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Examining the Dynamics of Labour Force Participation, Carbon Dioxide Emission and Population Health in Sub-Saharan Africa

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ABSTRACT

This study examined the dynamic causal relationship between population health, carbon dioxide (CO_2) emission and labour force participation. The study employed the block exogeneity wald test after estimating a panel VAR model using data for 24 sub-Saharan African countries from 1990 to 2018. The dynamic interactions among the variables and effect of shocks was also examined using the variance decomposition analysis and impulse response functions. For robustness, the estimation was done using both aggregate labour force participation and disaggregated labour force participation in order to investigate the differentials by gender. The results showed evidence of a feedback effect between life expectancy and total labour force participation. This also holds for male labour force participation however; a unidirectional causality was found from female labour force participation to life expectancy. A one standard deviation shock in CO_2 emission had a negative impact on life expectancy. Life expectancy also had the greatest contribution to variations in CO_2 emission. Male labour force participation shocks had a consistently negative impact over the 10-year period, however, shocks from female labour force participation had the least impacts on CO_2 emission. Environmental reforms encouraging less polluting energy and technology use is important for CO_2 emission reduction, which further increases life expectancy and ultimately labour force participation rates.

Keywords: CO_2 Emission, Labour Force Participation, Population Health, Granger Causality, Sub-Saharan Africa
JEL Classifications: I18, J21, Q53

1. INTRODUCTION

Labour force participation is expected to be a blessing but it could have health consequences when individuals work to the detriment of their health. For instance, having less time for rest and leisure means allocating more time for work inorder to increase earnings and meet household needs. Sometimes, labour force participation could have negative implications on health when the work environment is unhygienic and hazardous. Studies have also shown that an individuals' health status affects his or her ability to work (Nwosu and Woolard, 2017; Holt, 2010). Several studies have focused on the role of income and education on health but less attention has been given to the time allocation effect. This study attempts to capture the time allocation effect by examining the relationship between labor force participation and population health in sub-Saharan Africa (SSA). It also considers the gender differentials by decomposing labor force participation by gender. The number of hours spent working could be used to capture the time allocation effect. However, this study could not make use of this measure because wages are not generally earned per hour but in most cases, wages are paid monthly in SSA.

The high level of energy poverty in SSA has left many households relying on cheaper and usually less clean forms of energy including fossil fuel and solid fuel. These environmentally unfriendly energy sources contribute to poor environmental quality since they emit CO_2 during combustion. Labour force participation could increase CO_2 emissions since increased labour activities imply higher production activities, which generally rely mostly on fossil fuel and solid fuel use. Such energy consumption has been shown to cause

CO2 emission rise. (Alam et al., 2011). CO_2 emission however has health consequences as shown in the literature (Gangadharan and Valenzuela, 2001; Oyedele, 2022). The possibility of labour force participation explaining CO_2 emissions thus remains to be adequately considered in the literature especially in developing countries where achieving the sustainable development goal is still a challenge and several efforts have implications on the environment. Several studies have shown that labour participation explain the health status of a population (Cai, 2010; Anson and Anson, 1987) as well as determine CO_2 emission (Zhong and Su, 2021; Wang et al., 2020). Other studies have also found that population health affect CO_2 emissions (Dalton 2008; Afolayan et al., 2020) and also explain labour participation (Novignon et al., 2015; Mushtaq et al., 2013; Handa and Neitzert 1999; Nwosu and Woolard, 2017). The studies highlighted above confirm the possible interrelationship among CO_2 emission, labour force participation and health, however the dynamics of this relationship remains to be considered especially for SSA.

This study therefore examines the interrelationship among labour force participation, CO_2 emissions and health. It also examines the dynamic interactions among the variables and considers the effect of shocks. Going beyond previous studies on the relationship between labour participation and CO_2 emission, this study considers the gender differentials by disaggregating labour participation. It examines the case for Sub-Saharan Africa from 1990 to 2018. The analysis is carried out using both statistics and econometric methods. The rest of the paper is divided into four sections. The next section is the literature review followed by methodology and results. The final section is the conclusion.

2. LITERATURE REVIEW

A theoretical consideration on the demand for health by Grossman (1972) presented the demand for health as dependent on individual and household characteristics such as age, income, education; economic characteristics such as the labour market wage rate and environmental conditions such as sanitation and hygiene. This emphasizes the role of labour force participation, which provides wage earnings used to meet basic needs including health and healthcare needs. Environmental conditions could be detrimental to health when there is degradation, pollution and poor sanitation. Thus, an increase in greenhouse gas emission such as carbon dioxide not only degrades the environment but also could have health implications. The Environmental Kuznet Curve hypothesis which, applies Kuznet (1955) inverted U-shape curve hypothesis to the environment-income relationship emphasizes that there are initially increasing effects of income on environmental degradation but thereafter exists a turning point beyond which a decline occurs. Increasing labour force participation is a prerequisite to a growing output or income level.

2.1. Relationship between Labour Force Participation and Health

Participating in productive activities and having some earnings keep individuals active mentally and physically and this is important for good health. Such earnings also helps them meet their basic needs including health needs. Anson and Anson (1987) examined the impact of labour force status on women's health using five categories of labour force status including the long term employee, newly employed, unemployed, recently non-employed, and the housewife. Considering six measures of self reported health and illness behavior and employing the analysis of covariance, they found that the healthiest women were the long-term employees, followed by the recently employed while the unemployed and housewives had the same health status. The least healthy was the recently unemployed. While health outcome was worsened by labour force participation for males in Australia, it was found to improve the health status for females (Cai, 2010).

Several studies have focused on the effect of population health on the participation rate of labour. However, they did not consider the feedback effect between both variables and their response to shocks. Employing a GMM approach and examining the effect of population health status on labour force participation for 46 SSA countries, Novignon et al. (2015) found that life expectancy at birth had a positive effect on labour force participation especially for total and female labour force participation for the period 1990 to 2010. In the long run, Mushtaq et al. (2013) found that infant mortality rate caused labour force participation to decline, however, health expenditures had a positive effect on labour force participation but in the short run. The study focused on Pakistan and employed the autoregressive distributed lag model. They also found that gross capital formation and secondary school enrollment had a negative effect while trade liberalization had a positive effect.

Mohammed et al. (2020) also showed that reproductive health outcomes such as total fertility rate, contraceptive use and child spacing negatively affected women labour force participation in Nigeria, using the Nigeria Demographic and Health Survey of 2003, 2008 and 2013. Fertility rate was found to have no hindrance on female employment and re-employment in Malaysia as shown by Siah and Lee (2015). Thus, having children did not prevent labour force participation. Employing the ARDL approach and the granger causality test, they also found that female employment did not affect childbirth decisions of women. Examining the differentials in the effect of health on labour force participation by gender, Handa and Neitzert (1999) found that any health limitation affected the labour force participation behavior of males but only severe health limitations affected female labour participation. Poor health status affected both old and relatively young adults in Jamaica with ill-health causing only a temporary withdrawal from the labour market while permanent withdrawal was the case among older adults. Although the study was able to differentiate the health effect by gender, it did not consider the possible feedback effect between health and labour force participation.

Using data from the Living in Ireland Survey 1995-2000, Gannon (2005) examined the effect of disability on labour force participation in Ireland. Self reported chronic illness and disability was used comprising disability with severe limitation, disability with some limitation, disability with no limitation and no chronic illness or disability. Using the pooled dynamic probit model, men who are disabled and have severe limitation were 9% less likely to participate compared to non-disabled men. Using a dynamic model with correlated random effect, women with disability and having a severe limitation had a lower probability of participation by 26% compared to those with no disability. The effect of having disability with some limitation and no limitation were less substantial. The possibility of a feedback effect or a causal relationship becomes glaring since some studies have considered endogeneity bias in their one way analysis of the effect of health on labour foece partiipation or vice versa.

For instance, Cai and Kalb (2006) estimated a simultaneous equation model inorder to control for the potential endogeneity of health in the labour force participation model. They estimated a feedback effect but did not consider the effect of shocks. Employing the full information maximum likelihood (FIML) estimator and the two stage method, they found that improved health status increased the probability of labour force participation in Australia for all the four groups estimated separately including males aged 15-49, males aged 50-64, females aged 15-49 and females aged 50-64. The feedback effect showed that labour force participation had a significant effect on health and it is positive for older women but negative for younger males. Although the null hypothesis of exogeneity was not rejected using the two-stage method, it was rejected using the full information maximum likelihood.

Using data from the third wave of the Household, Income and Labour Dynamics Survey and employing the FIML and two stage method, better health status was also found to increase the probability of labour force participation for both males and females in Australia, however, the effect is larger for females (Cai and Cong, 2009). Examining the effect of chronic diseases, it was found to have a reduction effect on the probability of labour force participation. The largest effect was from circulatory conditions and bronchitis for males, however, for the case of females, circulatory conditions and coronary diseases had the largest effect. The smallest effect was from cancer for both males and females. Holt (2010) also showed that the odds and probability of participating in the labour force was lower for people with chronic diseases than those without in New Zealand.

Labour force participation could also be affected by not only the health of the individual concerned, but also by the health of individuals residing around the individual. Even the presence of a family member having a disabling cancer condition or musculoskeletal condition was found to increase female labour participation but male participation reduced for males residing with a mentally ill family member as found by Vecchio (2015). The study examined the effect of residing with an individual having a disabling condition on labour force participation.

Using data from the four waves of the National Income Dynamics Study for South Africa, Nwosu and Woolard (2017) examined the effect of self-reported health on labour force participation. Employing a fixed effect estimator and the pooled ordinary least squares for robustness check, they found that a self-reporting of excellent, very good or good health significantly increased labour force participation relative to self-reports of fair or poor health. A greater effect was however found among males. An additional year of schooling also increased the probability of labour force participation. Laplagne et al. (2007) emphasized the existence of endogeneity bias due to unobserved heterogeneity or simultaneity bias when examining the effect of health on labour force participation, which should be considered when examining the relationship. This is as a result of the possibility of a two-way effect. Although the study took necessary steps to control for such bias, it did not examine the two-way effect.

2.2. Relationship between Labour Force Participation and CO_2 Emission

Considering 22 SSA countries, Langnel et al. (2021) examined the effect of environmental degradation on female economic inclusion measured as women labour force participation. Employing the generalized least squares and the two stage least squares estimators, they found that CO_2 emission, CO_2 intensity, CO_2 emission from electricity and heat as well as CO_2 emission from liquid fuel consumption had negative effect on women labour force participation. They emphasized the detrimental implication of this on achieving sustainable development goal 5. Job creation and labour productivity effect were found to increase CO_2 emission with foreign job creation being more emission increasing than the domestic (Zhong and Su, 2021). However, intensity effect significantly reduced CO_2 emission followed by labour market structural change arising from participation in value chain.

Encouraging female employment has been shown to have the capacity to reduce carbon emission that is trade related. Wang et al. (2020) found that an increase in the female labour share had a reduction effect on trade related carbon emission using the method of emissions embodied in bilateral trade and employing the fixed effect estimator. They found that import and export related embodied carbon declined with greater female labour force participation in developed countries and this was significant in the industrial and service sectors. For developing countries, while export related embodied carbon declined with increasing female labour force participation in the service sector, import related embodied carbon declined in the industrial sector.

2.3. Relationship between Health Status and CO_2 Emission

Examining the effect of the environment on health, Gangadharan and Valenzuela (2001) found that increases in environmental variables such as CO_2, sulphur dioxide, water pollutant emissions amongst others significantly worsened life expectancy, infant mortality and child mortality rates in 51 countries. It also found a positive effect of income on health status. Narayan and Narayan (2008) employed a panel cointegration approach, the panel ordinary least squares and the dynamic ordinary least squares estimation methods to examine how environmental quality can determine per capita health expenditure in eight OECD countries and found a long run relationship among carbon monoxide emission, sulphur oxide emission, per capita income, per capita health expenditures and nitrogen oxide emission. In the long run, income, carbon monoxide and sulphur oxide significantly explained health expenditures with income being elastic while others were inelastic. The study however did not consider the effect of green house gases such as carbon dioxide.

Oyedele (2022) also found that CO_2 emission levels from various sectors of the economy worsened both infant and under five mortality rates in Nigeria. The greatest increasing effect was from CO_2 emission from solid fuel consumption. It also found a unidirectional causality from CO_2 to health outcomes using both mortality rates. Mathew et al. (2018) also found that an increase in green house gas emission proxied by carbon dioxide had a reduction effect on life expectancy at birth. However, the study was limited to Nigeria.

There are also studies that have empirically shown the implication of the health status of a country on the environment. For instance, population aging was shown to significantly reduce CO_2 emission levels in the long run (Dalton, 2008). Afolayan et al. (2020) found that high life expectancy at birth granger caused CO_2 emissions in Nigeria explaining that when people live longer, they get to participate more in carbon emitting economic activities thus increasing the carbon emission level.

3. METHODS AND DATA

3.1. The Model

The model of the study is based on the Grossman (1972) theory of health demand which posits the demand for health as a function of income among other health production inputs. Such income are spent on both health services and other market goods which are inputs for health production. This also shows the standard of living of that individual. We measure income using the percentage growth of gross domestic product per capita. We captured the effect of labour market activities in the model by including total labour force participation. Being employed or unemployed determines the level of investments in health that an individual can make based on possible earnings. Participation in the labour force also determines the time allocation of an individual for work if employed or time allocation for job search if unemployed as well as time allocated for other non labour market activities.

The model is thus presented as:

$$HS = f(GRGDPPC, TLFP) \quad (1)$$

Controlling for environmental conditions using the level of CO_2 emission, the linear form of the model is presented in equation (2) as:

$$HS_{it} = \beta_0 + \beta_1 GRGDPPC_{it} + \beta_2 ENC_{it} + \beta_3 CO_{2it} + e_{it} \quad (2)$$

Using life expectancy at birth as a measure of the population health status, we have:

$$LEB_{it} = \beta_0 + \beta_1 GRGDPPC_{it} + \beta_2 ENC_{it} + \beta_3 CO_{2it} + e_{it} \quad (3)$$

Examining the causal relationship among the variables, we employed the panel vector auto regression (VAR) model specification where each variable, beginning with the health outcome measure is presented as a function of its lag and the lag of other explanatory variables. The panel VAR model for life expectancy at birth is presented in equations (4), (5), (6) and (7) below.

$$LEB_{it} = a_1 + \beta_1 LEB_{it\text{-}1} + \ldots + \beta_1 U5MR_{it\text{-}p} + d_1 GRGDPPC_{it} + \ldots + d_1 GRGDPPC_{it\text{-}p} + v_1 TLFP_{it} + \ldots + v_1 TLFP_{it\text{-}p} + w_1 log\,(CO_{2it}) + \ldots + w_1 log\,(CO_{2it\text{-}p}) + e_{it} \quad (4)$$

$$GRGDPPC_{it} = a_1 + d_1 GRGDPPC_{it\text{-}1} + \ldots + d_1 GRGDPPC_{it\text{-}p} + \beta_1 LEB_{it} + \ldots + \beta_1 LEB_{it\text{-}p} + v_1 TLFP_{it} + \ldots + v_1 TLFP_{it\text{-}p} + w_1 log\,(CO_{2it}) + \ldots + w_1 log\,(CO_{2it\text{-}p}) + e_{it} \quad (5)$$

$$TLFP_{it} = a_1 + v_1 TLFP_{it\text{-}1} + \ldots + v_1 TLFP_{it\text{-}p} + d_1 GRGDPPC_{it} + \ldots + d_1 GRGDPPC_{it\text{-}p} + \beta_1 LEB_{it} + \ldots + \beta_1 LEB_{it\text{-}p} + w_1 log\,(CO_{2it}) + \ldots + w_1 log\,(CO_{2it\text{-}p}) + e_{it} \quad (6)$$

$$log\,(CO_{2it}) = a_1 + w_1 log\,(CO_{2it\text{-}1}) + \ldots + w_1 log\,(CO_{2it\text{-}p}) + d_1 GRGDPPC_{it} + \ldots + d_1 GRGDPPC_{it\text{-}p} + v_1 TLFP_{it} + \ldots + v_1 TLFP_{it\text{-}p} + \beta_1 LEB_{it} + \ldots + \beta_1 LEB_{it\text{-}p} + e_{it} \quad (7)$$

Where:
LEB = life expectancy at birth (total years)
TLFP = total labour force participation rate
GRGDPPC = GDP per capita growth (annual percent)
log(CO_2) = log of carbon dioxide emission (metric tons per capita)
FLFP = female labour force participation rate
MLFP = male labour force participation rate

The panel VAR model was estimated using aggregate/total labour force participation and also estimated using disaggregated labour force participation by gender (including female labour force participation and male labour force participation) inorder to capture the differentials by gender.

3.2. Data and Data Source

Data for this study covers the period from 1990 to 2018. The period was chosen based on data availability. The data include life expectancy at birth, total labour force participation rate, female labour force participation rate, male labour force participation, growth of the GDP per capita, and carbon dioxide emission per capita. The study focuses on sub-Saharan African, a region characterized by a relatively low life expectancy rate, relatively low female labour force participation rate and a growing level of carbon dioxide emission. Twenty four countries were considered including Nigeria, Benin, Cameroon, Ghana, Botswana, Congo Democratic Republic, Cote D'ivoire, Kenya, Senegal, Zambia, Zimbabwe, Ethiopia, Mozambique, Chad, Liberia, Uganda, Burkina Faso, Guinea Bissau, Malawi, Namibia, Niger, South Africa, Tanzania and Rwanda. The data was obtained from the World Development Indicators (2021) published by the World Bank.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

The descriptive statistics of the variables presented in Table 1 show that the mean life expectancy at birth (LEB) was 54.201 showing a low level of population health in the region. This implies that at birth, the average number of years an individual is expected to live is <55 years with the maximum number of years being 69.275. The total labour force participation (TLFP) rate was 72.902. The male labour force participation (MLFP) rate was 79.204, which is greater than the female labour force participation (FLFP) rate of 66.820. The mean level of CO_2 emission was 0.691 metric tons per capita with a maximum value of 8.569. The percentage growth of GDP per capita was 1.510 showing a poor growth in income per capita in the SSA region.

4.2. Unit Root Test

The unit root test was conducted to examine the stationarity status of the variables inorder to prevent biases in the result due to the use of non-stationary variables. Two unit root test methods were employed for robustness and they include the Levin, Lin and Chu test and the Im, Pesaran and Shin method. The results showed a mixed order of integration among the variables based on the im, Pesaran and Shin method. The results are presented in Table 2. Since some variables were stationary at levels while others were stationary at first difference, we employed the Kao residual cointegration test and Pedroni residual cointegration test.

4.3. Cointegration Test

The cointegration test was conducted to establish the existence of a long run relationship among the variables. The study employed two methods-the Kao residual cointegration test and the Pedroni residual cointegration test for robustness.

4.3.1. Kao residual cointegration test

This test is Engel Granger based and the null hypothesis states that there is no cointegration. This hypothesis was not rejected since the t-statistic value of −0.501 was not significant at 5% as shown in Table 3. Thus, there was no cointegration among the variables (life expectancy at birth, GDP per capita growth, total labour force participation and CO_2 emission). There was also no cointegration when total labour force participation was disaggregated.

4.3.2. Pedroni residual cointegration test

Testing for cointegration among life expectancy at birth, GDP per capita growth (GRGDP), labour force participation and CO_2 emission, we also employed the Pedroni residual cointegration test. The result obtained using total labour force participation is presented in Table 4 while Table 5 shows the result when we disaggregate total labour force participation by gender. The null hypothesis of no cointegration was not rejected since all of the 4 test statistics including the panel and group PP and ADF statistics were not significant at 5%. This is similar to the Kao residual cointegration test that also found no cointegration.

4.4. Relationship between Life Expectancy at Birth, Total Labour Force Participation and CO_2 Emission

Based on an estimated panel VAR model, a granger causality test or block exogeneity wald test was conducted to examine the causal relationship between life expectancy at birth, CO_2 emission and total labour force participation. The GDP per capita growth was included as a control variable in the model. The optimal lag applied in the panel VAR model estimation was determined as 2 based on the Akaike information criterion.

4.4.1. Granger causality test

Since there was no cointegration, a panel VAR model was estimated using the first difference values of all the variables and the error correction term was therefore not included. The panel granger causality test was conducted based on the estimated panel VAR model. The results in Table 6 revealed that CO_2 emission had an individual significant granger causality on life expectancy at birth and vice versa. This implies that there is a bidirectional causality existing between life expectancy at birth and CO_2 emission. Healthy individuals are able to carry out their daily economic and social activities that most times are energy intensive. Considering the fact that there is a greater use of fossil fuel than renewable energy in developing

Table 1: Descriptive statistics

Variable	Mean	SD	Minimum	Maximum
LEB	54.201	6.411	26.172	69.275
TLFP	72.902	9.821	47.110	92.490
FLFP	66.820	12.779	34.070	89.630
MLFP	79.204	8.427	59.090	95.440
CO_2 emission	0.691	1.508	0.016	8.569
GRGDPPC	1.510	5.218	−47.503	37.535
Observations	682	682	682	682

Source: Computed by author (2023)

Table 2: Unit root test

Variable	Levin, Lin and Chu statistic	Order of integration	Im, Pesaran and Shin W-statistic	Order of integration
TLFP	(−2.201)*	I (0)	(−3.113)*	I (1)
FLFP	(−5.551)*	I (0)	(−2.856)*	I (1)
Log (CO_2)	(−1.779)**	I (0)	(−12.592)*	I (1)
MLFP	(−5.148)*	I (0)	(−2.182)*	I (1)
LEB	(−19.142)*	I (0)	(−22.900)*	I (0)
GDPPC	(−6.219)*	I (0)	(−8.198)*	I (0)

* and ** denote significance at 1% and 5% level respectively

Table 3: Kao residual cointegration test

Variables	t-statistic	Probability
Life Expectancy at Birth		
LEB, GRGDP, TLFP, CO_2	−0.501	0.3083
LEB, GRGDP, FLFP, MLFP, CO_2	−0.535	0.2965

Source: Computed by author (2023)

Table 4: Pedroni residual cointegration test (Using Total Labour Force Participation)

Test Method	Statistic	Probability	Weighted statistic	Probability
Panel PP-statistic	0.374	0.6458	2.495	0.9937
Panel ADF-statistic	1.856	0.9683	3.673	0.9999
Group PP-statistic	4.172	1.0000	-	-
Group ADF-statistic	4.669	1.0000	-	-

Source: Computed by author (2023)

Table 5: Pedroni residual cointegration test (using disaggregated Labour force participation)

Test Method	Statistic	Probability	Weighted statistic	Probability
Panel PP-statistic	1.924	0.9728	2.772	0.9972
Panel ADF-statistic	4.931	1.0000	5.308	1.0000
Group PP-statistic	3.863	0.9999	-	-
Group ADF-statistic	4.457	1.0000	-	-

Source: Computed by author (2023)

countries, this contributes to CO_2 emission, which in turn has negative consequences on population health due to its associated respiratory and other health challenges. This is similar to Afolayan et al. (2020), which found that life expectancy granger caused CO_2 emission in Nigeria. Oyedele (2022) also found that CO_2 emission levels from various sectors of the economy worsened health outcomes, which was measured using both infant and under five mortality rates. It found a unidirectional causality from CO_2 to both mortality rates for Nigeria. The results also revealed that life expectancy at birth was found to granger cause total labour force participation. This implies that the health status of the population determines their ability to participate in labour market activities. Healthy individuals are able to supply their labour services and put in more hours for work. This supports the Grossman (1972) theory of health demand. The result is similar to Holt (2010), which showed that the presence of chronic disease reduced labour force participation in New Zealand. Nwosu and Woolard (2017) also showed that good health status increased labour force participation in South Africa. Total labour force participation also granger caused life expectancy at birth but only jointly with CO_2 emission and GDP per capita growth. Therefore, total labour force participation affects the health status of the population only when we control for the level of CO_2 emission and standard of living of individuals. This therefore shows a bidirectional causality between life expectancy and total labour force participation.

There was a significant unidirectional causality running from CO_2 emission to total labour force participation. A one way causality was also obtained from GDP per capita growth to total labour force participation. This implies that increases in the level of CO_2 emission affected the labour force participation rate and this could be due to the negative effects on human health and respiratory challenges associated with CO_2 exposure, which prevents an individual from being able to work or search for a job.

Table 6: Granger causality/block exogeneity wald test using total labour force participation

Dependent variable: D (LEB)			
Excluded	**Chi-square**	**df**	**Prob.**
D (LOG (CO_2_EMISSIONS))	10.57430	2	0.0051
D (TLFP)	3.121592	2	0.2100
D (GDPPC_GROWTH)	0.863095	2	0.6495
All	14.32700	6	0.0262
Dependent variable: D (LOG (CO_2_EMISSIONS))			
Excluded	**Chi-square**	**df**	**Prob.**
D (LEB)	9.770029	2	0.0076
D (TLFP)	0.007134	2	0.9964
D (GDPPC_GROWTH)	1.360132	2	0.5066
All	11.45087	6	0.0754
Dependent variable: D (TLFP)			
Excluded	**Chi-square**	**df**	**Prob.**
D (LEB)	6.208531	2	0.0449
D (LOG (CO_2_EMISSIONS))	7.373884	2	0.0250
D (GDPPC_GROWTH)	12.24116	2	0.0022
All	25.25190	6	0.0003
Dependent variable: D (GDPPC_GROWTH)			
Excluded	**Chi-square**	**df**	**Prob.**
D (LEB)	0.282099	2	0.8684
D (LOG (CO_2_EMISSIONS))	1.403204	2	0.4958
D (TLFP)	2.230286	2	0.3279
All	4.106968	6	0.6622

4.4.2. Variance decomposition analysis

The variance decomposition analysis showed the dynamic interactions among the variables in terms of their contributions to changes in life expectancy and other variables over a 10 year period. The results are presented in Table 7. The forecast error variance in CO_2 emissions which explained variations in life expectancy over the 10 year period increased from zero in the 1st year to 1.995% by the 10th year. The forecast error variance of total labour force participation, which explained variations in life expectancy also increased consistently from zero and 0.215% in the 1st and 2nd year to 1.306% by the 10th year. Therefore, the total labour force participation rate and CO_2 emission level contributed to the low life expectancy at birth in the SSA region. This shows the need for strategic efforts to reduce the level of CO_2 emission and improve the labour force participation rate inorder to mitigate their negative effect on the populations' health. The growth of the GDP per capita also contributed to variations in life expectancy although there were slight declines in its forecast error variance in the 3rd and 10th year. Therefore, poor income level could worsen the health status of the population since income is a requirement for households to be able to meet their health needs and spending.

The contributions of life expectancy at birth to variations in CO_2 emission consistently increased as shown by its forecast error variance increasing from 3.702 to 4.488 over the 10 year period as shown in Table 8. Hence poor health experiences could cause individuals, firms and the government to make changes in their economic behaviour and decision and embrace strategies towards reducing CO_2` emission. Life expectancy had the greatest contribution to variations in CO_2 compared to total labour force participation and GDP per capita growth. The growth rate of GDP per capita also had significant contributions to variations in CO_2 emission with its forecast error variance consistently but slightly increasing. Thus an increase in the production of goods and services has environmental consequences of increased CO_2 emission especially in developing SSA countries where a transition to the use of clean energy production technologies is yet to be achieved. Innovations in the total labour force participation also explained CO_2 emission over the 10-year period. This is not surprising since an increase in the marginal product of labour imply more production activities usually using technologies and equipment that emit CO_2 and other green house gasses.

Life expectancy also had the greatest contribution to variations in total labour force participation with a forecast error variance of 1.788 in the 1st year increasing to 1.880 by the 10th year as shown in Table 9. The health status of an individual determines their ability to participate in the labour force and the amount of time that individual can spend working or searching for a job. The more the number of illness free days, the more the possibility of participation in the labour force.

In summary, shocks from CO_2 emission and total labour force participation contributed to changes in population health. On

Table 7: Variance decomposition of LEB

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (TLFP)	D (GDPPC_GROWTH)
1	0.545944	100.0000	0.000000	0.000000	0.000000
2	0.567055	98.90303	0.812515	0.215679	0.068779
3	0.628586	97.95937	1.550459	0.422282	0.067886
4	0.644349	97.45220	1.795791	0.679965	0.072044
5	0.661707	97.15691	1.884877	0.884234	0.073977
6	0.669289	96.95427	1.936062	1.037333	0.072332
7	0.675289	96.81857	1.965027	1.145292	0.071108
8	0.678546	96.72642	1.980917	1.222089	0.070576
9	0.680788	96.66831	1.989600	1.271977	0.070115
10	0.682113	96.62961	1.995016	1.305531	0.069848

Table 8: Variance decomposition of CO_2 emission

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (TLFP)	D (GDPPC_GROWTH)
1	0.111187	3.701733	96.29827	0.000000	0.000000
2	0.111928	4.233449	95.70689	9.41E-05	0.059562
3	0.112380	4.442524	95.42640	0.004964	0.126110
4	0.112430	4.445356	95.36727	0.006318	0.181059
5	0.112451	4.479153	95.33112	0.006761	0.182968
6	0.112453	4.479375	95.32827	0.006770	0.185581
7	0.112458	4.485289	95.32055	0.006790	0.187370
8	0.112459	4.486113	95.31945	0.006960	0.187477
9	0.112460	4.487761	95.31766	0.007016	0.187559
10	0.112460	4.488278	95.31702	0.007063	0.187643

Table 9: Variance decomposition of total labour force participation

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (TLFP)	D (GDPPC_GROWTH)
1	0.475973	1.787561	0.055059	98.15738	0.000000
2	0.539120	1.394563	0.129906	97.30733	1.168201
3	0.563203	1.576830	0.934629	96.41114	1.077405
4	0.570707	1.605188	1.225567	96.11949	1.049755
5	0.573475	1.717519	1.292211	95.91167	1.078601
6	0.574435	1.768763	1.320317	95.83586	1.075060
7	0.574831	1.817788	1.335708	95.77291	1.073598
8	0.574997	1.846375	1.341469	95.73755	1.074604
9	0.575083	1.867402	1.344325	95.71399	1.074279
10	0.575128	1.880152	1.345769	95.69996	1.074116

the otherhand, life expectancy had the greatest contribution to variations in both total labour force participation and CO_2 emission. This confirms the bidirectional causality obtained above as well as the findings of Holt (2010), Nwosu and Woolard (2017) and Cai and Cong (2009).

4.4.3. Impulse response function

The impulse response function generated to examine the response of variables to its own shock and shocks from other variables is presented in Tables 10-12. The results show that a one standard deviation shock in the log of CO_2 emission had a negative impact on life expectancy. This emphasizes the detrimental effect of exposure to CO_2 on population health. Mathew et al. (2018) also found CO_2 emission to have a reduction effect on life expectancy in Nigeria. Shocks from total labour force participation also had a negative impact on life expectancy over the 10 year period implying that rather than having a positive income effect on health because earnings from labour participation enables an individual afford more health services, it rather had a depreciation effect. This could be due to the volume, stress and hazards associated with work for those who are employed. It could also be due to the psychological stress caused by the financial hardship and deprivation faced by those who are unemployed.

A one standard deviation shock in total labour force participation had a positive impact on CO_2 initially but the impact became negative from the 5th year to the 10th year. Thus CO_2 emission initially increased with more participation but later declined. This is not surprising since a greater proportion of the labour force in SSA are unemployed. Thus production activities that cause CO_2 emission would decline as unemployment rises. CO_2 emission also responded to shocks from GDP per capita growth with positive responses outweighing the negative. This again emphasizes the pollution consequences of growth.

A one standard deviation shock in life expectancy caused a positive response from labour force participation. Thus, improved health status enables an individual to work and earn income. On the other hand, shocks from CO_2 emission had a negative impact on labour force participation.

Table 10: Response of LEB

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (TLFP)	D (GDPPC_GROWTH)
1	0.545944	0.000000	0.000000	0.000000
2	0.141312	−0.051114	−0.026335	0.014871
3	0.262743	−0.059275	−0.031225	0.006861
4	0.132473	−0.036465	−0.033979	−0.005557
5	0.144222	−0.028234	−0.032381	0.004980
6	0.094326	−0.020482	−0.027840	0.000315
7	0.084867	−0.016978	−0.024000	−0.000502
8	0.062012	−0.012642	−0.020102	0.000827
9	0.051753	−0.010031	−0.016385	0.000136
10	0.039567	−0.007818	−0.013383	−0.000140

Table 11: Response of CO_2 emission

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (TLFP)	D (GDPPC_GROWTH)
1	0.021392	0.109109	0.000000	0.000000
2	−0.008528	0.009224	0.000109	0.002732
3	0.005541	−0.007853	0.000784	0.002909
4	−0.000928	−0.001822	0.000414	−0.002638
5	0.002118	2.45E−05	−0.000237	0.000500
6	0.000214	0.000112	−3.40E−05	0.000575
7	0.000892	−0.000232	−5.17E−05	−0.000478
8	0.000334	−0.000124	−0.000147	0.000118
9	0.000468	−6.43E−05	−8.40E−05	0.000104
10	0.000263	−7.09E−05	−7.68E−05	−0.000104

Table 12: Response of total labour force participation

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (TLFP)	D (GDPPC_GROWTH)
1	0.063637	0.011169	0.471567	0.000000
2	0.001890	−0.015901	0.245862	0.058270
3	0.030796	−0.050863	0.151626	0.004704
4	0.015051	−0.032049	0.085165	−0.001270
5	0.020500	−0.016062	0.048585	0.011319
6	0.013712	−0.010343	0.028404	0.000446
7	0.013041	−0.007542	0.015136	0.000273
8	0.009898	−0.004646	0.008058	0.002316
9	0.008449	−0.003284	0.004206	2.10E−05
10	0.006568	−0.002339	0.001763	0.000122

4.5. Relationship between Life Expectancy at Birth, CO_2 Emission and Disaggregated Labour Force Participation

Based on an estimated panel VAR model, a granger causality test or block exogeneity wald test was conducted to examine the relationship between life expectancy at birth, CO_2 emission and labour force participation disaggregated by gender into female labour force participation and male labour force participation. The GDP per capita growth was included as a control variable in the model. The optimal lag applied in the panel VAR model estimation was determined as 4 based on the Akaike information criterion.

4.5.1. Granger causality test

Since there was no cointegration, a panel VAR model was estimated using the first difference values of all the variables and the error correction term was therefore not included. The panel granger causality test was conducted based on the estimated panel VAR model. The results in Table 13 reveal that there was a unidirectional causality running from female labour force participation to life expectancy. However, a bidirectional causality was obtained between life expectancy and male labour force participation. Hence, participating in the labour force had implications on the health of both male and female individuals. This is similar to the result obtained using total labour force participation. This result also supports the findings of Holt (2010) that the presence of chronic disease reduced labour force participation as well as Nwosu and Woolard (2017), which showed that good health increased labour force participation. There was also a unidirectional causality running from CO_2 emission to life expectancy, which again emphasizes the negative health implication of being exposed to CO_2 emission. All the variables had a joint significant causality on life expectancy at birth.

Table 13: Granger causality/block exogeneity wald test using disaggregated labour force participation

Excluded	Chi-square	df	Prob.
Dependent variable: D (LEB)			
D (LOG (CO_2_EMISSIONS))	47.39463	4	0.0000
D (FLFP)	30.09613	4	0.0000
D (MLFP)	47.14718	4	0.0000
D (GDPPC_GROWTH)	1.947908	4	0.7453
All	102.7824	16	0.0000
Dependent variable: D (LOG (CO_2_EMISSIONS))			
D (LEB)	8.027501	4	0.0906
D (FLFP)	8.084184	4	0.0885
D (MLFP)	6.297755	4	0.1780
D (GDPPC_GROWTH)	2.526843	4	0.6398
All	21.24454	16	0.1693
Dependent variable: D (FLFP)			
D (LEB)	3.077050	4	0.5450
D (LOG (CO_2_EMISSIONS))	3.095335	4	0.5420
D (MLFP)	13.43077	4	0.0094
D (GDPPC_GROWTH)	4.783913	4	0.3102
All	24.43153	16	0.0805
Dependent variable: D (MLFP)			
D (LEB)	24.69669	4	0.0001
D (LOG (CO_2_EMISSIONS))	22.11358	4	0.0002
D (FLFP)	7.416323	4	0.1155
D (GDPPC_GROWTH)	18.44158	4	0.0010
All	77.87586	16	0.0000
Dependent variable: D (GDPPC_GROWTH)			
D (LEB)	29.94124	4	0.0000
D (LOG (CO_2_EMISSIONS))	12.23630	4	0.0157
D (FLFP)	6.414197	4	0.1703
D (MLFP)	11.22243	4	0.0242
All	54.83172	16	0.0000

Life expectancy significantly granger caused GDP per capita growth and the GDP per capita also had a causal effect on life expectancy although jointly with other variables.

GDDP per capita growth had a significant causal effect on male labour force participation and vice versa. Hence, greater labour force participation led to increased total output growth in the region and this increase in income further encouraged more individuals to join the labour force. A bidirectional causality was also found between GDP per capita and CO_2 emission.

Examining the relationship between CO_2 emission and labour force participation, there was a one way causal relationship from CO_2 emission to male labour force participation while a neutrality hypothesis (of no causal relationship) was found between CO_2 emission and female labour force participation. This is contrary to Langnel et al. (2021), which showed that CO_2 emission determined female labour force participation and Wang et al. (2020) that female labour force participation affects CO_2 emissions. Male labour force participation and female labour force participation granger caused GDP per capita growth. While male labour force participation had an individual significant causal effect on GDP per capita, female labour force participation had a causal effect on GDP only jointly with all other variables. However, the causal relationship was bidirectional for male labour force participation, showing a feedback effect while it was unidirectional, running from female labour force participation to GDP per capita.

4.5.2. Variance decomposition analysis

The variance decomposition analysis showed that male labour force participation had the greatest contribution to changes in life expectancy over the 10 year period with its forecast error variance increasing from zero in the 1st year to 6.256 and 5.905 in the 6th and 10th year respectively. The log of CO_2 emission had the next greatest contribution while female labour force participation had the least. Innovations in life expectancy had the greatest contributions to variations in CO_2 emissions over the 10 year period. The forecast error variance in male labour participation caused the greatest variation in female labour force participation. This is because an increase in the proportion of male participants would imply a decline in the female proportion and vice versa. Life expectancy had a substantial contribution to variations in both male and female labour force participation. This was also the case when total labour force participation was used. Therefore, the health status of the population significantly determined their ability to participate in labour market activities, whether to be employed and earn income or to be unemployed and actively searching for a job. This result supports the findings of Cai and Cong (2009) and Cai and Kalb (2006). The results are presented in Tables 14-17.

4.5.3. Impulse response function

The impulse response function was generated to examine the response of variables to its own shock and shocks from other variables and the results are presented in Tables 18-21. The results

Table 14: Variance decomposition of LEB

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)
1	0.415098	100.0000	0.000000	0.000000	0.000000
2	0.448295	97.27816	1.319403	0.002352	1.297863
3	0.524799	93.77619	1.509240	0.012410	4.615476
4	0.593206	89.90062	3.783703	0.029043	6.210500
5	0.620996	90.30508	3.488477	0.028113	6.094691
6	0.646221	90.25271	3.383121	0.028304	6.255768
7	0.659364	90.39882	3.331670	0.027189	6.153161
8	0.667701	90.53766	3.256843	0.078360	6.039955
9	0.673024	90.64556	3.227850	0.082679	5.946252
10	0.675905	90.69213	3.212482	0.092869	5.905421

Table 15: Variance decomposition of CO_2 emission

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)
1	0.104794	3.348424	96.65158	0.000000	0.000000
2	0.105936	4.125276	95.53620	0.001649	0.170616
3	0.106293	4.120996	95.17428	0.007721	0.494745
4	0.106901	4.077257	94.44239	0.486570	0.758849
5	0.106999	4.111729	94.36870	0.512695	0.766551
6	0.107089	4.122200	94.22483	0.519310	0.861518
7	0.107164	4.129811	94.09895	0.538389	0.960067
8	0.107209	4.147295	94.02037	0.560611	0.998741
9	0.107231	4.157484	93.98431	0.561807	1.023347
10	0.107249	4.161522	93.95512	0.563174	1.047134

Table 16: Variance decomposition of female labour force participation

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)
1	0.543292	0.947000	0.129485	98.92351	0.000000
2	0.622130	0.933575	0.099122	98.46968	0.196148
3	0.657054	0.936071	0.195910	97.67373	0.902264
4	0.669037	0.910323	0.455761	95.28773	3.027371
5	0.679213	0.884403	0.624412	94.49028	3.551963
6	0.685367	0.871096	0.632226	94.16337	3.892088
7	0.690021	0.871308	0.624077	93.98244	4.085587
8	0.693187	0.868441	0.618447	93.65364	4.425903
9	0.695351	0.871578	0.614674	93.40791	4.667497
10	0.696871	0.876060	0.612044	93.22035	4.849983

Table 17: Variance decomposition of male labour force participation

Period	S.E.	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)
1	0.523676	7.408625	0.004258	49.55042	43.03670
2	0.582190	6.108292	0.465220	50.42217	41.26949
3	0.604865	5.988493	1.592778	50.68373	40.12404
4	0.619184	7.227447	3.749198	49.07557	38.40924
5	0.627566	7.392884	3.762502	48.23573	39.05923
6	0.633388	7.776559	4.007276	47.61165	39.06549
7	0.637564	7.908235	4.134191	47.09902	39.27566
8	0.640115	8.031586	4.129406	46.84577	39.42245
9	0.641949	8.119613	4.148816	46.59280	39.57250
10	0.643363	8.143279	4.167024	46.39469	39.73543

Table 18: Response of LEB

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)	D (GDPPC_GROWTH)
1	0.415098	0.000000	0.000000	0.000000	0.000000
2	0.152288	−0.051494	−0.002174	−0.051071	0.014333
3	0.250548	−0.038795	0.005427	−0.100516	−0.005773
4	0.241001	−0.095697	0.008248	−0.095617	0.005402
5	0.178592	0.011758	0.002492	−0.040608	−0.007391
6	0.169256	−0.025983	0.003128	−0.051194	0.003455
7	0.126974	−0.018890	8.86E−05	−0.025048	0.007289
8	0.103052	−0.005915	0.015203	−0.013267	−0.001022
9	0.083371	−0.010056	0.005016	−0.002579	0.007327
10	0.061120	−0.007432	0.007054	0.006676	0.001115

Table 19: Response of CO_2 emission

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)	D (GDPPC_GROWTH)
1	0.019176	0.103025	0.000000	0.000000	0.000000
2	−0.009759	0.010368	−0.000430	−0.004376	0.004319
3	−0.001626	−0.005613	−0.000829	−0.006062	0.002048
4	0.000585	−0.006302	0.007398	−0.005552	−0.001999
5	0.002191	0.003367	−0.001759	−0.001020	0.000816
6	0.001410	−0.001257	−0.000926	−0.003322	−0.001922
7	0.001240	−0.000839	−0.001508	−0.003385	0.000342
8	0.001552	0.000236	0.001614	−0.002130	−0.000222
9	0.001171	0.000627	0.000406	−0.001696	0.000147
10	0.000789	0.000455	0.000423	−0.001666	−9.84E−05

Table 20: Response of female labour force participation

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)	D (GDPPC_GROWTH)
1	−0.052870	0.019550	0.540360	0.000000	0.000000
2	−0.028603	0.001204	0.298553	−0.027553	0.034159
3	−0.020684	−0.021497	0.201381	−0.056001	−0.009689
4	−0.005788	−0.034558	0.069575	−0.098263	−0.012897
5	−0.002306	−0.028993	0.096925	−0.053249	−0.025378
6	−0.003430	−0.009441	0.079998	−0.043543	0.001196
7	−0.007534	0.001291	0.071873	−0.034212	0.002488
8	−0.004938	0.000528	0.050357	−0.042593	−0.002154
9	−0.006424	0.000586	0.040327	−0.036071	−0.006006
10	−0.006340	−0.000478	0.032631	−0.031384	−0.004994

Table 21: Response of male labour force participation

Period	D (LEB)	D (LOG (CO_2_EMISSIONS))	D (FLFP)	D (MLFP)	D (GDPPC_GROWTH)
1	0.142538	0.003417	0.368626	0.343544	0.000000
2	−0.019662	−0.039562	0.187131	0.147846	0.076682
3	0.034726	−0.065196	0.120538	0.083174	0.003710
4	0.076155	−0.092448	0.052132	0.021404	−0.002178
5	0.037508	−0.021076	0.042671	0.081079	−0.014301
6	0.045629	−0.035471	0.032214	0.053785	0.008434
7	0.030789	−0.026992	0.021047	0.054106	0.016125
8	0.027626	−0.010731	0.022306	0.043379	0.001411
9	0.023485	−0.013306	0.007650	0.039305	0.004279
10	0.015672	−0.012280	0.005218	0.037336	0.000855

show that a one standard deviation shock in CO_2 emission and male labour force participation had a negative impact on life expectancy. GDP per capita growth had a positive impact on life expectancy for most of the 10 year period. Shocks from life expectancy, and GDP per capita growth had positive impacts on CO_2 emission for more of the periods over the 10 years. Male labour force participation shocks had a consistently negative impact over the 10 year period, however, shocks from female labour force participation had the least impacts on CO_2 emission. A one standard deviation shock in life expectancy and male labour force participation had negative impacts on female labour force participation. Therefore, poor health as shown by low life expectancy tend to hinder female participation than that of male probably due to the fact that women and girls are usually the first to be assigned care giving roles for children and any other adult household member who are sick. This affects their ability to participate in the labour market. Female and male labour force participation also responded to shocks from CO_2 emission and GDP per capita growth over the 10 year period.

5. CONCLUSION

This study examined the dynamic causal relationship between life expectancy, CO_2 emission and labour force participation. The study employed the block exogeneity wald test based on an estimated panel VAR approach. The dynamic interactions among the variables and the effect of shocks was also examined using the variance decomposition analysis and by generating impulse response functions. For robustness, the estimation was done using both aggregate labour force participation as well as disaggregating labour force participation inorder to investigate the differentials by gender. The results showed that there was evidence of a feedback effect in the relationship between life expectancy and total labour force participation based on the bidirectional causality that was found. Disaggregating total labour force participation, we found that there was a unidirectional causality running from female labour force participation to life expectancy. However, the bidirectional causality was obtained only between life expectancy and male labour force participation. Thus as more adults get to participate in labour market activities, they are able to earn income to meet their healthcare needs and thereby improve their longevity and health. On the other hand, a healthy population enables more labour to be able to supply their services or work for more hours in the labour market.

A one standard deviation shock from total labour force participation had a negative impact on life expectancy over the 10 year period; with male labour force participation having negative impacts while shocks from female labour force participation and GDP per capita growth had positive impacts for most of the 10 year period. Life expectancy also had the greatest contribution to variations in total labour force participation.

There was a bidirectional causality between life expectancy and CO_2 emission. A one standard deviation shock in the log of CO_2 emission had a negative impact on life expectancy. Life expectancy also had the greatest contribution to variations in CO_2 emission. Shocks from life expectancy had a positive impact on CO_2 emission for most of the periods during the 10 years. This implies that as more of the population become healthy and live longer, they get to participate in production and other daily activities, most of which involve the use of fossil fuel that contribute to CO_2 emission.

Examining the relationship between CO_2 emission and labour force participation, there was a significant unidirectional causality running from CO_2 emission to total labour force participation. However, after disaggregation, the unidirectional causality was found to hold only for male labour force participation while a neutrality hypothesis was found between CO_2 emission and female labour force participation. An increasing environmental pollution due to CO_2 emission, would increase policy efforts towards environmental protection and this would involve employing more labour for the implementation of such strategies including tax imposition and public health awareness campaigns. Male labour force participation shocks had a consistently negative impact on CO_2 emission however, shocks from female labour force participation had the least impacts on CO_2 emission for most of the periods during the 10 years. This result is possible since an increase in labour force participation does not necessarily mean that the participants are employed and busy with production activities that would emit CO_2. Shocks from GDP per capita growth also had more positive impacts on CO_2 emission than negative impacts over the 10 year period. Therefore, policies towards the use of less polluting production technologies ino rder to reduce the negative environmental effect of increased female labour force participation and economic growth.

A one way causality was also obtained from GDP per capita growth to total labour force participation. However, after disaggregating, there was a feedback effect for male labour force participation while it was unidirectional, running from female labour force participation to GDP per capita.

Creating policy strategies for the reduction of CO_2 emission is therefore pertinent for increasing life expectancy in SSA. However, more enlightenment and incentives towards encouraging more environmentally friendly behavior and transition to clean energy use is important to prevent a negative effect of improved population health or longevity on the environment in the form of more CO_2 emissions. This study is limited to carbon dioxide emission, however, this relationship could also be examined using other green house gasses as well as other environmental quality measures.

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