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Political factors, carbon footprints, and fertility of women in sub-Saharan Africa

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Abstract

The study aims to investigate how political factors such as government policies and economic development impact carbon emissions and subsequently affect the fertility rates in sub-Saharan Africa (SSA). The study made use of the data sourced from the World Development Indicators (WDI) and World Governance Indications (WGI) covering 45 SSA countries for the period 2000 -2021. The study applied the Pooled Ordinary Least Squares, and control for endogeneity, and the Generalized Method of Moments (GMM). The results show that carbon footprints have the potential of reducing fertility rate in sub-Saharan Africa (SSA). This impact in the full sample was also reflected in most of the subregions. With respect to governance, the result shows that regulatory quality has the potential of improving fertility rate in SSA. On the other hand, government effectiveness has a reduction impact on fertility rate. The research highlights the need for sustainable development policies that take into consideration the impact of carbon footprints on fertility rates in SSA. *(Afr J Reprod Health 2023; 27 [11]: 44-54).*

Keywords: Carbon footprints, fertility, governance, politics, government effectiveness

Résumé

L'étude vise à étudier comment des facteurs politiques tels que les politiques gouvernementales et le développement économique ont un impact sur les émissions de carbone et affectent par la suite les taux de fécondité en Afrique subsaharienne (ASS). L'étude a utilisé les données provenant des Indicateurs de développement dans le monde (WDI) et des Indications de la gouvernance mondiale (WGI) couvrant 45 pays d'ASS pour la période 2000-2021. L'étude a appliqué la méthode des moindres carrés ordinaires groupés, le contrôle de l'endogénéité et la méthode des moments généralisés (GMM). Les résultats montrent que les empreintes carbone ont le potentiel de réduire le taux de fécondité en Afrique subsaharienne (ASS). Cet impact sur l'échantillon complet s'est également reflété dans la plupart des sous-régions. En ce qui concerne la gouvernance, le résultat montre que la qualité de la réglementation a le potentiel d'améliorer le taux de fécondité en ASS. D'un autre côté, l'efficacité du gouvernement a un impact réducteur sur le taux de fécondité. La recherche souligne la nécessité de politiques de développement durable qui prennent en compte l'impact de l'empreinte carbone sur les taux de fécondité en ASS. *(Afr J Reprod Health 2023; 27 [11]: 44-54).*

Mots-clés: Empreinte carbone, fertilité, gouvernance, politique, efficacité du gouvernement

Introduction

African countries are experiencing the impacts of climate change in a variety of ways, including rising temperatures, increased frequency and severity of extreme weather events, and changes in precipitation patterns[1,2]. These impacts are having significant effects on agriculture, water resources, and human health, among other areas. In terms of CO2 emissions, African countries are responsible for a relatively small proportion of global emissions, but they are still contributing to the problem. Many African countries are working to reduce their emissions and transition to cleaner energy sources, but they face significant challenges in doing so, including limited resources and competing priorities. Other environmental variables, such as deforestation and land degradation, are also major concerns in many African countries, as they can exacerbate the impacts of climate change and threaten biodiversity and ecosystem services[2].

Against this backdrop, the relationship between carbon footprints and political factors such as government policies and economic development has become a topic of growing concern in the extant literature. This concept is essential, because, as the global population continues to grow, there is an urgent need to address the impact of carbon footprints on fertility rates, which has been excluded in the body of the previous literature, to the best of the knowledge of the authors. To expand the frontiers of knowledge, this study investigates the complex interplay between political factors, carbon footprints, and fertility rates in SSA. By examining the impact of government policies and economic development on carbon emissions and fertility rates, this research contributes to the development of sustainable development policies that take into consideration the impact of carbon footprints on fertility rates in SSA. Ultimately, this study sheds light on the challenges facing SSA as it seeks to balance economic development with sustainable environmental practices and reproductive health.

The examination of this concept is essential because the impact of pollution on health is emerging, which are likely to affect demographic trends[1-10]. Furthermore, the impact of carbon footprints – climate change, pollution, may have already continued to exert significant adverse effects on health. Irrespective of the significant conceptual grounds upon which the relationship between climate change and health and fertility is built, the empirical evidence which incorporates the aspect of carbon footprints in such connection remains relatively sparse[11,12]. This lacuna forms the basis of this study to extend the frontiers of knowledge. Therefore, the study aims to provide answers to the specific research questions, what is the impact of -i) political factors on women's fertility in SSA? ii) carbon footprints on women's fertility in SSA?

Literature review

Ahinkorah[13] assessed individual and environmental factors that contribute to unintended pregnancies among adolescent girls and young women in a few high-fertility nations in sub-Saharan Africa. Descriptive and multilevel logistic regression statistics were carried out, and the adjusted odds ratios with a level of confidence of 95% were calculated for the multilevel logistic regression analysis' fixed effect outcomes. In the chosen nations, there were 22.4% of unplanned pregnancies. Adolescent girls and young women between the ages of 15 and 19 had a high risk of unwanted pregnancies. Adolescent girls and young women who had three or more births were more probable to experience unwanted pregnancies than those who had only one. The likelihood of unplanned pregnancies also rose due to the rising birth order[14-16].

Anser *et al.*[17] investigated how COVID-19 measures affected the world's environment and reproductive rate. Utilizing data from 1980 to 2019, outcomes demonstrated that communicable diseases, including COVID-19 measures, decrease carbon emissions and raise the likelihood of fertility rates in account of a city-wide lockdown. Bongaarts[18] investigated the factors that influence fertility trends in SSA and its desired and undesirable features, utilizing a regression approach on country-level data. Data came from 103 Demographic and Health Survey (DHS) surveys conducted between 1989 and 2019 in 25 SSA nations, each of which had at least two DHS surveys. Family planning programs and women's education were determined to be the main factors influencing fertility drop, and their impacts work by lowering both desired and unwanted fertility, which is similar to Avogo and Somefun[19].

McLoughlin and Weinreb[20] investigated how West African fertility are impacted by climate change. Data from 11 West African nations' Demographic and Health Survey rounds collected between 2001 and 2014, were merged by the researchers. A multistage cluster sample was employed in the investigation. The study's conclusions showed that fertility is increased impacted by periods of rising mean rainfall, but decreased by periods of rising variance. Additionally, it was discovered that reliance on agriculture and the percentage of land under cultivation raises the likelihood of giving birth or becoming pregnant, however, the impact varies greatly by parity.

Conforti *et al.*[21] analyzed the systematic analysis of studies evaluating the effect of air pollution on female infertility. The main findings were the live birth rate following in vitro fertilization (IVF) operations and the rate of conception following impulsive sexual activity. The number of oocytes and embryos obtained, stillbirths, infertility, and first-trimester miscarriages were the subsequent results. According to the study, ozone and nitrogen dioxide were linked to a lower live birth rate in the IVF group, whereas particulate matter of 10 mm was linked to a higher miscarriage rate.

Sharma[22] examined the factors influencing fertility among Nepalese women of reproductive age. The research was examined using regression and correlation testing. In the 1996 NFHS, there were 4.6 births per woman; in the 2011 NDHS, there were only 2.6 births per woman, according to the research. The five years from 2001 to 2006 (a one-child fall) saw the greatest reduction in fertility. Over the past 15 years, fertility had decreased across all age groups, with women between the ages of 25 and 34 experiencing the biggest declines. However, women between the ages of 20 and 24 had the greatest reduction during the past five years. Wheeler and Hammer[23] estimated the economics of population policy for reducing carbon emissions in underdeveloped countries. The research maintained the practice of selecting the highest of two costs and employed robustness tests.

Methods

Data and variables

In this study, the dependent variable, fertility rate, which was proxied by Fertility rate, total (births per woman), sourced from the World Development Indicators (WDI) database. WDI is a database compiled by the World Bank that provides a comprehensive overview of global development data on different indicators. The database includes hundreds of indicators related to economic growth, poverty reduction, and environmental sustainability, among others. The proxies for carbon footprints and a control variable, per capita income was also sourced from the WDI database. Political factors were proxied by two variables which were sourced from the WGI database. To achieve the objectives of the study, a panel data analysis on selected sub-Saharan Africa (SSA) countries for the periods, 2001 to 2021 was carried out.

The countries under investigation include - Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, Central African Republic, Chad, Comoros, Congo, Rep., Congo, Dem. Rep., Cote d'Ivoire, Djibouti, Eritrea, Equatorial Guinea, Ethiopia, Gabon, Gambia, The, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. These countries are selected based on data availability. The variables used in this study were summarised in full detail in Table 1.

Model specification and estimation techniques

The techniques used in this study to analyse the interrelationship between political factors, carbon footprints and fertility in Sub-Saharan Africa were the Pooled Ordinary Least Squares (POLS) and the one-step system Generalised Method of Moments (GMM). These techniques were adopted due to their merits.

In this study, The POOLS technique was used as the baseline prior to the Generalised Method of Moments (GMM). The POLS technique, however, suffers some setbacks, which include the inability to address problems of heterogeneity, and the inability to identify country-specific effect[23]. The POLS estimation technique is expressed in equation (1)

$$lnFR_{it} = \beta_0 + \beta_1 lnCO2_{it} + \beta_2 lnGDPPC_{it} + \beta_3 lnI'_{it} + \mu_{it} \quad (1)$$

Where $lnFR_{it}$ represents the natural logarithm of fertility rate. β_0 represents the intercept term while β_1, β_2 and β_3 are the coefficients of the independent variables. In addition, $lnCO2_{it}$, $lnGDPPC_{it}$ and lnI'_{it} represent the natural logarithm of carbon footprints, per capita income, the control variable and the covariate for government institutions in this study, respectively. The disturbance term is represented by μ, while *i* represents the country spanning from 1 to 45, and *t* represents the time period which spans from 1 to 21.

The GMM technique is also suitable when analysing panel data with problems of endogeneity, as it addresses issues that may arise[24-26]. The GMM estimation technique is expressed in equation (2)

$$lnFR_{it} = \beta + \beta_1 lnFR_{it-1} + \beta_2 lnCO2_{it} + \beta_3 lnGDPPC_{it} + \beta_4 lnI'_{it} + \mu_{it} \quad (2)$$

Where $lnFR_{it}$ represents the natural logarithm of fertility rate, $lnPCF_{it-1}$represents the first lag of logarithm of fertility rate.

Table 1: Variables, measurements, sources and expectations

Variable	Code	Measurement	Source	Expectations
Fertility Rate	FR	Fertility rate, total (births per woman)	WDI	Not Applicable
Carbon footprint	CO2	CO2 emissions (kt)	WDI	Negative (-)
Per Capita Income	GDPPC	GDP per capita (current US$)	WDI	Negative (-)
Regulatory Quality	RQ	Regulatory Quality: Estimate	WGI	Positive/ Negative (+/-)
Government Effectiveness	GE	Government Effectiveness: Estimate	WGI	Positive/ Negative (+/-)

NB: WDI and WGI mean World Development Indicators and Governance Indicators respectively.
Source: Authors' Compilation

In addition, $lnCO2_{it}$, $lnGDPPC_{it}$ and lnI'_{it} represent the natural logarithm of carbon footprints, per capita income, the control variables and the covariate for government institutions in this study, respectively. β is the intercept term, β_1 is the coefficient of the lagged dependent variable (fertility rate), β_2, β_3 and β_4 are the coefficients of the explanatory variables, the disturbance term is represented by μ, *i* represents the country spanning from 1 to 45 while *t* represents the period which spans from 1 to 21.

Ethical consideration

Ethical consideration is not applicable for this study, as the study did not made use of human or animal subjects.

Results

Summary statistics

Table 2 shows the descriptive statistics of the variables which include fertility rate (FR), CO2 emissions (CO2), GDP per capita (GDPPC), regulatory quality (RQ) and government effectiveness (GE) for the full sample and the individual regions. The average fertility rate in the full sample (Sub-Saharan Africa) was approximately 5 births. This indicates that on average, every woman gave birth to approximately 5 children in SSA. After analysing individually, it was revealed that the average fertility rate in the Central Africa region (5.408884) was the largest as compared to other regions and the Southern African region (3.086131) had the least average fertility rate.

Furthermore, the country with 1.36 births fertility rate, which is the minimum value in SSA was recorded in the Eastern Africa region. The country which has 7.695 births fertility rate, which is the maximum value in the entire region was recorded in the Western Africa region.

The average per capita income in the full sample (Sub-Saharan Africa) was $2075.67. This indicates that on average, individuals had $2075.67 per capita income in SSA. After analysing individually, it was revealed that the average per capita income in the Southern Africa region (4333.883) was the largest as compared to other regions and the Southern African region (1069.457) has the least average per capita income. Also, the country with $110.4609 per capita income, which is the minimum value in SSA was recorded in the Eastern Africa region. The country which has 19849.72 per capita income, which is the maximum value in the entire region was recorded in the Central Africa region.

The average CO2 emissions in the full sample (Sub-Saharan Africa) was 14678.28. This indicates that on average, 14678.28kt of carbon dioxide was emitted in SSA. After analysing individually, it was revealed that the average CO2 emissions in the Southern Africa region (103680.2) was the largest as compared to other regions and the Eastern African region (4378.575) has the least CO2 emissions. Also, the country with CO2 emissions of 53.5, which is the minimum value in SSA was recorded in the Central Africa region. The country with CO2 emissions of 448298.1, which is the maximum value in the entire region was recorded in the Southern Africa region.

The average regulatory quality index in the full sample (Sub-Saharan Africa) was 1.811684. This indicates that on average, SSA has an index of 1.811684 for regulatory quality. After analysing individually, it was revealed that the average regulatory quality in the Southern Africa region (2.646503) was the largest as compared to other regions and the Central African region (1.458035) has the least average regulatory quality index.

Table 2: Descriptive statistics of the variables

	Full Sample		Central Africa		Eastern Africa		Southern Africa		Western Africa	
Variable	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)
FR	4.844674 (1.293572)	1.36 (7.695)	5.408884 (0.9673)	3.491 (7.231)	4.650603 (1.355228)	1.36 (7.582)	3.086131 (0.450)	2.261 (3.827)	5.185271 (1.081172)	1.896 (7.695)
GDPPC	2075.67 (2977.26)	110.4609 (19849.72)	3018.209 (3944.245)	148.4471 (19849.72)	1989.462 (3369.058)	110.4609 (16851.12)	4333.883 (2366.3)	388.3675 (8737.0)	1069.457 (799.89)	203.5265 (3928.30)
CO2	14678.28 (59566.31)	53.5 (448298.1)	5445.737 (6555.463)	53.5 (31648.9)	4378.575 (5262.442)	109.7 (22131.5)	103680.2 (175554)	1770.8 (448298)	9208.29 (23919.8)	148.2 (119544.1)
RQ	1.8116 (0.6381)	-0.0477 (3.6969)	1.458035 (0.407825)	0.7871881 (2.5)	1.739206 (0.7570877)	-0.04772 (3.6969)	2.6465 (0.4808)	1.7627 (3.4001)	1.883 (0.382)	0.64403 (2.773)
GE	1.7446 (0.638)	0.05490 (3.6609)	1.3864 (0.4121)	0.6126 (2.501)	1.752441 (0.7340716)	0.0549042 (3.66092)	2.585 (0.4093)	1.549205 (3.1199)	1.727 (0.454)	0.7087 (2.8556)

Source: Authors' Compilation

Also, the country with -0.0477257 regulatory quality index, which is the minimum value in SSA was recorded in the Eastern Africa region. The country which has 3.696947 regulatory quality index, which is the maximum value in the entire region was also recorded in the Eastern Africa region.

Lastly, the average government effectiveness index in the full sample (Sub-Saharan Africa) was 1.744696. This indicates that on average, SSA has an index of 1.744696 for government effectiveness. After analysing individually, it was revealed that the average government effectiveness in the Southern Africa region (2.585354) was the largest as compared to other regions and the Central African region (1.386457) has the least average government effectiveness index. Also, the country with 0.0549042 government effectiveness index, which is the minimum value in SSA was recorded in the Eastern Africa region. The country which has 3.66092 government effectiveness index, which is the maximum value in the entire region was also recorded in the Eastern Africa region.

Pooled ordinary least squares (POLS) estimation results

This study proxied fertility rate (FR), carbon footprints (CO2), per capita income (GDPPC), regulatory quality (RQ), and government effectiveness (GE) by fertility rate, total (births per woman), CO2 emissions (kt), GDP per capita (current US$), Regulatory Quality and Government Effectiveness, respectively. POLS was used in the section to examine the interrelationship between political factors, carbon footprints and fertility of individuals of reproductive age in Sub-Saharan Africa and its subregions. The results are summarised in Table 3.

All variables in the study were logged. This meant that the interpretations would be made in percentage form. The independent variables in this model would be explained to be significant if the P-value falls within significance levels 10%, 5%, and 1%. The F-statistic revealed that the independent variables (CO2, GDPPC, RQ and GE) were jointly significant in the model for explaining the systemic variations in the dependent variable (FR) in both the full sample (SSA) and the subregions (Central Africa, Eastern Africa, Southern Africa, and Western Africa).

The result in Table 3 revealed that per capita income has the potential of decreasing fertility rate for the full sample. This indicates that an increase in per capita income in Sub-Saharan Africa would result in a decrease in fertility rate. The POLS estimate on the full sample predicted that a percentage increase in per capita income would result in a 0.18% decrease in fertility rate. The POLS estimates revealed that the impact of per capita income on fertility rate across the subregions was also negative and statistically significant except in Southern Africa, whose estimates were insignificant. This explains that a percentage increase in per capita income in Central Africa, Eastern Africa and Western Africa would result in a 0.1%, 0.26% and 0.31% decrease, respectively in fertility rate.

Table 3 revealed that CO2 emissions has a positive and statistically significant impact on fertility rate for the full sample. This indicates that an increase in CO2 emissions in Sub-Saharan Africa would result to an increase in fertility rate. The POLS estimate on the full sample predicted that a percentage increase in CO2 emissions would result in a 0.03% increase in fertility rate. This was not in line with the expectations established in this study. The POLS estimates revealed that the impact of CO2 emissions on fertility rate across the subregions was also positive and statistically significant except in Southern Africa, whose estimates showed a negative and statistically significant relationship. This explains that a percentage increase in CO2 emissions in Central Africa, Eastern Africa and Western Africa would result in a 0.03%, 0.01% and 0.09% increase, respectively in fertility rate, while resulting in a 0.06% decrease in fertility rate in Southern Africa.

The result in Table 3 revealed that regulatory quality has a positive and statistically significant impact on fertility rate for the full sample. This indicates that an increase in regulatory quality index in Sub-Saharan Africa would result in an increase in fertility rate. The POLS estimate on the full sample predicted that a percentage increase in regulatory quality index would result in a 0.06% increase in fertility rate. This was in line with the expectations established in this study.

Table 3: Pooled Ordinary Least Squares estimates

	Full Sample	Central Africa	Eastern Africa	Southern Africa	Western Africa
logGDPPC	-0.1841***	-0.10298***	-0.2567***	0.0062	-0.3132***
	(0.000)	(0.000)	(0.000)	(0.664)	(0.000)
logCO2	0.02913***	0.03205***	0.0120*	-0.0643***	0.08952***
	(0.000)	(0.000)	(0.088)	(0.000)	(0.000)
logRQ	0.0596361*	-0.0200185	0.1224644***	-0.2992***	0.1994***
	(0.098)	(0.717)	(0.002)	(0.000)	(0.006)
logGE	-0.3170***	-0.17451***	-0.2539***	0.3117578***	-0.2255***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
_cons	2.721105***	2.2405***	3.188393***	1.6602***	3.0360***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.5778	0.5758	0.7821	0.8633	0.6378
F-Stat	308.92***	59.37***	289.77***	118.42***	138.70***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, **, *** means significant at 1%, 5% and 10%, respectively.
Source: Authors' Compilation

Table 4: GMM Results

Variables	Full Sample	Central Africa	Eastern Africa	Southern Africa	Western Africa
logGDPPC	-0.1571***	-0.0924***	-0.2363***	0.00727	-0.2787***
	(0.000)	(0.000)	(0.000)	(0.221)	(0.000)
logCO2	0.0354***	0.0414***	0.01026***	-0.0615***	0.0798***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
logRQ	0.1545***	0.0273	0.1532***	-0.3317***	0.2340***
	(0.000)	(0.101)	(0.000)	(0.000)	(0.000)
logGE	-0.4031***	-0.255***	-0.2735***	0.3355***	-0.231***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cons	2.473***	2.0984***	3.0568***	1.6349***	2.860***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR (1)	-4.50***	-4.26***	-2.50**	-1.72*	-5.65***
	(0.000)	(0.002)	(0.012)	(0.085)	(0.003)
AR (2)	-0.76	2.58	0.16	0.91	-0.36
	(0.449)	(0.934)	(0.874)	(0.364)	(0.451)

Note: *, **, *** means significant at 1%, 5% and 10%, respectively.
Source: Authors' Compilation

The POLS estimates revealed that the impact of regulatory quality on fertility rate across the subregions was heterogenous. A percentage increase in regulatory quality index in Eastern Africa and Western Africa would result in a 0.12%, 0.2% increase, respectively in fertility rate, while leading to a 0.3% decrease in Southern Africa. The estimate for Central Africa was insignificant. Table 3 revealed that government effectiveness has a negative and statistically significant impact on fertility rate for the full sample. This indicates that an increase in government effectiveness index in Sub-Saharan Africa would result in a decrease in fertility rate.

The POLS estimate on the full sample predicted that a percentage increase in government effectiveness index would result in a 0.32% decrease in fertility rate**.** The POLS estimates revealed that the impact of government effectiveness on fertility rate across the subregions was also negative and statistically significant except in Southern Africa, whose estimates showed a positive relationship. This explains that a percentage increase in government effectiveness index in Central Africa, Eastern Africa and Western Africa would result in a 0.17%, 0.25% and 0.23% decrease, respectively in fertility rate and a 0.31% increase in Southern Africa.

GMM estimation results

The one-step system Generalised Method of Moments was used in this section to examine the interrelationship between political factors, carbon footprints and fertility of individuals of reproductive age in Sub-Saharan Africa and its subregions. The results are summarised in Table 4.

Like the Pooled Ordinary Least Squares estimates (POLS), the independent variables in this model would be reported as significant if the Probability value falls within the significance level at 1%, 5%, and 10%. The AR (1) and AR (2) were used in checking for autocorrelation in the results. From Table 4, there was no presence of autocorrelation in the region and sub regions as the coefficients of AR (1) were statistically significant while the coefficients of AR (2) were not statistically significant. Table 4 revealed that per capita income has a reduction impact on fertility rate in Sub-Saharan Africa. This finding corresponds with the Pooled Ordinary Least Squares estimates summarized in Table 3. Furthermore, GMM estimates in Table 4 predicted that a percentage increase in per capita income is associated with a 0.16% decrease in fertility rate, in Sub-Saharan Africa, in the short run, ceteris paribus. This estimate indicates an inelastic relationship between the two variables.

The GMM estimates revealed that there were also negative and statistically significant impacts at 10% levels in all the sub regions, excluding Southern Africa whose estimates were insignificant. There also exists an inelastic relationship between per capita income and fertility rate in these sub regions. A percentage increase in per capita income will result in a 0.09%, 0.24% and 0.28% decrease in fertility rate in the short run, ceteris paribus, in Central, Eastern and Western Africa respectively. The results from Table 4 revealed that CO2 emissions has a positive and statistically significant impact on fertility rate in Sub-Saharan Africa. This finding corresponds with the Pooled Ordinary Least Squares estimates summarized in Table 3. Furthermore, GMM estimates in Table 4 predicted that a percentage increase in CO2 emissions is associated with a 0.04% increase in fertility rate, in Sub-Saharan Africa, in the short run, ceteris paribus. This estimate indicates an inelastic relationship between the two variables. The GMM estimates revealed that there were also positive and statistically significant impacts at 10% levels in all the sub regions, excluding Southern Africa whose estimates showed a negative relationship. There also exists an inelastic relationship between CO2 emissions and fertility rate in these sub regions. A percentage increase in CO2 emissions will result in a 0.04%, 0.01% and 0.08% increase in fertility rate in the short run, ceteris paribus, in Central, Eastern and Western Africa respectively. A percentage increase in CO2 emissions will result in a 0.06% decrease in fertility rate in the short run, ceteris paribus, in Southern Africa.

Table 4 revealed that regulatory quality has a positive and statistically significant impact on fertility rate in Sub-Saharan Africa. This finding corresponds with the Pooled Ordinary Least Squares estimates summarized in Table 3. Furthermore, GMM estimates in Table 4 predicted that a percentage increase in regulatory quality index is associated with a 0.15% increase in fertility rate, in Sub-Saharan Africa, in the short run, ceteris paribus. This estimate indicates an inelastic relationship between the two variables.

The GMM estimates revealed that there were also positive and statistically significant impacts at 10% levels in all the sub regions, excluding Central Africa whose estimates were insignificant and Southern Africa whose estimates revealed a negative relationship. There also exists an inelastic relationship between regulatory quality and fertility rate in these sub regions. A percentage increase in regulatory quality index will result in a 0.15% increase, a 0.33% decrease and a 0.23% increase in fertility rate in the short run, ceteris paribus, in Eastern, Southern and Western Africa respectively.

The results from Table 4 revealed that government effectiveness has a negative and statistically significant impact on fertility rate in Sub-Saharan Africa. This finding corresponds with the Pooled Ordinary Least Squares estimates summarized in Table 3. Furthermore, GMM estimates in Table 4 predicted that a percentage increase in per government effectiveness index is associated with a 0.4% decrease in fertility rate, in Sub-Saharan Africa, in the short run, ceteris paribus. This estimate indicates an inelastic relationship between the two variables. The GMM estimates revealed that there were also negative and statistically significant impacts at 10% levels in all the sub regions, excluding Southern Africa whose estimates revealed a positive relationship. There also exists an inelastic relationship between government effectiveness and fertility rate in these sub regions. A percentage increase in government effectiveness index will result in a 0.26% decrease, a 0.27% decrease, a 0.34% increase and a 0.23% decrease in fertility rate in the short run, ceteris paribus, in Central, Eastern, Southern and Western Africa respectively.

Discussion

The techniques above were used to examine the interrelationship between political factors, carbon footprints and fertility of individuals of reproductive age in Sub-Saharan Africa and in its subregions. The findings were summarised in Table 3 and Table 4 above. The findings from both techniques revealed that per capita income has a negative impact on fertility rate in Sub-Saharan Africa. This impact in the full sample was also reflected in most of the subregions.

In Sub-Saharan Africa, an increase in per capita income is associated with higher economic growth. As these countries in the region experience economic growth and development, there is an increase in access to education and awareness about family planning. Educated individuals tend to have fewer children as they focus on pursuing career and personal development. Also, economic growth leads to rapid urbanization and in urban areas, families tend to have fewer children due to the cost of living, limited space and changing societal norms. By implementing a combination of measures, SSA countries can continue to see a decline in fertility rates as they progress towards economic and social development. Some of these measures include: education and public awareness to family planning, especially for women and social support to families with fewer children.

Both techniques revealed that CO2 emissions has a positive impact on fertility rate in Sub-Saharan Africa. This impact in the full sample was also reflected in most of the subregions. CO2 emissions are often higher in urban areas due to increased energy consumption, transportation, and industrial activities[28]. AS SSA countries urbanize, rural to urban migration may lead to changes in family size preferences. Urban environments might offer more job opportunities and access to education, making people more likely to delay marriage and childbearing. However, this might be counteracted by urban living expenses, leading to higher fertility rates as families struggle to sustain themselves. Governments should regularly monitor and evaluate the impact of policies aimed at reducing CO2 emissions and fertility rates to make necessary adjustments if needed. This may involve policymakers addressing urban challenges and investment in renewable energy sources, as this might indirectly influence fertility rates as energy availability impacts living standards.

The findings from both techniques revealed that regulatory quality has a positive impact on fertility rate in Sub-Saharan Africa. This impact in the full sample was also reflected in most of the subregions. Improved regulatory quality can lead to better healthcare infrastructure and access to social services, such as education and childcare facilities. This can reduce child mortality rates and provide families with the necessary support to have more children. Favourable regulatory conditions in SSA countries, such as parental leave policies and flexible work arrangements, can help create a better work-life balance for parents. This may incentivize individuals to have more children without compromising their career prospects. Governments should prioritize the establishment and strengthening of regulatory institutions to ensure transparency, accountability, and fairness in the implementation of policies and regulations. This should be done to promote investment-friendly regulations such as investment in education and gender equality. This will lead to informed family planning decisions and reduced fertility rates. Both techniques revealed that government effectiveness has a negative impact on fertility rate in Sub-Saharan Africa. This impact in the full sample was also reflected in most of the subregions.

Effective government institutions will provide access to family planning services, leading to increased knowledge about contraceptive methods and options for family planning. This will result in lower fertility rates as families will have the means to control their family size effectively. An effective government with focus on improving healthcare and educational awareness can contribute to reducing fertility rates, leading to improved overall development and quality of life for their citizens.

Strengths and limitations

This study employed the Pooled Ordinary Least Squares as the baseline estimator and the one-step system GMM to address problems of endogeneity. This study achieved it objectives by examining the interrelationship between political factors, carbon footprints and fertility of individuals of reproductive age in Sub-Saharan Africa. As regards to that, addressing these challenges requires a comprehensive approach that involves considering the socio-economic context, promoting affordability, improving infrastructure, and supporting sustainable energy transitions.

Some of the strengths of the study is that - the study focuses on a specific region, sub-Saharan Africa, which allows for a more targeted analysis of the political factors, carbon footprints, and fertility of women in this area. Secondly, the study considers multiple factors that contribute to fertility including political factors and carbon footprints, which provides a comprehensive understanding of the issue. However, the study is not without limitations; some of which include the study may not be generalizable to other regions outside of SSA, as political factors, carbon footprints, and fertility rates may vary significantly in different parts of the world. Also, the study may be limited by the availability and quality of data on political factors, carbon footprints, and fertility rates in SSA.

Recommendations and conclusion

The effectiveness of government institutions plays a crucial role in shaping fertility rates in Sub-Saharan Africa (SSA) countries. Additionally, the carbon footprints resulting from unsustainable practices further exacerbate the challenge of achieving sustainable development. To reduce fertility rates and foster sustainable development, governments must prioritize investments in healthcare, education, and family planning programs. Simultaneously, efforts to address carbon footprints through sustainable policies and practices are essential for the region's long-term prosperity and environmental health. By working towards these goals, SSA countries can pave way for a more prosperous, equitable, and environmentally responsible future. Also, policy measures, technological innovations, and targeted interventions can help mitigate the potential negative impacts on food security while maximizing the positive benefits of clean energy adoption.

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