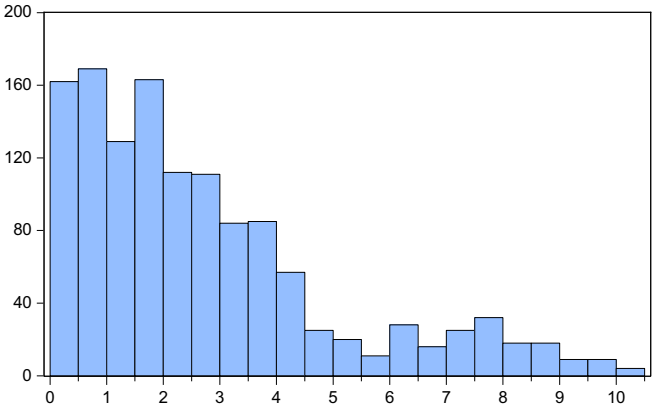
At a 1% level of significance, the unit root tests indicate that CO_2 is I(1), while FEM is I(0) [8]. Accordingly, not all variables are I(1). For that the ECM specification proposed by Pesaran *et al.* (1999) is used because cointegration requires that all variables are I(1). Pesaran *et al.* (1999) have proven that a long-run relationship can exist even if not all variables are I(1). ECM has many advantages, among which are the inclusion of the disequilibrium term ensures that no information is disregarded and the minimization of the chance of obtaining spurious results [9].

To conduct Granger causality test in an ECM specification, the following equations are used:

$$\Delta\ Co2_{i,t} = \text{lagged}\left(\Delta\ Co2_{i,t-1},\ \Delta\ fem_{i,t-1}\right) - \lambda_1 e_{1i,t-1} + \in_{1i,t} \tag{4}$$

$$\Delta\ fem_{i,t} = \text{lagged}\left(\Delta\ fem_{i,t-1},\ \Delta\ Co2_{i,t-1}\right) - \lambda_2 e_{2i,t-1} + \in_{2i,t} \tag{5}$$

where in equations (4) and (5), CO_2 is carbon dioxide per capita, FEM is the percentage of female population in the total population as residents in a country and λ represents the



Source: Based on data from the WDI

Figure 1.
Summary statistics (CO_2)

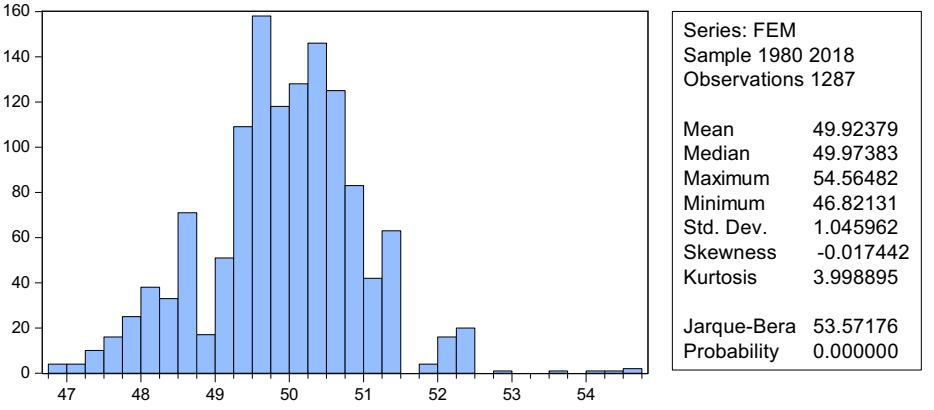


Figure 2.
Summary statistics (women)

Source: Based on data from the WDI

Table 1.
Results of the augmented Dicky–Fuller unit root tests of CO_2

	Level		First difference	
Method	Statistic	Prob	Statistic	Prob
ADF-Fisher Chi-square	42.5342	0.9890	461.985	0.000
ADF-Choi Z-stat	4.54322	1.0000	−17.1195	0.000

Table 2.
Results of the Phillips–Perron unit root tests of CO_2

	Level		First difference	
Method	Statistic	Prob	Statistic	Prob
PP-Fisher Chi-square	45.9137	0.9717	723.339	0.000
PP-Choi Z-stat	5.87900	1.0000	−23.1609	0.000

Table 3.
Results of the augmented Dicky–Fuller unit root tests of FEM

	Level		First Difference	
Method	Statistic	Prob	Statistic	Prob
ADF-Fisher Chi-square	398.193	0.000	640.419	0.000
ADF-Choi Z-stat	−12.6918	0.000	−20.089	0.000

Table 4.
Results of the Phillips–Perron unit root tests of FEM

	Level		First difference	
Method	Statistic	Prob	Statistic	Prob
PP-Fisher Chi-square	148.123	0.000	74.5374	0.2204
PP-Choi Z-stat	0.05980	0.52	−1.43393	0.0758

coefficient of the disequilibrium error term (e). The disequilibrium error term (e) is the lagged residual obtained from the long-run estimation.

In an ECM specification, there are two channels for Granger causality (Zhang and Felmingham, 2001). The first channel is represented through λ reflecting adjustment to the long-run equilibrium of the variables, whereas the second channel considers the short-run response of one variable. The null hypothesis tested in the first channel is no long-run effect between the variables while that of the second channel is to test whether the lagged changes of the independent variables and the coefficient of the disequilibrium error term are jointly equal to zero. Not considering the first channel results in the misspecification of the Granger causality tests. Accordingly, a bidirectional relationship is realized when λ_1 and λ_2 are significant. A unidirectional relationship is achieved if only one of them is significant. If both are insignificant, Granger causality can still exist through the second channel, which reflects the short-run interaction between the two variables. If so, the standard Granger causality tests are conducted using the F-test (Ibrahim, 2000). Tables 5 and 6 show the results of Granger causality test between women and the environment in developing countries via the first and second channels, respectively. The two lags are chosen as depicted by the unit root test results. This also avoids the loss of degrees of freedom given the relatively small size of the sample. Hausman test indicates that the random effects panel data model is more appropriate than the fixed effects. The interpretation of results is at 1% level of significance.

Explaining the results of the two channels of Granger causality tests of equations (4) and (5), the coefficient of the lagged error term of short-run disequilibrium term depicted by λ_1 and λ_2 indicated that women Granger-cause environmental quality while the environment does not Granger-cause women in developing countries when testing for no long-run effect. This is because λ_1 is found significant and with the expected negative sign, whereas λ_2 is found insignificant at 1% level of significance but with the expected negative sign as well. This indicates the presence of a unidirectional relationship between women and the environment going from women to the environment and the absence of a bidirectional relationship in the

Table 5.
Granger causality test results for developing countries (no long-run effect) H_o: $\lambda = 0$

Results	Significance of λ	Decision
FEM does not Granger-cause CO_2	−0.0125 (−3.6438)*	Reject null
CO_2 does not Granger-cause FEM	−0.0001 (−0.4800)	Do not reject null

Note: *Significant at 1% level of significance

Table 6.
Granger causality test results for developing countries (all coefficient jointly to test for Granger causality in the short and long run in the case of two period lags)

Results	F-statistic	Probability	Decision
FEM does not Granger-cause CO_2	4.3195	0.00067	Reject null
CO_2 does not Granger-cause FEM	11,710.98	0.00000	Reject null

Note: H_o: the lagged changes of the independent variables and λ jointly = 0

long run. The results are thus in line with the Western view, socialization theory, ecofeminism approach, gender identity maintenance theory and the multiplier effect argument, and opposite to the oriental view.

Nevertheless, the second channel results of Granger causality in ECM specification via F-test indicate the presence of a bidirectional relationship between women and the environment. This is because the null hypothesis of whether the lagged changes of the independent variables and the coefficient of the disequilibrium error term are jointly equal to zero has been rejected. Accordingly, the results show that there is a bidirectional relationship between women and the environment in developing countries when both the short and long run are considered together [10]. The discrepancy in results when the long run is examined, and the long and short run are examined jointly can be attributed to the short-run interaction between the dependent and the independent variables.

Based on these results, the inclusion of women as a determinant of environmental quality improves the estimation of environmental quality. Accordingly, women is used as an explanatory variable of environmental quality among other traditional determinants stated previously. ECM is the chosen estimation technique for a random effects panel data model, as shown in equation (6):

$$\Delta\ CO_{2i,t}\ = \left(Lagged\left(\Delta\ CO_{2i,t-1},\ \Delta\ Fem_{it},\Delta\ TO_{it},\Delta\ FDI_{it},\ \Delta\ EDU_{it},\right)\ -\lambda\ \ e_{i,t-1}\ \ +\varepsilon_{i,t}\right. \tag{6}$$

where $CO_{2i,t-1}$ is carbon dioxide per capita at time $t-1$ for country i, Fem_{it} is percentage of female in the total population at time t for country i, TO_{it} is trade openness at time t for a country i, FDI_{it} is FDIs inflows at time t for a country i, EDU_{it} is the total enrolment that corresponds to a successful completion of secondary school education at time t for a country i, λ is the coefficient of the disequilibrium error term, $e_{i,t-1}$ is the lagged residual from the long-run regression representing the disequilibrium error term and $\varepsilon_{i,t}$ is the error term which is composed of c_i representing the random variation between the cross-sectional units and e_{it} is the idiosyncratic error, which is independent of the cross-sectional units and time periods in random effects model.

Random effects panel data model is chosen as it has been proven to be more efficient than the fixed-effects panel data model by the Hausman test results. Two periods lag was used to save degrees of freedom given the small size of the sample. The ECM results of the random effects panel data model with homogenous slopes are shown in Table 7.

The empirical results indicated that the coefficient of current change of women contributes positively towards environmental improvement because it is found significant and negative at 5% level of significance. This indicates that women decrease carbon dioxide emissions per capita and hence are more environmentally friendly, which moves in line with Western view, socialization theory, ecofeminism approach, gender identity maintenance theory and the multiplier effect argument and is opposite to the oriental view. Also, this finding is similar to the results obtained by many researchers discussed in the empirical review such as Sundström and McCright (2014), Brough *et al.* (2016) and Al Ayouty *et al.* (2021). However, this contradicts the work of McEvoy (1972), Eisler *et al.* (2003) and Xiao and Hong (2010). However, in one period and two periods lag, it was found insignificant.

The coefficient of current change of FDI is also significant and positive at 1% level of significance. This moves in line with the pollution havens hypothesis, which states that the freer the trade and movement of capital are, the more the shift of polluting industries via FDI from developed to developing countries, resulting in a deterioration of environmental

Variable	Coefficient	Std. error	*t*-statistic	Prob.
D(CO_2(−1))	*0.201085*	*0.039490*	*5.09205**	*0.0000*
D(CO_2(−2))	0.030959	0.039226	0.789252	0.4304
D(FEM)	*−1.642806*	*0.654325*	*−2.51068***	*0.0124*
D(FEM(−1))	2.360828	1.193395	1.97824*	0.0485
D(FEM(−2))	−1.127930	0.658127	−1.713849	0.0872
D(TO)	0.000191	0.001075	0.177729	0.8590
D(TO(−1))	*0.003600*	*0.001051*	*3.42439**	*0.0007*
D(TO(−2))	0.002013	0.001059	1.901106	0.0579
D(FDI)	*0.013915*	*0.004478*	*3.10731**	*0.0020*
D(FDI(−1))	−3.88E−05	0.004442	−0.008731	0.9930
D(FDI(−2))	−0.007823	0.004439	−1.762139	0.0787
D(EDU)	0.000662	0.005049	0.131077	0.8958
D(EDU(−1))	0.003080	0.005365	0.574053	0.5662
D(EDU(−2))	−0.004766	0.005159	−0.923932	0.3560
RES1(−1)	*−0.027114*	*0.005060*	*−5.35831**	*0.0000*
C	0.017261	0.011118	1.552501	0.1212

Notes: Sample (adjusted): 1990–2018; total panel observations: 522; periods included: 29; cross sections included: 18; dependent variable: D(CO_2); *R*-squared: 0.3; italics indicate significance; * and **significant at 1% and 5%, respectively

Table 7.
ECM results of the random effects model

quality in developing countries. Nevertheless, in one period and two periods lag, it was found insignificant.

The coefficient of the change of carbon dioxide emissions per capita at one period lag is found significant and positive at 1% level of significance. This indicates that there is persistence of carbon dioxide emissions level because it is dependent on previous period. However, it was found insignificant when two periods lag is considered.

The coefficient of the current change of trade openness and at two periods lag is found insignificant. However, it was found significant and positive at 1% level of significance in one period lag. This indicates trade of the previous period deteriorates the current environmental quality.

The coefficient of the lagged error term of the short-run disequilibrium is found significant and with expected negative sign at 1% level of significance. This indicates that there is adjustment towards the long-run relationship.

The coefficient of the change of education at the current period, one period lag and two periods lag is found insignificant. This may point to the need for greater effort to promote education and to raise awareness on the preservation and improvement of environmental quality.

It is important to comment at the relatively low value of the *R*-square because it is only 0.3. Usually in dynamic panel, *R*-squared is not expected to be high because of the heterogeneity in cross sections and the reliance should be on the individual significance and the overall significance of the model [11].

5. Conclusion and policy implications

This research work studied the relationship between women and the environment. This has been conducted using Granger causality test in a panel data model in a sample of developing countries over the period 1980–2018. The results of the test indicated the existence of a unidirectional relationship between women and the environment in the long run. However,

the results show that there is a bidirectional relationship between women and the environment in developing countries when both the short and long run are considered together. Furthermore, the effect of women on environmental quality is examined using a random effects panel data model in a sample of developing countries during the period 1987–2018 because of data availability. The empirical results of the random effects panel data model indicated the positive effect of women on improving environmental quality. This shows that women are concerned about environmental degradation in middle income developing countries. In addition, FDI inflows contribute negatively to environmental quality as indicated by the positive significant coefficient of current change of FDI. Results also raise concerns about the types of goods and services traded in developing countries. This is because of the positive significant coefficient of change of TO in the previous period. Education coefficient is insignificant, indicating that the government, NGOs and people in general should exert more effort to use education properly and efficiently in the fight against the deterioration of environmental quality.

The research results have important implications for the empowerment of women, the reduction of gender bias and the increase in government expenditure on women's education and health because of women's positive effect in improving environmental quality. Accordingly, the governments and non-governmental organizations in developing countries should exert greater effort to improve women living conditions through providing women with access to credit, training programs and offering employment opportunities. This is not only because of women's positive effect on environmental quality but also because of their multiplier effect because environmentally friendly mothers will transmit their environmentally friendly concerns and attitude to their children resulting into a multiplier effect.

In addition, developing countries governments should continue monitoring the type of FDI flowing to their countries to ban polluting FDI and to shift to more environmentally friendly FDI. Hence, stringency of environmental laws is a must.

Furthermore, more effort is needed to promote education because the results have shown that the efforts exerted are not enough. Accordingly, governments in developing countries should spend more in education through building new schools, reviewing the taught curriculum, raising teachers' salaries to reduce private lessons, motivating parents to send their children to school, combating child labour and reducing children drop-off from school rates.

Concerning trade openness, developing countries should adopt stringent laws regarding polluting or illegal goods. Quotas or tariffs can be used to control the flow of these types of goods. Penalties can be used to reduce any illegal behaviour. International agreements regarding this issue should be enforced and complied with.

Regarding the persistence of carbon dioxide emissions, stringent environmental regulation is of great importance here, too. This can be through choosing between the command-and-control approach, economic incentive approach or the non-mandatory approach. Each country should pick whichever regulatory approach suitable to its condition. Usually when markets are well developed, and information is available, which is not the case in many developing countries, economic incentive approach or non-mandatory approach will be more useful. This explains why the command–control approach is more dominant in developing countries. Accordingly, more efforts are needed to remove market distortions, to raise awareness and to reduce asymmetric information to enable the shift from the inefficient command and control approach to the more efficient regulatory approaches. Furthermore, ensuring compliance is also vital. This can be done using penalties and rewards. Laws must be clearly specified and clear. Frequent inspection and

proper monitoring should be used to promote enforcement of environmental laws and above all fighting corruption that is widely spread in developing countries will substantially reduce the persistence of carbon dioxide emissions level. These are just few suggestions regarding environmental quality improvement.

Finally, although it is a milestone that women in developing countries contribute positively to environmental quality in middle-income developing countries through their negative effect on carbon dioxide emissions level, yet more is needed to ensure a better future for the children of developing countries, as shown above. This research has faced the limitations of lack of data to capture the technology improvement effect on environmental quality, especially for expenditures on research and development and innovation. For future research work, it will be interesting for comparative purposes to examine the effect of women on the environment in low-income developing countries and developed countries to see whether the same result will be realized or not.

Notes

1. For more information on environmental condition in developing countries, visit: www.who.int/heli/risks/ehindevcoun/en/
2. For more information, visit https://www.unescap.org/sites/default/d8files/05Chapter3.pdf
3. See at www.bbc.com/news/science-environment43294221#:~:text=Women%20are%20more%20likely%20than,when%20flooding%20and%20drought%20occur
4. For more papers on testing for Granger causality between environmental quality and the population, see Meng and Han (2018) and Pachiyappan *et al.* (2021).
5. As a robust check, women participation in the labour force was also used; however, the empirical results were not meaningful.
6. See https://databank.worldbank.org/source/world-development-indicators
7. The list of developing countries for Granger causality test includes Algeria, Albania, Argentina, Bulgaria, China, Congo, Costa Rica, Egypt, Ecuador, Guinea, Guatemala, Guyana, Honduras, Indonesia, India, Iran, Iraq, Jordan, Lebanon, Libya, Malaysia, Mexico, Morocco, Nepal, Pakistan, Panama, Peru, Romania, Thailand, Tunisia, Turkey, Vietnam and South Africa.

   The list of developing countries for the random effects panel data model includes Algeria, Albania, Argentina, Bulgaria, China, Honduras, Indonesia, India, Jordan, Malaysia, Mexico, Morocco, Nepal, Panama, Romania, Thailand, Tunisia and Vietnam. It is noteworthy to highlight that the 33 countries are kept in the first model due to the benefits of large sample as larger samples result in more accurate mean values, have smaller margin of error and in general are a better reflection of the population understudy. Any additional observation is a wealth of information, and this was the only reason for not decreasing the sample size from 33 cross sections to 18 in the Granger causality test model.
8. All unit root tests results, including ADF-Fisher Chi-square, ADF-Choi Z-stat and PP-Fisher Chi-square showed that Fem is I(0) except for PP-Choi Z stat.
9. In its simplest form, ECM is represented by $\Delta y_{i,t} = b_{1i}\,\Delta x_{i,t} - \lambda_i\,(y_{i,t-1} - \beta_0 - \beta_{1i}\,x_{i,t-1})^{+\varepsilon}$, where y is the dependent variable and x is the independent variable at time t for country i and the disequilibrium error from the period $t-1$ is illustrated by $(y_{i,t-1} - \beta_0 - \beta_{1i}\,x_{i,t-1})$, β_{1i} is the long run elasticity of y with respect to x and b_{1i} is the short run elasticities.
10. Granger causality does not imply that environmental quality is the cause of women in the conventional sense. It only measures the effect of environmental quality in predicting or forecasting women. Hence, it is more a measure of correlation caused by precedence, rather than

causation in its conventional sense. Following this logic, we can deduce that environmental degradation is not the cause of women, but rather it affects their survival through its effect on women's health. In this context, more CO_2 emissions increase global climate change problem, which in turn increases heat waves, for instance, which results in more deaths among women leading to less percentage of women in the population.

11. www.researchgate.net/post/What-to-do-when-R-Square-in-panel-data-regression-is-20-to-45-less-than-60

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