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Effect of the Energy Transition on Food Security : The Role of the Female Agricultural Workforce in WAEMU Countries

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Abstract

This article looks at the problem of food insecurity and nutrition in Africa. The study analyses the role of women in the relationship between the energy transition and food security in the 8 WAEMU countries over the period 1996-2022. The use of an ARDL model shows that the energy transition significantly and symmetrically improves food security in the short term, but has a negative and asymmetric effect in the long term. The interaction between the energy transition and the female agricultural workforce has a positive effect in the long term, but is neutral in the short term. We recommend that, in order to ensure sustainable food security, the involvement of women in the agricultural sector must be strengthened. Public policies and private initiatives must therefore promote women's access to sustainable energy resources, while supporting their role in innovation and the management of agricultural practices.

Keywords: Energy transition, female agricultural workforce, Food security, WAEMU, ARDL

Introduction

Africa is struggling to make progress towards the food security and nutrition targets set by the Sustainable Development Goal (SDG) and the Malabo targets of eliminating hunger and all forms of malnutrition by 2025. After a period of improvement between 2000 and 2010, the hunger situation has deteriorated significantly, particularly between 2019 and 2022 (FAO, 2023). In 2022, nearly 282 million people in Africa were undernourished, representing an increase of 57 million people since the start of the COVID-19 pandemic. In 2022, an estimated 868 million people in Africa were moderately or severely food insecure, of which more than one-third (342 million people) were severely food insecure. More than two-thirds of the population in Central, East and West Africa face moderate or severe food insecurity, meaning they do not have access to adequate food (FAO, 2023).

Food security is a condition in which everyone has, at all times, physical, social and financial access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2002). However, climate change, increasing unpredictability of rainfall, prolonged droughts and unexpected heavy floods pose serious threats to the energy transition, sustainable livelihoods and food security of segments of the world's population (De Moraes Sá et al, 2017). These inevitable fluctuations require a systemic transition in human socioeconomic systems to develop sustainable pathways to achieving food security (Wheeler and Von Braun, 2013).

According to a study by Agbokpanzo et al, (2023), WAEMU countries rely heavily on fossil fuels and biomass to meet their energy needs. Yet, a transition to clean, renewable energy sources is crucial to reduce greenhouse gas emissions and mitigate the effects of climate change.

Faced with challenges such as climate variability, land degradation, rural poverty and low agricultural productivity, WAEMU countries face food security issues and gender inequalities.

Gender equality is essential to building a world free from hunger, malnutrition and poverty (FAO, 2021). Indeed, persistent inequalities between women and men are a major constraint on agriculture and rural development and these disparities must be eliminated in order to build sustainable and inclusive food systems and resilient and peaceful societies. Women are considered the backbone of rural economies, and they also contribute significantly to food security and nutrition as they provide the bulk of domestic and care work at the household and community levels. In addition, rural women have extensive knowledge of natural resources such as land, water and forests, as they are often responsible for their management, often as farmers, foresters, fishers, and the main providers of water, food and energy at the household and community levels (FAO, 2021).

However, they face barriers such as unequal access to land, credit, participation in decision-making, and agricultural technologies (UNDP Report, 2014). In addition, rural women continue to face gender-based constraints that hinder their potential economic contribution and prevent them from making the most of their work. From the perspective of a fair and effective environmental policy, this study analyses the role of women in the link between the energy transition and food security.

The WAEMU countries have a real challenge to meet in terms of food security, because out of 113 countries, the WAEMU zone occupies 91st place with an index of 47. More specifically, a first type of country including Mali, Senegal and Burkina Faso, which occupy 85th, 86th and 89th place respectively with average food security indices of 48.8; 48.4 and 47.5. A second type of country, including Benin, Côte d'Ivoire, Niger and Togo occupying the respective places 91; 95 ; 97 and 98 and have food security indices of 44.8; 48,4 ; 48 and 46.3 on average (FAO, 2023).

The energy transition can help reduce inequalities in food security that could influence prevailing food security systems by avoiding the resource-intensive model (Kline et al., 2017). In addition, the "just energy transition" protects workers' livelihoods and the future of communities in energy transitions and ensures a low-carbon economy.

This involves social discourse between employees, trade unions, government, consultation of employers with civil society and communities (Evans and Phelan, 2016; Galgóczi, 2020). The energy transition also emphasizes the decentralization of energy systems, the importance of place, and the priority needs of marginalized societies and communities (O'Neill et al., 2018; Heffron et al., 2021). In addition, a just energy transition aims to promote environmental integrity, economic sustainability, well-being and social resilience, underpinned by strong and fluid democratic governance processes. In this way, it accelerates the mapping of the energy transition that ensures reasonable outcomes rightly aligned with the economic and social development of the affected communities, cities, societies and regions.

First, gender equality is fundamentally a matter of social justice and human development, having a direct impact on food security and participation in the energy transition, as highlighted by Sen (1999) and Ericksen (2008). This equality plays a crucial role in the distribution of food resources and access to food (Ingram, 2011), while the inclusion of women in the management of domestic energy resources promotes sustainable and inclusive energy solutions (Clancy et al., 2011). Renewable energy, on the other hand, can reduce dependence on fossil fuels and energy costs for farmers (FAO, 2017), while women's equitable access to resources can significantly increase agricultural production (Quisumbing and Pandolfelli, 2010). However, bioenergy production can conflict with food production, leading to increases in food prices and worsening food insecurity (Tilman et al., 2009). In addition, new energy technologies risk exacerbating inequalities if they are not accessible to vulnerable populations, such as smallholder farmers, due to a lack of adequate support (Van der Horst and Vermeylen, 2011). As a result, inequalities in access to natural and financial resources can hinder the ability of rural and marginalized populations to benefit from the energy transition and ensure their food security.

Thus, to be effective, policies must address these inequalities (Clapp and Fuchs, 2009) and require robust and inclusive regulatory frameworks for the governance of the energy transition and food security. However, these frameworks are often criticized for favoring the interests of corporations and political elites at the expense of local communities (Scoones, 2015).

In addition, some renewable technologies can have negative environmental impacts, such as hydroelectric dams that lead to population displacement and ecological disruption (Ansar et al., 2014). On the one hand, recent approaches in feminist economics highlight the undervaluation of women's unpaid work and call for a more equitable redistribution of domestic tasks to improve food security (Folbre, 2021). On the other hand, the intersectional approach is crucial to understanding how different forms of discrimination interact and exacerbate food inequalities (Crenshaw, 2019). Globalized food systems are criticized for contributing to food insecurity by concentrating food production and distribution in the hands of a few large corporations, which strengthens the advocacy for local and sustainable food systems that integrate the needs of local communities, especially women (McMichael, 2020). Food sovereignty and agroecology remain key concepts, emphasizing the right of peoples to control their own food systems and to use sustainable agricultural practices (Pimbert, 2018). However, women, especially in rural areas, often face barriers in accessing essential resources, limiting their ability to produce food and access nutritious food (Doss et al., 2018). Traditional gender roles often confine women to domestic and care tasks, restricting their participation in economic and agricultural activities, impacting their food security and that of their families (FAO, 2020).

In addition, women are particularly vulnerable to climate change due to their increased dependence on natural resources and their central role in household management, requiring gender mainstreaming into climate policies to be effective and equitable (Women UN, 2021). Finally, women's underrepresentation in decision-making processes limits their influence on policies and programs that directly affect their food security (Cornwall, 2016), highlighting the need for deep reform of agriculture and food policies to promote gender equality and improve food security (Quisumbing and Meinzen-Dick, 2020).

Data

The aim of this article is to analyze how a complementarity between the energy transition and women's agricultural employment can strengthen food security in WAEMU countries.

Annual data involving 08 WAEMU countries ranging from 1996 to 2022 were used in the analysis. The summary of the variables in this study is presented in Table 1 below. *The food security variable is a flexible and diverse concept with various definitions. Thus, according to FAO (2023), food security is a condition in which everyone has, at all times, physical, social and financial access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*. The "pillars" associated with food security are availability, utilization, accessibility, and stability (Grainger, 2016; Aliaga and Chaves-Dos-Santo, 2014). In terms of (local) food production and distribution, with a focus on supply, food accessibility refers to the ease of access to nutritional sources. The ability of a household or individual to obtain readily available food is called access to food. Since food security exists when all individuals have physical, economic, and social access to sufficient, safe, and nutritious food at all times, we use the food production index as a measure.

The food production index covers food crops that are considered edible and contain nutrients. *Our variables of interest are on the one hand the energy transition, which is measured* by the consumption of renewable energies *(*ERN) in (%) of total energies, according to studies by Najm and Matsumoto (2020), Zhuang et al, (2022) and Pons and Tanguy (2021). The energy transition can be effective in increasing the level of food supply. This implies that traditional energies lead to a decrease in productivity due to their massive costs, while in the case of renewable energies, the total cost of production can decrease and lead to a further increase in the level of food supply. The energy transition can also contribute to reducing inequalities in food security that could influence current food security systems by avoiding the resource-intensive model (Kline et al., 2016). On the other hand, women's agricultural employment, which reflects the number of women employed in the agricultural sector as a percentage of total women's employment.

Agricultural employment is crucial for food security, as women in most developing countries are responsible for the nutrition and well-being of their families, which strengthens their role in food security.

Table 1: Study variables

Variables	Definition	Sources
IPA	Food Production Index	World Development Indicator (WDI, 2024)
ERN	Renewable energy consumption as a % of energy	World Development Indicator (WDI, 2024)
EAFEM	Agricultural employment of women	FAO stat (2024)
EDUF	Female primary school enrolment ratio	ILO Stat (2024)
GDP	GDP per capita	World Development Indicator (WDI, 2024)
STAB	Political stability, absence of violence	Worldwide Govermance Indicator (WGI, 2024)
ERP	Precipitation in min/year	Energy Statitics Data (2024)
CO2	CO2 consumption as % of GDP	Energy Statitics Data (2024)
ARABL	Arable land	FAO stat (2024)
AOI	Agricultural orientation index of public expenditure.	FAO stat (2024)
MOA	Agricultural mechanization. Use of tractors, machines	FAO stat (2024)
POP	Population growth rate	World Development Indicator (WDI, 2024)

Source: The authors

Similarly, women's agricultural employment is essential to ensure sustainable food security because of their contribution to food production, crop diversification, access to resources and the promotion of sustainable agricultural practices. Women often have valuable knowledge of sustainable agricultural practices and natural resource management. Their involvement in decision-making about land and resource use can contribute to more sustainable agriculture, thus safeguarding food security in the long term. For control variables, we use macroeconomic variables such as GDP per capita to measure per capita income. Also, we use energy variables such as rainfall in mn/year and CO2 consumption. Institutional variables such as the Agricultural Orientation Index of Public Expenditure to measure progress in agricultural financing.

It is an index that allows for an accurate assessment of the government's commitment to agriculture, and economic stability to measure the absence of violence is used. In addition, variables related to population, education and agriculture such as population growth rate, women's education, use of machinery and tractors and arable land. A summary of the variables used is presented in Table 1 above.

Methodology

The aim here is to describe the basic theoretical model, the specific model and then the estimation technique

Model used

In the neoclassical production function, the sources of production are the accumulation of factors of production and the improvement of total factor productivity. The starting point of our modeling is the Cobb-Douglass production function defined as follows:

$$Y = AK^{\beta}L^{\alpha} \tag{1}$$

where Y represents the results of production, A is the total productivity, K is the capital factor, and L are the labour inputs, while β and α are the coefficients of the production of capital (K) and labour (L). However, Zhang et al, (2022) and Zakari et al, (2022) argued that energy has become a factor of production, as it is a driver of economic development. Thus, equation 1 above becomes:

$$Y = AK^{\beta}L^{\alpha}E^{\sigma} \tag{2}$$

Applying the logarithm to equation 2, we obtain the following equation 3:

$$y = a + \beta k + \alpha l + \sigma e \tag{3}$$

Where y is the logarithm of output, a is the logarithm of total factor productivity, k is the logarithm of capital, l is the logarithm of labour, and e is the logarithm of energy. Then the elasticities of the capital, labor and energy factors respectively.$\beta;\ \alpha\ et\ \sigma$

Based on the studies of Ogbolumani and Nwulu (2022); Fetanat et al. (2021); Lu et al. (2021); Zakari et al. (2022) and Agbokpanzo et al, (2023), our objective is to analyze the role of women in the relationship between energy transition and food security, we specify our model as follows:

Model 1: No interaction

$$\begin{aligned} lnIPA_{it} = \beta_0 + \beta_1 lnERN_{it} + \beta_2 lnEDUF_{it} + \beta_3 lnPRE_{it} + \beta_4 lnGDP_{it} \\ + \beta_5 POP_{it} + \beta_6 CO_{2\,it} + \beta_7 lnARABL_{it} + \beta_8 lnMOA_{it} \\ + \beta_9 lnSTAB_{it} + \beta_{10} AOI_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

Model 2: Interaction

$$\begin{aligned} lnIPA_{it} = \beta_0 + \beta_1 lnERN \times EAFEM_{it} + \beta_2 lnEDUF_{it} + \beta_3 lnPRE_{it} \\ + \beta_4 lnGDP_{it} + \beta_5 POP_{it} + \beta_6 CO_{2\,it} + \beta_7 lnARABL_{it} \\ + \beta_8 lnMOA_{it} + \beta_9 lnSTAB_{it} + \beta_{10} AOI_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

Where IPA stands for the food production index. ERN, renewable energy, EDUF, primary school enrolment rate for women, PRE, rainfall in mn/year.

GDP, GDP per capita; POP, the annual population growth rate. CO2, the consumption of carbon dioxide as a % of GDP; ARABL, refers to arable land. represents the training of women in modern and sustainable farming practices which is equal to the product between women's primary education and the use of machinery and tractors; STAB, economic stability absence of violence. EAFEM, women's agricultural employment. MOA

AOI, Agricultural Orientation Index of Public Expenditure and represents an interaction variable between renewable energy and women's agricultural employment that represents women's involvement in the use of sustainable practices (ERNF). represents the error term. In addition, i and t represent the individual and temporal dimension indices respectively.

$$ERNF \times EAFEM\ \varepsilon$$

Estimation technique

Dynamic panel models are estimated by the Generalized Moment Method (GMM) proposed by Arellano and Bond (1991), the system-GMM estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998) and the representation in ARDL form proposed by Pesaran et al., (1999). The first two models require the data to have a large number of countries relative to the period (Roodman, 2009). These conditions seem to be violated by this study due to very small number of countries compared to the period. Moreover, these estimation procedures are likely to produce non-convergent and misleading long-run coefficients unless the slope coefficients are in fact identical (Pesaran and Shin, 1999). Starting from Pesaran et al., (1999), we can use a representation in ARDL form (p,q) to model a homogeneous dynamic panel in the form of an error-corrected model.

In an Auto Regressive Distributive Lags (ARDL) model, estimates are made by the methods known as "Pooled Mean Group (PMG)", "Mean Group (MG)" and "Dynamic Fixed Effects (DFE)" proposed by Pesaran et al. (2001).

The advantage of the PMG method is that it considers the combination of pooling and the average of the coefficients. This estimator makes it possible to distinguish between short-term and long-term dynamics and takes into account the heterogeneity of countries. The PMG estimator also allows you to solve endogeneity and heterogeneity problems in a dynamic specification. As for the MG estimator, it considers the heterogeneity of the long-run coefficients by taking their average. The DFE estimator, like the PMG estimator, restricts the coefficients of the vector to be equal between all panels. In the estimation process, the study favors the Pooled Mean Group (PMG) estimator given its ability to take into account endogeneity and heterogeneity problems in dynamic models on the one hand and the fact that it considers the combination of pooling and the average of coefficients. However, these conditions can be met by including ARDL (p,q) delays for dependent (p) and independent (q) variables as error correction as follows:

$$\Delta IPA_{i,t} = \theta_{1j} ECT_{1i,t-1} + \sum_{j=1}^{q_1} \lambda_{ij} \Delta IPA_{i,t-1} + \sum_{j=1}^{q_1} \gamma_{ij} \Delta X_{i,t-1} + \sum_{j=1}^{q_1} \delta_{ij} Z_{i,t-1} + \varepsilon_{i,t} \quad (6)$$

With Where $\theta_i ECT_{i,t-1} = Y_{i,t-1} - \phi_{0i} - \phi_{1i} X_{t-1}$ is the linear error correction term of each unit, the parameter is the error correction rate of the fit term for each individual that is also equivalent to $\theta_i \beta_{1i}$. The parameters and are calculated by doing and respectively in each model.$\phi_{0i} \phi_{1i} - \frac{\beta_{0i}}{\beta_{1i}} - \frac{\beta_{2i}}{\beta_{1i}}$ X and Z represent the vectors of the variables of interest and controls respectively.

Empirical results

Here, we will first present the results of the econometric tests and then the estimation results.

Test Results

Here we perform Fisher homogeneity, individual dependencies, and unit root tests.

Results of preliminary tests on panel data

When looking at relationships in a panel data model, there are two possible problems to consider. First, it is the homogeneity or heterogeneity between individuals.

The coefficients affiliated with individuals may not be homogeneous as countries differ in their stages of development and levels of technology. In general, the homogeneity hypothesis can mask country-specific characteristics (Menyah et al., 2014).

Second, cross-sectional dependence between individuals (Countries), which means that a shock affecting one country can also affect other countries in the model due to the direct and indirect economic relationships between countries. Testing for homogeneity and cross-sectional dependence therefore seems to us to be an important step in a panel data model. For the problem of homogeneity between individuals, we use the Fisher test, because it allows us to see if there is overall homogeneity between the coefficients and the constants. The null hypothesis (H0) states that the panel is homogeneous. In other words, the constants and coefficients are identical. Against the alternative hypothesis (H1), there is an individual effect between the panel data. At the level of significance, which is set a priori at 5%, if the Fisher probability is greater than this threshold, there is homogeneity, so we accept H0, otherwise we reject it. Regarding the cross-sectional dependence problem, the LM test (i.e., the Lagrange transsectional dependence multiplier) was developed by Breusch and Pagan (1980), subsequently Pesaran (2004) developed the LM CD cross-sectional dependence test for small panels.

However, when the number of units (N) is small and the time dimension (T) is large, the test LM of Breusch and Pagan (1980) is preferred over that of Pesaran (2004). In the case of our work N= 7 and T= 31, we use the test of Breusch and Pagan (1980). This test is based on the null hypothesis (H0) of interindividual independence between the cross-sectional units against the alternative hypothesis (H1) of dependence. We accept the null hypothesis, if the probability is below the significance threshold of 5%, otherwise, the H1 hypothesis is accepted. The results of these tests are shown in Table 2 below.

Table 2: Summary of cross-sectional dependence and homogeneity tests

Equations	***Model 1: Interaction-free model***		***Model 2: Model with interaction***	
Fisher Homogeneity Test				
	Statistics	Prob	Statistics	Prob
Fisher	118.67***	0.0000	150.20***	0.0000
Breusch-Pagan transverse dependence test (1980)				
Breusch-Pagan (1980)	87.134***	0.0000	72.915***	0.0000

Source: Author, based on BCEAO (2021) and WDI (2021) databases

Note: (***) represents significance at the 1% threshold. Then model 1 and 2 represent the model without interaction and with interaction between the energy transition and women's agricultural employment respectively.

Unit Root Test Results

Studying the stationarity of a variable means testing the presence or absence of a unit root. There are two types of unit root tests for panel data. The first category is called first-generation tests. The tests in this category are based on the assumption of cross-sectional independence of the units.

The second category is called second-generation tests, they are based on the assumption of unit dependence. Since there is inter-individual dependence, the order of integration of the series should be determined using the second-generation unit root tests. For our analysis, we use the Pesaran (2007) (CDF) and Pesaran (2003) (PESCADF) databases. The null

hypothesis of these tests assumes that all series are nonstationary. The results of the tests are recorded in Table 2 below.
The second-generation unit root tests of Pesaran (2003) and Pesaran (2007) reveal that the variables precipitation (PRE), agricultural orientation index (AOI), population growth rate (POP), arable land (ARABLE), GDP per capita (GDP), agricultural employment of women (EAFEM) and use of machinery and tractor (MOA) are stationary in level. While the variables, food production index (IPA), CO2 consumption (CO2), renewable energy (ERN) and the female primary school enrolment rate (EDUF) are not stationary in level, but in primary difference (see Table 3 below).

Table 3: Unit root test on study variables

Variables	*Pesaran (2007) CIPS*		*Pesaran (2003) PESCADF*		*Decision*
	Level	Difference	Level	Difference	
LIPA	-0.935 (0.175)	-6.787*** (0.000)	-2.081 (0.175)	-4.087*** (0.000)	I(1)
LERN	0.570 (0.716)	-3.398*** (0.000)	-1.564 (0.716)	-2.925*** (0.000)	I(1)
LPRE	-3.874*** (0.000)	-	-3.088*** (0.000)	-	I(0)
AOI	-1.418* (0.078)	-	-3.663* (0,000)	-	I(0)
LSTAB	-4.709*** (0.000)	-	-3.375*** (0.000)	-	I(0)
CO2	1.759 (0.961)	-4.552*** (0.000)	-1.157 (0.961)	-3.321*** (0.000)	I(1)
POP	-3.242*** (0.001)	-	-2.872*** (0.001)	-	I(0)
LARABLE	-1.423* (0.077)	-	-2.248*** (0.077)	-	I(0)
LGDP	-3.519*** (0.000)	-	-2.967*** (0.000)	-	I(0)
LEDUF	-1.285 (0.099)	-2.593*** (0.005)	-2.201 (0.099)	-2.649*** (0.005)	I(1)
EAFEM	-1.501* (0.067)	-	-2.275* (0.067)	-	I(0)
MOA	-6.579*** (0.000)	-	-4.016*** (0.000)	-	I(0)

Source: Author from the BCEAO database (2021) and WDI, (2021)
Note: (*) and (***) represent significance at the 1% and 10% thresholds respectively

Panel Cointegration Testing

The concept of cointegration can be defined as a long-term systematic co-movement between two or more economic variables, Yoo (2006). However, authors such as Pedroni (1999, 2004), Kao (1999) and Westerlund (2005) have proposed cointegration tests that apply to longitudinal data. In contrast to the Pedroni and Westerlund tests, Kao considers the special case where the cointegration vectors are assumed to be homogeneous between individuals. In other words, these tests do not allow for heterogeneity under the alternative hypothesis. Kao (1999) also proposed tests of the null hypothesis of absence of cointegration: Dickey-Fuller test and Augmented Dickey-Fuller test. The tests of Pedroni (1999, 2004) and Westerlund (2005 and 2007) are only applicable on regressors of less than 07 variables. For our analysis, we have 09 regressors, we use the test of Kao (1999).

With regard to the Kao test, the results of models 1 and 2 show that the probability associated with the unadjusted Dickey-Fuller t-statistic and the Dickey-Fuller t-statistic increased by 0.0000 respectively; 0.0000 and 0.0000. This makes it possible to reject the null hypothesis of the absence of cointegration and to accept the alternative hypothesis of cointegration between the variables in the long run (see Table 4 below).

Table 4: Kao cointegration test (1999)

	Model 1		*Model 2*	
Tests	Statistic	P-Value	Statistic	P-Value
Dickey-Fuller modified	1.5260	0.0635	1.1217	0.1310
Dickey–Fuller	1.4077	0.0796	0.4481	0.3270
Dickey–Fuller Augmented	3.1074	0.0009	2.2071	0.0137
Dickey-Fuller Unadjusted Modified	-3.9201	0.0000	-6.3587	0.0000
Dickey-Fuller Unadjusted	-2.6735	0.0038	-4.3775	0.0000

Source: Authors, based on BCEAO (2021) and WDI (2021) databases

Estimation results

Here we present the short- and long-term results of our estimates.

Short-term outcomes

Our short-term results show that the Energy Transition Coefficient (LERN) is positive and statistically significant. Thus, an increased energy transition of 1% leads to an increase in food security of 0.6879%.

This result shows that switching from fossil fuels to renewable energy sources can have positive effects on food security. Indeed, the energy transition contributes to food security by contributing to the reduction of CO_2 and other greenhouse gas emissions and contributes to limiting the impacts of climate change. A more stable climate helps protect crops, soils, and water resources, creating more sustainable, resilient, and equitable food systems. On the other hand, renewable technologies, such as solar pumps for irrigation, allow for a more efficient use of water resources, which are essential for agriculture, especially in arid or semi-arid regions.

Our results are in line with the conclusions of Zhuang et al., (2022) for Egypt, Morocco, Tunisia and Lebanon and Zakari et al. (2022) for 28

African countries, for whom the energy transition is fundamental to achieving food security and eliminating hunger.

Our results also show that rainfall, while crucial for agriculture, can have negative effects on food security when it is excessive. Indeed, excessive rainfall can cause flooding that can cause soil erosion, reducing soil fertility and their ability to support future crops, and consequently reducing agricultural production and therefore food security. Also, the high or poorly balanced agricultural orientation index of public expenditure can have negative effects on food security. A large flow of public spending into agriculture can increase opportunities for corruption and mismanagement, reducing the effectiveness of programs and diminishing benefits for food security. As for economic growth, our results show a positive effect on food security.

Table 5: Short-term outcomes

	Model 1: No interaction			**Model 2: with interaction**		
VARIABLES	Coefficients	Standard deviation	P-Value	Coefficients	Standard deviation	P-Value
LERN	0.687976**	0.310430	0.027	-	-	-
LERNF	-	-	-	0.071127	0.30205	0.814
LPRE	-0.21270***	0.113019	0.06	0.145038	0.19603	0.459
AOI	-0.498706	0.321073	0.120	-0.59119**	0.28107	0.035
LSTABP	0.028817	0.025917	0.266	0.016547	0.01349	0.220
CO2	0.820014	1.14859	0.475	-0.96085	1.2273	0.434
POP	-0.173110	0.149865	0.248	-0.10194	0.11349	0.369
LARABLE	1.170548	1.40516	0.405	-0.503268	0.710333	0.479
LGDP	0.884169**	0.405562	0.029	0.943734**	0.393205	0.016
LMEDUF	-0.003873	0.004254	0.363	-0.00722***	0.002415	0.003
ECT	-0.521242	0.16068	0.001	-0.54501***	0.16086	0.001
CSTE	-33.58591	13.11588	0.010	-30.8499***	10.18529	0.002

Source: Authors, based on BCEAO (2021) and WDI (2021) databases

Note: (*), (**) and (***) represent significance at the 1%, 5% and 10% thresholds respectively

Long-term results

Our long-term results show that the energy transition has a negative effect on food security, while in the presence of women agricultural labour, it has a positive effect. Indeed, an increase in energy transition of 1% leads to a decrease in food production of 0.929%.

This finding states that increased competition between energy and food crops can lead to higher food prices, making access to food more difficult for the most vulnerable populations and worsening food insecurity in the long term. Our results are in agreement with Kim's (2019) study. For him, due to the increase in industrial production, urbanization and economic development, as well as the expansion of transport systems, the energy transition in developing countries leads to a significant increase in the accessibility and affordability of energy services, which can in some cases lead to a decrease in food supply.

As for our interaction variable, i.e. women's agricultural employment and the energy transition, the coefficient is statistically significant and positive. This is in line with our expectations. Our results show that countries that adopt an energy transition by reducing gender inequalities in agricultural jobs are more likely to improve their food security. These results show that a fair and inclusive energy transition by taking into account the participation of men and women in agricultural production is essential to eradicate hunger, malnutrition and poverty and positively affect food security. With better access to sustainable energy resources, women farmers can diversify their crops and farming practices. This can strengthen the resilience of food systems to climate change and climate hazards, reducing the risks of crop losses and food insecurity.

Table 6: Long-term results

	Model 1: No interaction			Model 2: with interaction		
VARIABLES	Coefficients	Standard deviation	P-Value	Coefficients	Standard deviation	P-Value
LERN	-0.92958***	0.16344	0.000	-	-	-
LERNF	-	-	-	0.078657**	0.03046	0.010
LPRE	0.31119***	0.10590	0.003	-0.31597**	0.15423	0.040
AOI	0.12117***	0.0428	0.005	0.58314***	0.075393	0.000
LSTABP	0.02792**	0.01186	0.019	0.004817	0.014832	0.745
CO2	-0.65338**	0.28637	0.023	-0.22750	0.223720	0.309
POP	0.258071***	0.02865	0.000	0.073292**	0.031589	0.020
LARABLE	0.279460	0.349319	0.424	1.21175***	0.133237	0.000
LGDP	-0.081025	0.101719	0.426	0.076352	0.070516	0.279
LMEDUF	0.001902	0.006107	0.755	0.01994***	0.005852	0.001

Source: Authors, based on BCEAO (2021) and WDI (2021) databases

Note: (*), (**) and (***) represent significance at the 1%, 5% and 10% threshold respectively.

Table 7: Short- and Long-Term Wald Test Results

VARIABLE	SHORT-TERM	LONG-TERM
$LERN^+ = LERN^-$	0,06 (0,8094)	11,70 (0,0006)
$LEAFEM^+ = LEAFEM^-$	2,59 (0,1075)	61,85 (0,0000)
$LERNF^+ = LERNF^-$	0,01 (0,9130)	18,35 (0,0000)

Source: Authors

The Wald test was used to show the presence of asymmetry of our short- and long-term variables. Based on Table 7 above, the results indicate that the null hypothesis of no asymmetry can be rejected in the long term. Therefore, we accept that there are asymmetric effects of the variables renewable resources, women's agricultural employment and their interaction only in the long run, but symmetrical in the short run.

Conclusion and Economic Policy Recommendations

This study provides an in-depth analysis of the interactions between the energy transition, food security and the role of women in WAEMU countries, over the period 1996-2022. The use of an ARDL model on all 08 WAEMU countries indicates that the energy transition, although it significantly and symmetrically improves food security in the short term, generates negative and asymmetric effects in the long term. This suggests that, although immediate benefits may arise from increasing energy resources, these positive effects are likely to be reduced or reversed as long-term dynamics stabilize, possibly due to reliance on unsustainable energy models or energy models that are ill-suited to local specificities. However, the study also highlights the crucial role of the female agricultural workforce in managing these transitions. The interaction between the energy transition and women's participation in agriculture shows a positive long-term effect on food security, although this effect is neutral in the short term. This underscores the importance of adopting an inclusive approach that recognizes the contributions of women not only as beneficiaries, but also as central agents of change, including in the sustainable management of agricultural and energy resources. Thus, to maximize the benefits of the energy transition while ensuring long-term sustainable food security, it is essential to strengthen the involvement of women in the agricultural sector. Public policies and private initiatives must promote women's access to sustainable energy resources, while supporting their key role in the innovation and management of agricultural practices. At the same time, energy transition management strategies should be put in place that anticipate the long-term effects, so as not to jeopardize future food security.

Limitations and future research

This study uses the aggregate variables of energy transition (renewable energy) and food security (food production), which prevented the analysis of the specific effect of the variables making up energy transition and food security. Future research could therefore focus on a more detailed analysis of the different components of the energy transition and food security. By examining the specific effect of each variable on the relationship between energy transition and food security. And also the effects of the interactions of the components of the energy transition and the female agricultural workforce on food security. Such approaches will allow a better understanding of the underlying mechanisms. And will be useful in identifying the most critical components of the energy transition in order to optimize public investments in a more targeted way in food security.

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