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Original Article

Food Insecurity and Health Status in the CEMAC Sub-Region

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Abstract - *Many developing countries today suffer from both food insecurity and poor health. Addressing food insecurity is crucial for promoting overall health and longevity. This study sought to examine the long-run effect of food insecurity on health status in the CEMAC sub-region by using data from FAO and the World Bank for the period 1990-2021. To achieve this aim, annual food insecurity indices were constructed by applying the Principal Components (PCA) technique. By employing the panel Dynamic Ordinary Least Squares (DOLS), panel Fully Modified Ordinary Least Squares (FMOLS) and Pooled Mean Group (PMG) estimators with life expectancy at birth as a proxy for health status, the study found that food insecurity contributes to poor health in the sub-region. A unit increase in the food insecurity index leads to a fall in life expectancy by 0.1 to 0.2 years. A bi-directional causality was found between food insecurity and life expectancy. On this basis, it is recommended that CEMAC countries adopt policies that address food insecurity, such as increasing the minimum wage, improving infrastructure, combatting climate change, and improving access to healthcare.*

Keywords **-** *Causality, Cointegration, DOLS, FMOLS, PMG.*

1. Introduction

Food insecurity and poor health constitute a major obstacle to human wellbeing and development. Whereas the World Food Summit of 1996 set the target of halving the number of hungry people in the world by 2015 from 800 million to 400 million, the World Food Program (2020) predicts that with the current trend in malnutrition, the number of hungry people could reach 840 million by 2030. FAO (2022), in its report on the state of food security and nutrition in the world, noted that the prevalence of undernourishment rose from 8% in 2019 to 9.3% in 2020, then to 9.8% in 2021, with as many as 702 to 828 million people affected by hunger in 2021 – an increase of 46 million from the previous year. The number of people affected by hunger in Africa alone was estimated to be 278 million people in 2021, representing about 20.2% of Africa's population. The report also estimates the number of moderately or severely food insecure people in the world in 2021 to be 2.3 billion, representing about 30% of the world's population. This represents a rise of more than 350 million people from 2019, the year prior to the Covid 19 pandemic.

Life expectancy at birth is a widely used indicator of population health status by many health agencies, such as the World Health Organization and the Centre for Disease Control and Prevention (CDC). This is because it represents the cumulative effects of physical, environmental, social, behavioural and genetic factors on population health (WHO, 2006). While life expectancy has improved significantly over the last centuries in many countries around the world, it is still relatively low in Sub-Saharan Africa (SSA). Life expectancy in SSA is still less than 60 years, compared to more than 80 years in many developed countries, such as those in Europe and Japan (Ortiz-Ospina & Roser, 2016; WHO, 2023).

The Central African Economic and Monetary Community (CEMAC) is one of the least developed economic blocs in the world despite its strong social and economic potential. CEMAC countries conduct over 80% of their trade with Europe, China and Russia and only 4% with each other (Voice of Africa, 2024). Among the six CEMAC member countries, Chad and the Central African Republic (CAR) are low-income countries; Cameroon and Congo are lower-middle income countries; and Equatorial Guinea and Gabon are upper-middle income countries (World Bank 2024). Notwithstanding their enormous natural resource reserves, Doing Business indicators rank these countries among the bottom 30 of 190 countries (World Bank 2020).

Most CEMAC countries face diverse conflicts which, coupled with problems of poor hygiene and sanitation, malnutrition, lack of clean water for domestic use and a poor and costly healthcare delivery system, have caused a greater part of the population to remain in poor health. For instance, life expectancy at birth in 2020 was just 58.9 years in Cameroon, 52.8 in the Central African Republic (CAR), 53.98 in Chad, 58.4 in Equatorial Guinea and 66.2 in Gabon as opposed to 71.9 years in middle-income countries and 71 years in low and middle-income countries (World Bank, 2023). The Global Hunger Index (GHI) ranking of 121 countries in 2022 ranked the Central African Republic at 120, just second to Yemen in terms of the country with the highest prevalence of hunger. Chad ranked at 117, the Republic of Congo at 105 and Cameroon at 80. However, in 2000, 2007 and 2014, the GHI scores for these countries (calculated on a scale of 0 to 100) were much worse than they were in 2022 (Grebmer, et al., 2022). However, the nature of the interrelationship between food insecurity and life expectancy in the sub-region has not been sufficiently investigated.

2. Literature Review

2.1. Theoretical Review

Food security is conceived as "access by all people at all times to enough food for an active and healthy life" (Bickel et al., 2000). Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. A person is food insecure if they lack regular access to safe and nutritious food for normal growth and development and an active and healthy life (FAO, 2024). Conversely, Bickel et al. (2000) define food insecurity as limited or uncertain availability of nutritionally adequate and safe foods, while Food Forward (2019) defines food insecurity as a lack of access to adequate, good, healthy and culturally appropriate food.

Food insecurity exists if any of the four dimensions of food security are compromised, namely food availability, food access, food utilization and food stability (FAO, 2013). Food availability exists when there is a sufficient supply of food, which can originate from local production, imports or from food aid. Access implies that food should be physically accessible (physical access), affordable (economic access), and should be obtainable in socially acceptable ways that exclude begging or stealing (social access). Utilization means the food should be safe, nutritious and assimilable. Stability means the food should be available at all times (FAO, 2013).
WHO (1948), in the preamble of its constitution, insisted that health is not the mere absence of disease or infirmity but a state of complete physical, mental and social wellbeing. This holistic definition of health has not changed over the years. Health status is thus the condition or quality of the physical, mental and social wellbeing. While some measures of health status are subjective (such as self-reported health), others are objective and quantifiable. Objective measures of health status, such as mortality and longevity indicators, include a range of age and gender-specific mortality rates, as well as derived indicators of age and gender-specific life expectancy and potential years of life lost to disease and injury (Australian Institute of Health and Welfare, 2023).

Several theories have been advanced over the years to explain the observed differences in health and longevity in different parts of the world. According to the Grossman model of health capital (Grossman, 1972a; 1972b; Strulik, 2014), health can be viewed both as a consumption and an investment good, produced with a combination of time inputs and inputs of other goods like medical care and nutrition. Still it can, however, depreciate as a result of negative lifestyle habits and exogenous factors like aging. However, the efficiency of a combination of these inputs depends on the level of educational attainment. As such, medical care, nutrition, and education are key determinants of health and longevity, according to the health capital model.

The naturalistic theory of illness and health (Foster, 1976; Brown & Closser, 2016) argues that illness and poor health can be explained by natural factors like malnutrition, injuries from accidents or battle-related wounds, and parasites. This theory identifies malnutrition, an extreme case of food insecurity, as a leading cause of poor health and low life expectancy.

Theories of social or wider determinants of health, such as the Evans and Stoddart (1990) comprehensive model of health determinants and the Dahlgren and Whitehead (1991) 'rainbow model', describe the interrelationship between the individual, their environment and their health status. According to these models, elements of the social, economic, cultural and physical environments interact with individual, biological and behavioural factors to influence a person's or a population's health status.

2.2. Empirical Review

Food insecurity has been shown to have adverse effects on health, notably a fall in life expectancy (Beyene, 2023), an increased risk of diet-related diseases such as diabetes (Hutchinson & Tarasuk, 2021; Tait et al., 2018), increased vulnerability to infectious diseases (Cox & Hamelin, 2017; Bekele, et al., 2018), poor oral health (Muirhead et al., 2009), increased injury-related emergency department visits (Men et al., 2021), and chronic conditions. Such conditions include depression and anxiety (Jessiman-Perreault & McIntyre, 2017; Shafiee et al., 2021), heart disease, hypertension, arthritis, back problems and chronic pain ((Men et al., 2021; Tarasuk et al., 2013). It has also been found that food insecurity can make it hard for people to manage existing health challenges and can even lead to the worsening of such challenges (Aibibula et al., 2016).

In a recent study, Beyene (2023) showed that a 1% increase in the prevalence of undernourishment reduces life expectancy by 0.0035% points and increases infant mortality by 0.012% points in SSA countries. On the contrary, a 1% increase in the average dietary energy supply increases life expectancy by 0.0032% points and reduces infant mortality by 0.014% points. In a similar study, Gundersen et al. (2018) found that mortality is linked to food insecurity. By studying 90,368 adults who participated in the Canadian Community Health Survey (CCHS) in 2004 and within four years of the interview, they found that the odds of death at any time were higher for food-insecure individuals, namely: 1.28 for marginally food-insecure individuals, 1.49 for moderately food-insecure individuals and 2.60 for severely food-insecure individuals.

Gundersen and Ziliak (2015) reviewed the literature on the health consequences of food insecurity on children, young adults and seniors in the United States. What they observe is a consistent association of food insecurity with negative health outcomes. Concerning children, they found that food insecurity is associated with some congenital disabilities, anaemia, lower nutrient intake, asthma, cognitive problems, aggression, anxiety and depression, bad oral health, increased hospitalizations, poor general health and suicidal dispositions. In young adults, they found that food insecurity is associated with decreased nutrient intake, depression and mental ill-health, diabetes, hypertension, hyperlipidaemia, poor sleep and poor self-rated health. In seniors, they found that food-insecure adults are more likely to report lower nutrient intakes, to be depressed, and to have functional limitations.

Men, Urquia and Tarasuk (2021) examined the relationship between food insecurity and causes of injury among 212,300 Canadians aged 12 and above for the period 2003 to 2017. In this retrospective cohort study, they estimated the incidence of injury-related emergency department visits for individuals based on their food insecurity status while controlling for other correlates. They found that, compared to individuals from food-secure households, the incidence rate of emergency department visits was 1.35 times higher for individuals from severely food-insecure households and 1.19 times higher for individuals from moderately food-insecure households. They observed the same nature of association across age groups and across genders. They found food insecurity to be associated with intentional injuries such as self-harm and violence, as well as with unintentional injuries such as falling, medical complications, being struck by objects, overexertion, skin piercing, and poisoning.

On the link between food insecurity and mental health, Jones (2017) has calculated two indices to measure mental health, namely, the negative experience index and the positive experience index (both measured on a 0-100 scale) in 149 countries by using data from the 2014 Gallup World Poll. He found that the negative experience index increased by 10.1, 17.7, and 24.5 units for every unit increase in mild, moderate and severe food insecurity, respectively. On the other hand, the positive experience index decreased by 8.3, 12.6, and 16.2 units for every unit, which increased in mild, moderate, and severe food insecurity, respectively. In a similar study, Shafiee et al. (2021) found that household food insecurity is a strong predictor of mild-to-severe depressive symptoms. Specifically, the odds of depressive symptoms are 2.87 times higher for adults from food insecure households than otherwise.

Tarasuk et al. (2013), on the other hand, have shown that chronic physical and mental health conditions may increase vulnerability to food insecurity. For instance, they found that adults with chronic health conditions (asthma, arthritis, back problems, bowel disorders, diabetes, heart disease, hypertension, migraines, mood or anxiety disorder) have higher odds of being food-insecure or of belonging to food-insecure households. Compared with adults with no chronic condition, the odds of household food insecurity were 1.43, 1.86, and 3.44 for adults with 1, 2, and 3 or more chronic conditions, respectively.

3. Methodology

3.1. Scope and Area of the Study

This study covers the six member states of the Central African Economic and Monetary Community (CEMAC), namely Cameroon, the Central African Republic (CAR), Chad, Congo, Gabon and Equatorial Guinea. With a population of around 37 million, CEMAC covers a total surface area of about 3 million square kilometres. The union was created in March 1994 and has headquarters in Bangui. Its objective is to promote peace and the harmonious development of its member states in the context of a common market based on the free mobility of persons, goods, services, and capital. Cameroon is the most populated of these countries, but based on surface area, Chad is the largest (see Table 1). Equatorial Guinea and Gabon have high incomes per head and very developed service sectors. Only Equatorial Guinea has a low ethnic fractionalization index, which corresponds to the probability that any two randomly drawn individuals from a country do not belong to the same ethnic group.

3.2. Construction of Food Insecurity Index

This study followed Napoli et al. (2011) and FAO (2013) to construct annual food insecurity indices based on FAO's Suite of Food Security Indicators (see Table 2). Each indicator was normalized and then multiplied by 100 in order to obtain an identical range (0 to 100) as follows:

$$Indicator\ Index = 100 \times \left(\frac{actual\ value - r(\min)}{r(\max) - r(\min)} \right) \quad (1)$$

In Equation 1, *r(min)* and *r(max)* are the minimum value and maximum values, respectively. Next, the 'good' indicators, those that do not positively correlate with food insecurity, were inversed.

Table 1. Brief presentation of CEMAC countries

CEMAC Country	Total Population	Surface area (km^2)	GDP per Capita (LCU)	Employment structure (%) Agric:Industry: Services	Ethnic Fractionalization
Cameroon	27,224,262	475,440	921,464	43.5: 14.4: 42.1	0.864
CAR	4,919,987	622,980	283,633	69.8: 06.3: 23.9	0.830
Chad	16,914,985	1,284,000	386,187	75.1: 01.9: 23.1	0.862
Congo	5,657,017	342,000	1,227,664	33.5: 21.5: 45.0	0.875
Equatorial Guinea	1,449,891	28,050	4,692,597	39.5: 19.4: 41.1	0.347
Gabon	2,278,829	267,670	4,445,667	30.0: 10.7: 59.3	0.769

Note: LCU = constant local currency units (Franc CFA). Agric = Agriculture. All figures are 2021 estimates.

Source: World Bank (2023) and Fearon (2003).

Table 2. Food security dimensions and their indicators used in this study

Indicator	Description
Average value of food production[1]	Per capita value of net food production in constant 2004-06 international dollars
Rail-lines density[2]	Total route in km per 100 square km of land area
Consumer price index (2010 = 100) [2]	Reflects changes in the cost to the average consumer of acquiring a basket of goods
Access to improved water sources[3]	Percentage of people using clean water available within 1 km of their premises
Access to improved sanitation facilities[3]	Percentage of households using piped sewer systems and improved latrines
Wasting (children <5 years), %[3]	Children below -2 Standard Deviations (SD) from the median weight-for-height of the WHO Child Growth Standards
Stunting (children <5 years), %[3]	Children below -2 SD from the median height-for-age of the WHO standards
Prevalence of anaemia among women of reproductive age[3]	Haemoglobin levels below 12 g/dL for non-pregnant women and 11 g/dL for pregnant women.
Value of food imports over total merchandise exports[4]	The value of food imports (excluding fish) is divided by the total merchandise exports.
Per Capita food production variability[4]	Variability of net food production per capita in constant 2004-06 international dollars

[1]Indicator of food availability; [2]Indicator of food access; [3]Indicator of food utilization; [4]Indicator of food stability.

Source: Compiled by authors from the FAO Term Portal (FAO, 2013) and World Bank (2023).

They include the average value of food production, rail line density, access to improved water sources, and access to improved sanitation facilities. They were inversed as follows:

$$Inversed\ indicator = 100 - actual\ indicator\ index \quad (2)$$

The final food insecurity index was constructed through two aggregations: first, a synthetic index for each dimension (availability, access, utilization, stability) computed as the arithmetic mean of its indicators, then a composite index computed as the power mean of the four dimensions. By computing a power mean, more weight is given to dimensions that are larger in value since they contribute more to food insecurity (Tooth and Dobelman 2016).

Following Anand and Sen (1997) and Napoli et al. (2011), a power of 3 was chosen as it places more weight on those dimensions where deprivation is greatest. The final index (Foodins) was calculated as:

$$Foodins_{it} = \left[{}^{1}\!/_{4}\left(Availability_{it}^{3} + Access_{it}^{3} + Utilization_{it}^{3} + Stability_{it}^{3}\right)\right]^{1/3} \quad (3)$$

Following Napoli et al. (2011), an index below 30 implies the country is food secure; an index of 30-40 signals moderate food insecurity; an index of 40-50 signals serious food insecurity; an index of 50-60 signals alarming food insecurity and an index above 60 signals extremely alarming food insecurity.

3.3. Specification of Model

To investigate the effect of food insecurity on health status, health status (measured by life expectancy at birth, $Lifeexp_{i.t}$) is expressed as a function of food insecurity ($Foodins_{i.t}$) and a vector of other theorised correlates (income as measured by the natural logarithm of GDP, physician density and adult literacy rate – see Tables 3 and 4).

$$Lifeexp_{i.t} = \beta_0 + \beta_1 Foodins_{i.t} + \beta_2 lgdp_{i.t} + \beta_3 physician_{i.t} + \beta_4 literacy_{i.t} + \delta_i + \mu_t + \epsilon_{it} \quad (4)$$

Where δ_i is the country-specific fixed effects which are time-invariant, μ_t represents time-fixed effects which affect all countries alike, ϵ_{it} is the error term, and α_i are the parameters to be estimated.

Table 3. Meaning of variables and sources of data

Variable	Meaning	Source	Expected sign
Lifeexp	Life expectancy at birth as a proxy for health status	World Bank	
Foodins	Food insecurity index	Computed by authors	-
lgdp	Natural logarithm of Gross Domestic Product (GDP)	World Bank	+
Physician	Physician density (number of physicians per 10,000 inhabitants)	World Bank	+
Literacy	Percentage of people aged 15 and above who can read and write	World Bank	+

Source: Compiled by authors based on existing literature.

Table 4. Descriptive statistics of variables under study

Variables	Obs	Mean	Std Dev	Min	Max	Skew.	Kurt.
Lifeexp	192	54.23	5.59	44.06	66.91	0.27	2.37
Foodins	192	51.34	9.03	37.48	81.10	0.77	3.33
lgdp	192	22.38	1.30	18.43	24.54	-0.78	3.35
Physician	192	0.19	0.24	0.02	1.99	4.13	25.83
Literacy	192	58.54	9.24	35.27	83.12	0.12	2.34

Source: Authors' calculations using Stata 17.

It is hypothesized that food insecurity would contribute to declines in life expectancy, which is in line with Grossman's (1972a, 1972b) theory of health capital, which identifies nutrition and diet as key inputs in health production. Income, as measured by lGDP, should have a positive effect on life expectancy since economically disadvantaged people have been found to come first in the ranking of groups of people reported to be in poor health (CPHI, 2015). An increase in physician density should lead to gains in life expectancy following Basu et al. (2019), and improvements in adult literacy should contribute to gains in life expectancy following Gilbert et al. (2018) and Fayan et al. (2021).

3.4. Cross-Sectional Dependence Tests

Cross-section dependence exists if time series for different cross-sectional units are correlated. This may arise from common events that have different spill-over effects. The Breusch and Pagan (1980) LM, the Pesaran (2015) CD, the Pesaran (2004) scaled LM, and the Baltagi et al. (2012) bias-corrected scaled LM tests were employed to test for cross-section dependence (Table 5). The findings show sufficient evidence that the series are cross-sectionally dependent.

3.5. Second Generation Panel Unit Root Tests

Second-generation unit root tests were employed, namely, the Cross-section augmented Dickey-Fuller test (CADF) and the Cross-section augmented Im-Pesaran-Shin test (CIPS) (Pesaran 2003; 2007) due to cross-section dependence. As shown in Table 6, the variables are stationary at the first difference, that is, integrated of order 1 or I(1).

3.6. Panel Second Generation Cointegration Tests

The Westerlund (2007) error-correction-based panel cointegration tests (see Table 7) allow for slope heterogeneity and dependence across and within panels. The first set of tests (Gt and Ga) test the hypothesis that cointegration exists in at least one of the panels, while the second set of tests (Pt and Pa) test the hypothesis that cointegration exists in all the panels. The results strongly reject the hypothesis of the absence of cointegration among the series.

Table 5. Findings of cross-sectional dependence tests

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Lifeexp	375.253 (0.000)	65.773 (0.000)	65.676 (0.000)	19.225 (0.000)
Foodins	181.563 (0.000)	30.410 (0.000)	30.313 (0.000)	8.2687 (0.000)
lgdp	411.712 (0.000)	72.429 (0.000)	72.332 (0.000)	20.250 (0.000)
physician	141.949 (0.000)	23.177 (0.000)	23.081 (0.000)	1.941 (0.052)
literacy	269.566 (0.000)	46.477 (0.000)	46.380 (0.000)	-1.929 (0.053)

Note: p-values in parentheses. The null hypothesis states that there is no cross-section dependence.

Source: Authors' calculations using EVIEWS 10.

Table 6. Findings of the CADF and CIPS tests for unit roots

	Cross-section augmented Dickey-Fuller test (CADF)		Cross-section augmented Im-Pesaran-Shin test (CIPS)	
	Level	1st difference	Level	1st difference
Lifeexp	-0.400	-2.607**	-0.400	-4.835***
Foodins	-1.277	-2.427**	-1.491	-5.099***
lgdp	-1.437	-2.793***	-1.516	-4.872***
physician	-0.122	-3.336***	-1.318	-4.532***
literacy	-1.852	-3.510***	-1.420	-2.497***

Source: Authors' calculations using Stata 17.

Table 7. Cointegration tests for the life expectancy model

Statistic	Value	Z-value	P-value	Robust P-value
Gt	-4.924	-5.562	0.000	0.000
Ga	-5.271	3.427	1.000	0.000
Pt	-7.655	-1.220	0.111	0.000
Pa	-5.590	2.361	0.991	0.000

Source: Authors' calculations using Stata 17.

3.7. Estimation Techniques

The first estimators employed in this study account for heteroskedasticity, serial correlation and cross-section dependence, namely the Feasible Generalized Least Squares (FGLS) proposed by Parks (1967) and popularized by Kmenta (1986); regression with Panel-Corrected Standard Errors (PCSE) proposed by Beck and Katz (1995); and regression with Driscoll-Kraay Standard Errors (DKSE) proposed by Driscoll and Kraay (1998). These estimators are more efficient than the traditional Ordinary Least Squares (OLS) estimator. They are helpful in estimating relationships among variables that are stationary at level or integrated of the same order, where heteroskedasticity, serial correlation or cross-section dependence may be a problem. FGLS and PCSE are valid only if the time dimension (T) is greater than the number of cross-sections (N), while DKSE works well even if N > T.

This study also employed three efficient dynamic estimators to investigate the long-run effect of food insecurity on life expectancy: the panel Fully Modified Ordinary Least Squares (FMOLS), panel Dynamic Ordinary Least Squares (DOLS) and the Pooled-Mean Group (PMG) in order to account for small sample bias, simultaneity bias, endogeneity problems, serial correlation and heteroskedasticity. The DOLS approach takes care of serial correlation, heteroskedasticity and endogeneity by adding lags and leads of the regressors (Stock & Watson, 1993). Following Pedroni (2001), this regression is stated as:

$$y_{it} = \alpha_i + \beta_i x_{it} + \sum_{j=-q}^{p} \gamma_{it} \Delta x_{it-j} + \mu^*_{it} \quad (5)$$

In the context of this study, this regression is specified as:

$$Lifeexp_{it} = \alpha_0 + \vec{\alpha}_1 Foodins_{it} + \vec{\alpha}_2 \text{lgdp}_{it} + \vec{\alpha}_3 \text{physician}_{it} + \vec{\alpha}_4 \text{literacy}_{it} + + \sum_{j=-q}^{p} \vec{d}_1 \Delta Foodins_{t-j} + \sum_{j=-q}^{p} \vec{d}_2 \Delta \text{lgdp}_{t-j} + \sum_{j=-q}^{p} \vec{d}_3 \Delta \text{physician}_{t-j} + \sum_{j=-q}^{p} \vec{d}_4 \Delta \text{literacy}_{t-j} + \mu_i \quad (6)$$

Where $\vec{\beta}$ is the cointegrating vector, which represents the long-run effect of a change in the independent variable on the dependent variable; p is the lag length; q is the lead length, and $\vec{\beta}$ and $\vec{d}$ are parameters to be estimated. The corresponding group-mean panel DOLS estimator and its t-statistic are given as:

$$\beta^*_{DOLS} = \left[N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} z_{it} z'_{it}\right)^{-1} . \left(\sum_{t=1}^{T} z_{it}(y_{it} - \bar{y}_i)\right)\right] \quad (7)$$

$$t_{\hat{\beta}^*_{DOLS}} = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \left(\hat{\beta}^*_i - \beta_0\right) \left[\hat{\sigma}_i^{-2} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)^2\right]^{\frac{1}{2}} \quad (8)$$

Where $z_{it} = (x_{it} - \bar{x}_i, \Delta x_{it-K}, \ldots, \Delta x_{it+K})$ is a $2(K+1) \times 1$ vector of regressors and $\hat{\sigma}_i^2$ is a long-run variance estimate of μ^*_{it}. The panel FMOLS uses a semiparametric approach to eliminate the problems of cross-correlation between the cointegration equation error and the regressor innovations. The group-mean panel FMOLS estimator (Pedroni 2001) is stated as:

$$\beta^*_{FMOLS} = N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} (x_{it} - \bar{x}_i)^2\right)^{-1} . \left(\sum_{t=1}^{T} (x_{it} - \bar{x}_i) y^*_{it} - T\hat{\gamma}_i\right) \quad (9)$$

where $y^*_{it} = (y_{it} - \bar{y}_i) - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}} \Delta x_{it}$

$$\hat{\gamma}_i = \hat{\Gamma}_{21i} + \hat{\Omega}^0_{21i} - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}} \left(\hat{\Gamma}_{22i} + \hat{\Omega}^0_{21i}\right)$$

Ω_i is the covariance matrix of the error process, which can be decomposed as $\Omega_i = \Omega^0_i + \Gamma_i + \Gamma'_i$ where Ω^0_i is the contemporaneous covariance and Γ_i is a weighted sum of autocovariances.

The PMG estimator (Pesaran et al. 1999) is useful in estimating long- and short-run effects even if the variables are integrated into different orders. It controls for endogeneity and serial correlation by using sufficient lags of the dependent and independent variables. It constraints the long-run coefficients to be similar across panels but allows the short-run coefficients, intercepts and error variances to vary across panels. Following Pesaran et al. (1999), the following ARDL model is specified:

$$y_{it} = \sum_{j=1}^{p} \delta_i y_{i,t-j} + \sum_{j=0}^{q} \beta'_{ij} x_{i,t-j} + \varphi_i + e_{it} \qquad (10)$$

Where y and x are the dependent variable and vector of covariates defined in equation (4); φ_i represents the country-specific fixed effects; $p\ and\ q$ are optimal lag orders, and e_{it} represents the error term. The re-parameterized error correction ARDL model is specified as follows:

$$\Delta y_{it} = \theta_i[y_{i,t-j} - \lambda'_i x_{i,t}] + \sum_{j=1}^{p-1} \xi_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \beta'_{ij} \Delta x_{i,t-j} + \varphi_i + e_{it} \qquad (11)$$

$\theta_i = -(1-\delta_i)$ is the group-specific speed of adjustment; $ECT = [y_{i,t-j} - \lambda'_i x_{i,t}]$ is the error-correction term; $\xi_{ij}\ and\ \beta'_{ij}$ are short-run coefficients.

3.8. Panel Causality Test

This study also aims to investigate the nature of causality between food insecurity and life expectancy following Dumitrescu and Hurlin's (2012) procedure, which accounts for slope heterogeneity and cross-section dependence. The underlying regression is stated as follows:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} x_{i,t-k} + \varepsilon_{i,t} \qquad (12)$$

Where $y_{i,t}$ and $x_{i,t}$ are life expectancy and food insecurity scores for country i in year t, respectively. Coefficients can differ across panels but not over time periods, and the lag order K is assumed to be the same for all units. To test for causality means to test for significant effects of the past values of x on the present value of y. The null hypothesis of no causality (H_0) and the alternative hypothesis (H_1) are:

$$H_0: \beta_{i1} = \cdots = \beta_{iK} = 0 \qquad \forall i = 1, \dots, N$$

$$H_1: \begin{pmatrix} \beta_{i1} = \cdots = \beta_{iK} = 0 & \forall i = 1, \dots, N_1 \\ \beta_{i1} \neq 0\ or \dots \beta_{iK} \neq 0 & \forall i = N_1 + 1, \dots, N \end{pmatrix} \qquad (13)$$

Where N_1, which is unknown, is strictly less than N. If $N_1 = 0$, there is causality for all the cross-sectional units. But if $N_1 = N$, then H_1 reduces to H_0 and there is no causality for all the units.

4. Findings and Discussion

Table 8. Regression estimates of the life expectancy model

VARIABLES	PSCE	FGLS	DKSE	DOLS	FMOLS	PMG
Foodins	-0.141***	-0.129***	-0.141**	-0.180**	-0.108***	-0.101**
	(0.0337)	(0.00906)	(0.0468)	(0.075)	(0.009)	(0.041)
lgdp	2.084***	1.948***	2.084***	2.461***	2.368***	1.143***
	(0.192)	(0.0892)	(0.243)	(0.179)	(0.003)	(0.204)
Physician	6.418***	5.892***	6.418***	5.346***	6.578***	5.238***
	(0.988)	(0.378)	(1.047)	(3.328)	(0.004)	(0.514)
Literacy	0.0790***	0.0888***	0.0790**	0.119	0.085***	0.0790**
	(0.0193)	(0.00824)	(0.0291)	(0.047)	(0.002)	(0.029)
ECT						-0.025***
						(0.004)
Constant	9.090	10.85***	9.090			0.793***
	(6.242)	(2.378)	(8.445)			(0.156)
Observations	192	192	192	192	192	192
R-squared	0.633		0.633	0.833	0.621	
Number of groups	6	6	6	6	6	6
Wald chi2	395.0***	4281***				
F			135.3***			
Hausman chi2 (PCSE, FGLS)= 5.26 Prob>chi2 = 0.2614						
Hausman chi2 (DKSE, FGLS)= 3.83 Prob>chi2 = 0.4297						

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Estimated by authors using Stata 17 and EVIEWS 10.

Table 8 reports the estimates of the life expectancy model. The R-squared values show that the included covariates explain between 62% and 83% of the variation in life expectancy. The F- and the Wald chi2 statistics also reveal that the models are globally significant at 1%. The error correction term is significant at 5%, implying the existence of cointegration among the variables. It is interesting to note that the results are somehow similar across the different estimations.

Table 9. Test for Causality between food insecurity and life expectancy (Dimistrescu & Hurlin, 2012)

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
FOODINS does not homogeneously cause LIFEEXP	11.1390	9.25819	0.0000
LIFEEXP does not homogeneously cause FOODINS	10.7823	8.88991	0.0000

Source: Authors' estimates using EVIEWS 10.

The findings reveal that food insecurity has a negative and statistically significant long-run effect on life expectancy at 5% in the DOLS and DKSE models and at 1% in all the other models. A unit increase in the food insecurity index contributes to a fall in life expectancy by 0.1 to 0.2 years in the long run. On the other hand, income, as measured by the natural logarithm of Gross Domestic Product (lGDP), has a positive and statistically significant effect on life expectancy. A rise in GDP by 100 percentage points leads to a rise in life expectancy by 1.14 to 2.5 years in the long run, and this effect is significant at 1%. Physician density also has a positive and significant effect on life expectancy at 1%. An improvement in the physician density ratio by 1 unit (that is, an additional physician to 10,000 people) contributes to an improvement in life expectancy by 5.2 to 6.5 years. Lastly, adult literacy also has a positive and significant effect on life expectancy. Precisely, a unit increase in the adult literacy rate would contribute to an improvement in life expectancy by 0.1 years in the long run.

From the findings of the Granger non-causality test (see Table 9), the null hypothesis of no causality is rejected, implying food insecurity Granger-causes life expectancy and life expectancy on its part also Granger-causes food insecurity. As such, there exists a clear cause-effect relationship between the two variables, whereby each is useful in predicting the other.

The finding that food insecurity has a negative and statistically significant effect on health status in the CEMAC sub-region is consistent with the underlying theory of human capital and with the empirical literature on the link between food security and health status. The Canadian Population Health Institute, for instance, ranks food and nutrition at the top among the first four factors that contribute to good health (CPHI, 2005). This finding also corroborates that of Tarasuk (2001), Vozoris and Tarasuk (2003) and Seligman, Laraia and Kushel (2010), who found that people who report longstanding and multiple health conditions and functional problems such as heart disease, diabetes, and depression are 2 to 3 times more likely to report household food insecurity and hunger.

Recent studies such as Beyene (2023) have also found a close association between food insecurity and poor health. Food insecurity contributes to an increased risk of diet-related diseases such as diabetes (Hutchinson & Tarasuk, 2021; Tait et al., 2018), increased vulnerability to infectious diseases (Cox & Hamelin, 2017; Bekele, et al., 2018) and chronic conditions like depression, anxiety and hypertension (Jessiman-Perreault & McIntyre, 2017; Shafiee et al., 2021; Men et al., 2021; Tarasuk et al., 2013). Gundersen et al. (2018) on the part found that the odds of mortality are 2.60 higher for severely food insecure individuals than it is for food secure individuals.

The finding that income (as measured by GDP) positively contributes to life expectancy at birth is consistent with previous findings. Even though some researchers like Cesarini, Lindqvist, Ostling, and Wallace (2016) have shown that wealth does not improve health, especially for those in the upper wealth quantile, other studies have established a positive association between an increase in income and improvements in health status. Economically disadvantaged people have been found to come first in the ranking of groups of people reported to be in poor health (CPHI, 2015). In another study, the gap in life expectancy at birth between the richest 1% and the poorest 1% in the United States was found to be about 14.6 years (Chetty, et al., 2016). This implies that efforts to improve population health, especially for the economically impoverished, must centre around their economic empowerment.

This study also found that physician density is a major determinant of life expectancy in the CEMAC sub-region. Increasing the physician ratio by just 1 physician to 10,000 people would lead to a tremendous improvement in life expectancy. From the descriptive statistics, the average physician density in the CEMAC sub-region is only 0.2 physicians to 10,000 people, which is extremely low. Improving this ratio will significantly increase access to quality medical care in the region and lead to improvements in overall health. Basu et al. (2019) have documented the contribution of physician supply in primary health care to improving health and reducing mortality rates. They found that for the period 2005-2015 in the United States, every 10 additional physicians per 100,000 population was associated with an increase in life expectancy by 51.5 days.

The study also found that adult literacy plays a significant role in improving health status in the CEMAC sub-region. In fact, previous studies have found that low literacy is associated with poor health behaviours and poor hygiene and sanitation (Gilbert, Teravainen-Goff, & Clark, 2018; Fayan, Yang, & Zhang, 2021). By learning how to read, write and express ourselves adequately, people can better understand how to take care of themselves, how to handle certain medications, how to practice hygiene and sanitation, and how to make better choices relating to nutrition and diet. These behaviours are all important for good health and prolonged life.

5. Conclusion

Food security is indispensable to human wellbeing and overall health. Most poor countries suffer both from food and health crises. The Universal Declaration of Human Rights sanctions individuals' economic, social and cultural rights, which are embedded in the right to healthcare and safe nutrition. The findings of this study have important theoretical and policy implications. They raise key issues relevant to attaining the SDGs in fragile economies. The food insecurity index constructed in this study reiterates the position that food insecurity is a multidimensional construct. Food insecurity was found to be a limiting factor to population health and wellbeing. Governments must adopt policies that address food insecurity, such as increasing the minimum wage to enable people experiencing poverty to meet their food and nutrition needs, improving infrastructure to promote the production and distribution of food, combatting climate change, which contributes to declines in food production and consumption; and improving access to healthcare, especially preventive care.

6. Limitations and Future Research

The main limitations of this study concern the non-availability of data on some food security indicators for some CEMAC countries like Equatorial Guinea and Gabon. For this reason, this study considered only 10 indicators of food insecurity, whereas there are over 18 such indicators. Perhaps more interesting findings could be made if the study was to cover more than just the six CEMAC countries and if data on other indicators of food insecurity were available. Future researchers may even want to narrow down their scope and focus on analyses at the level of households.

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