

Productivity of Rice Production: A Study of Ecowas Countries

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Abstract- This study aims to analyze how productive the countries in the Economic Community of West African States (ECOWAS) are in producing rice. Rice is a vital staple food that contributes to food security, hunger reduction, and poverty alleviation for a large segment of the ECOWAS population. However, rice importation and prices are high across the region, reflecting the low domestic production. This study considers the role of agriculture in the economy and the diversity of resources among the countries, and evaluates the effect of various inputs such as labour, harvested area, fertilisers, and energy (electricity) on rice cereal production at the country level from 2011 to 2020. This study uses Malmquist Productivity Index (MPI) to measure the performance of countries. The findings indicate that the performance of countries differs, with six out of 11 countries have increased their productivity over the time period studied. According to the study, improved production management can help optimize the inputs and increase rice production.

Index Terms- agriculture, rice production, productivity, ECOWAS countries, Malmquist productivity index (MPI).

I. INTRODUCTION

The growth of the economy depends largely on the performance of the agricultural sector, particularly in the developing nations that are popping up all over the globe. Not only does this sector serve as the primary source of employment in rural areas and the foundation of rural economies, but it also makes a significant contribution to the revenues earned from exports in developed economies. This is in addition to the fact that it ensures the continued availability of food and adequate nutrition. Because agriculture plays such a vital role in industrialized nations, academics have dedicated a significant amount of attention and resources to research aimed at increasing agricultural output.

Numerous academics have conducted in-depth investigations on the topic of TFP development in agriculture from a variety of different points of view. According to Le et al. (2019), agriculture is vital for both food security and economic development in many countries. A regional group of fifteen countries in West Africa is called the Economic Community of West African States (ECOWAS) aims to promote economic integration in various sectors, such as industry, agriculture, commerce, and social and cultural matters (African Union). A major source of food for many West African countries is rice, which makes up nearly 40% of their total cereal intake. According to Duvall et al. (2021), the rice production in the Gulf region, where it has been a customary food for the nations along the western shore (Lançon & Erenstein, 2002), is being impacted by climate change

1. Importance of Agriculture

One of the most vital activities for human survival and well-being is agriculture, which produces food, fiber, fuel, and other necessities for life. Agriculture also has a significant impact on the economic, social, and environmental aspects of many countries and regions. Across the board, nations are concerned about food security, and the agriculture industry plays a critical role in increasing food supply. More than other economic sectors, agriculture can contribute to the improvement of food security and the reduction of poverty. Moreover, agriculture can also increase food availability and contribute to global food security by being more productive and efficient in using natural resources and conserving biodiversity (Pawlak & Kołodziejczak, 2020). With 2781 million hectares of arable land, agriculture employs around 30.7% of the global workforce, making it a very important sector (Sarkar et al, 2018). A key component of sustainable development is agriculture. It gives humans nourishment and influences the world economy as well as how civilization interacts with the natural world. Additionally, it is necessary to achieve a number of Sustainable Development Goals (SDGs) that the United Nations adopted in 2015 (United Nations, 2015), including eradicating poverty and hunger, enhancing human well-being, and lessening the effects on the environment (United Nations Economic and Social Council, 2016; Kanter et al., 2018).

2. Importance of Rice

Rice is a cereal crop that feeds about half of the global population and provides income and employment for

hundreds of millions of households (Asibi et al., 2019). It is cultivated in more than 100 countries, with Asia accounting for 90% of the world's production. There are over 110,000 varieties of rice that differ in quality and nutrition, but they can be classified as white or brown after post-harvest processing. The availability and consumption of rice depend on regional and cultural preferences as well as storage and transport stability. Many nations, like Thailand, where rice cultivation has a long history and cultural importance, see it as a reflection of the country's natural surroundings and its historical roots in the migration of rice-growing communities from southern China (Suebongsang et al., 2020). Rice consumption has also increased in some countries due to urbanization and changes in consumer preferences, such as in Tanzania, where rice has become more popular than traditional staples since the 1960s and is expected to continue to rise (Sekiya et al., 2020). According to Fahad et al. (2019), the world needs to produce 140 million tons more rice in 2020 than it did in 2009, which means a 50% increase in rice production. This is due to the rising demand for this staple crop. More over half of the world's population, particularly in Asia and Africa, is fed by rice, a significant food crop. It makes a substantial contribution to people's nutritional intake of protein and calories in developing nations, where ensuring food security is a major concern. However, the demand for rice is growing faster than its supply, due to the increasing human population and the limited land and water resources. Therefore, improving rice yield and quality is essential to ensure the food security and well-being of billions of people. To achieve this goal, rice production needs to overcome various biotic and abiotic stresses that affect its growth and development. Rice researchers have been using various approaches, such as conventional breeding, molecular biology, and biotechnology, to enhance the genetic potential and resilience of rice varieties. (Ngalimat et al., 2021; Jiang et al., 2018; Yu et al., 2020; Daramola et al., 2020). The West African subregion's agriculture industry is acknowledged as the engine of the region's economy and has a crucial place in it. This is due to the fact that the industry has a broad influence on society at different phases, especially in West African countries where access to food, labour force participation, and wages are highly dependent on it (Matthew et al., 2019).

3. Area of the Study

The objective of this research is to assess and analyze the rice production performance across the countries of the Economic Community of West African States (ECOWAS) through the use Total Factor Productivity: Malmquist Productivity Index (MPI). This method is suitable for analyzing the agriculture sector, which involves multiple inputs and outputs and different returns to scale. MPI is a technique that measures the productivity change over time and decomposes it into efficiency change and technical change. This study identified the factors that affect rice production and provided policy implications for improving the rice sector like (Zhang et al.,

2020; Chen et al., 2020; Kamal et al., 2021; Prasetyo & Sugiarto, 2021; Khani & Safaei, 2022). The study further examines the factors that influence the performance of rice production based on literature review. The study also offers suggestions for policy makers to increase the effectiveness and output of rice cultivation in the countries of ECOWAS and to foster regional cooperation and food security. The following countries are part of the ECOWAS and are included in the analysis:

- Benin
- Burkina Faso
- The Gambia
- Ghana
- Guinea
- Guinea-Bissau
- Ivory Coast
- Mali
- Niger
- Nigeria
- Senegal
- Togo

II. LITERATURE REVIEW

This chapter reviews some of the existing literature on the factors that affect the productivity of rice production in ECOWAS, a region where rice is a vital crop. We use the MPI Method, which is based on the concept of a production frontier, to measure the efficiency and technological change of rice producers.

A production frontier represents the maximum output that can be obtained from a given set of inputs. We compare our study with some previous studies that applied the MPI Method to different sectors and regions, focusing on those that used desirable outputs as indicators of productivity. Sharma (2022) analyzed the rice production performance of twenty South Asian countries from 2002 to 2014 using the Malmquist Index (MI) approach attributed the differences in TFP growth to the variations in technical efficiency and technological progress among the countries.

According to Lançon & Erenstein (2002), rice consumption and production are both on the rise in West Africa, but the latter cannot keep up with the former, leading to more imports. This poses a challenge for the sustainability of the region's rice sector. Duvallet et al. (2021) assessed the yield variability of rice and five other crops across 15 West African countries (excluding islands) using subnational data. They found that rice had higher yield variability than the other crops on average in the region. They suggested that climate change might have a negative impact on rice production and recommended diversifying the cropping systems and adopting climate-smart practices.

1. Importance of Rice to Ecowas

In many West African nations, rice is an essential staple crop that helps to provide food security and nutrition for both rural and urban people (Fiamohe et al., 2015; Wailes, 2015). However, the region faces a significant gap between local production and consumption, which leads to heavy reliance on imports and exposure to price volatility (Ajetomobi, 2009; Wailes, 2015). Rice consumption varies across the region, depending on the availability and preference of other staples. Some countries, such as Senegal, consume more rice than others, such as Ghana and Nigeria (Ajetomobi, 2009). Rice production in the region accounts for about half of the demand, but it has potential for improvement through better cultivation and processing practices (Nwafor and Chukwu, 2020; Ugwuja and Chukwukere, 2021). African food security, income and employment depend largely on rice, especially in West Africa where it makes up 37% of cereal intake (Tondel et al., 2020). However, the domestic production of rice is not keeping up with the growing demand, driven by population growth, urbanization and changing food preferences (Fiamohe et al., 2018). As a result, West Africa relies heavily on rice imports from overseas, which exposes the region to price shocks and food insecurity. To address this challenge, various country-specific, regional and multinational initiatives have been launched to develop improved rice varieties and supportive policies to boost rice production and reduce the import gap (Nwalozi et al., 2018). Rice is mainly grown by small-scale farmers under suboptimal conditions in most parts of sub-Saharan Africa (SSA), which limits its productivity and quality (Mutiga et al., 2021). Therefore, there is a need for more research and innovation to enhance the resilience and profitability of rice farming systems in Africa. Rice is a strategic crop for the continent's development and prosperity, as one of the speakers at a recent conference on rice in Africa stated: "Rice is the way to go." (Nwalozi et al., 2018) The demand for rice in West Africa is growing rapidly and will continue to do so in the future. According to the ECOWAS Rice Commission, the annual consumption of rice in the region will reach 24 million tons by 2025, which is equivalent to 12 billion USD. This is three times the amount of rice that was produced in West Africa in 2010, which was 7.9 million tons. To meet the demand in 2010, West Africa had to import 5.7 million tons of rice from other countries (Styger & Jaoui, 2022).

In the ECOWAS, rice is essential to both socioeconomic growth and food security, but since the area imports most of its rice, it is susceptible to outside shocks from the world market. Rising income levels, urbanisation, and population expansion have all contributed to a sharp rise in the demand for rice. As a consequence, in addition to more general policies for the cereal sector, the majority of ECOWAS member states have created National Rice Development Strategies (NRDS) (Orer, et al., 2020). For half of the world's population, especially the underprivileged and destitute in

Asia and Africa, rice is also an essential staple meal. This is why a number of countries and areas have started developing new germplasm and implementing policy changes to increase rice output and food security (Rahman & Zhang, 2022). Since Nigeria has the biggest economy and most people in Africa, rice is a daily necessity for Nigerians. They also eat a significant quantity of it (Ugwuja & Chukwukere, 2021)

2. Productivity of Rice in Ecowas

The growth of total factor productivity (TFP), which measures the increase in outputs that is not explained by the growth in production inputs (OECD, 2022), depends on addressing inefficiencies in the agriculture sector (FAO, 2017). However, despite the increased liberalization of agricultural trade, Africa continues to be a net importer of agricultural products. This is because agriculture in Africa suffers from high levels of productive inefficiency. Previous studies have examined the relationship between trade liberalization and productivity growth, but not the link between trade liberalization and efficiency (Sunge & Ngepah, 2020). The System of Rice Intensification (SRI) is a new way of growing rice that started in Madagascar in 1983. SRI improves rice productivity by making the best use of the plant-soil-water-microbe interactions. It involves planting young and single seedlings in a square pattern, using less water, adding organic matter, and removing weeds. SRI has been used by many farmers in different countries and regions, and has been studied by researchers and practitioners in agriculture Barrett et al. (2022).

Graf and Oya (2021) studied the effect of SRI on rice yield, profitability, and labor productivity using data from a large survey in Bangladesh. They used a regression model (Model 8) to account for other factors that may affect rice production, such as production system, area under rice cultivation, and labor-saving technologies (herbicides and tractors). They found that SRI had a positive effect on all three outcomes, showing that SRI can benefit the economic and social well-being of rice farmers. They also found that one of the main changes that SRI requires is planting seedlings in straight lines instead of randomly, which many farmers called a change from 'scattered' to 'in lines' transplanting. SRI has also been backed by theory and evidence from other sources that show its benefits over traditional methods of rice cultivation that depend a lot on external inputs that have environmental and economic costs. Thakur et al. (2023) explained that SRI changes the appearance and function of rice plants to make them more efficient in making food, using water, taking nutrients, and fighting pests and diseases. Also, SRI improves the interactions between rice plants and the soil organisms that make up their microbiome, which further helps their growth and performance. The productivity of irrigated rice in the Sahel is higher than in other parts of Africa, but it is still far from reaching its potential. This is because of various challenges that affect the crop management and the

environment of the smallholder farmers who grow rice in this region. Some of these challenges are sub-optimal nutrient, weed, and water management, as well as abiotic stresses such as extreme temperatures and salinity. Agronomists have created and tested a variety of agronomic solutions in an effort to address these issues and raise the sustainability and productivity of irrigated rice-based systems in the Sahel. Tools for weather adaptation, water, weed, and nutrient management techniques are some of these possibilities. The results of these research and development (R&D) activities are described in the subsections that follow Ibrahim et al., (2021). Rice (*Oryza sativa* L.) is one of the main grain crops that feeds more than three billion people worldwide (Zhao et al., 2021). Tanzania is the biggest country in East Africa (947,303 km²) and accounts for 9% (2.6 MT) of Africa's total rice production (30.8 MT) 2018; FAOSTAT, 2014; Mateeru et al. After maize, rice is Tanzania's most significant food and commercial crop (Gowelee et al., 2020). However, Tanzania's rice production is modest, with upland regions producing between 0.5 and 2 t ha⁻¹ and irrigated fields producing between 4.5 and 6.0 t ha⁻¹. These yields are much less than the 5 t ha⁻¹ and 10–11 t ha⁻¹ potential under ideal circumstances (Gowelee et al., 2020; IRRI, 2013). Poor soil fertility, environmental degradation, intensive cropping methods, insufficient and uneven fertilizer application, the adoption of local varieties, and farmers' ignorance of better crop management techniques are the primary issues limiting rice yield (Baral et al., 2020; Thakur et al., 2013). The most important component for rice development and productivity is nitrogen (N), which is often lacking. Nitrogen (N) is the most critical nutrient for rice growth and yield, and it is often deficient in rice cropping systems. One of the main goals of agricultural policies in developing countries is to increase agricultural productivity. This requires not only identifying the factors that constrain productivity, but also improving efficiency, as this can lead to higher productivity (Amegnaglo, 2020).

3. Sustainability of Rice Production in Ecowas

Rice is a staple meal for many people in West Africa, where it is produced in a variety of habitats, including rain-fed uplands and marshes, respectively. Rice is also grown in other parts of the world. Nevertheless, it is anticipated that the demand for rice would rise from 44 kilogrammes per capita to 53 kilogrammes per capita between the years 2011 and 2025, making it difficult for the area to achieve rice self-sufficiency by the year 2025. In order to overcome this obstacle, the Economic Community of West African States lends its support to national plans that are part of a regional offensive and have the goal of increasing rice production and consumption. In this research, economic models are used to estimate rice consumption patterns and to evaluate the effects that obtaining rice self-sufficiency in West Africa might have on the economy as a whole. In addition, this paper examines the continuing research that is being conducted to enhance rice varieties, crop and water management, and sustainable

practices for aerobic rice systems. Aerobic rice systems are appropriate for water-scarce regions or rainfed wetlands with extra irrigation. In conclusion, this research highlights the need of taking preventative steps to safeguard the environment and guarantee the long-term viability of rice farming, particularly in developed wetlands where water management has the potential to lower emissions of greenhouse gases (Fofana et al., 2014). Furthermore, continual single cropping has a detrimental influence on rice yields because of the high occurrence of pests, illnesses, and weeds in rice fields. This is due to the fact that rice fields are often planted with just one crop at a time (Loko et al., 2022). Because of this, the long-term viability of the rice industry is threatened, Kega et al. (2017) found that under conditions of continuous rice farming, pests had a higher rate of reproduction. Rice production is affected by various factors related to CO₂ and climate change.

A study found that irrigated rice yields in East Africa would benefit from higher temperatures and CO₂ fertilization (+25%) (Van Oort & Zwart, 2018). On the other hand, it was estimated that irrigated rice yields in West Africa would fall by -21 percent or rise by +7 percent (without/with adaptation) during the rainy season, and they would decrease by -45 percent with a doubling of CO₂ during the dry season (Sossa et al., 2022). Acevedo-Siaca et al. (2021) shown, with the use of technology that enriches free-air CO₂, that boosting rice's photosynthesis throughout the growing season results in a greater yield response in the crop. Moise & Issidor, (2022) proposed that in order to lower the intensity of CO₂ emissions and to counteract the reciprocal impacts of climate change and rice agriculture, rice producers should employ a greater proportion of organic fertilisers than chemical ones. In their study, Huang et al. (2020) found that climate change-induced emission reduction would, over time, result in a decrease in agricultural output growth.

4. Research Gaps

The level of productivity of rice production in ECOWAS as a regional bloc has not gotten a great deal of attention from academics; the majority of the earlier studies concentrated on the performance of individual farmers and enterprises on a more granular level. Ajetomobi (2012) and (2009) compared the productivity factor before and after the formation of ECOWAS until 2005 and concluded that they were productive. However, since then, the demand for rice has increased significantly in the subregion due to population growth, urbanization, and rising purchasing power. Therefore, there is a need to examine the technical progress in rice production and its relation to domestic supply or import of rice to meet the demand and productivity. Moreover, no study has assessed how rice production contribute to the achievement of SDGs goals (Two No Hunger and 13 Climate Change) in ECOWAS countries.

5. Statement of the Problem

Rice is a staple food for many people in the ECOWAS countries, where it is both grown locally and bought from abroad. Despite the significant growth in rice production in West Africa in the last decade, the region still relies on imports for about half of its rice consumption (Akpoti et al., 2022). Nigeria and Côte d'Ivoire are the main buyers of milled rice in the region, mainly from Asian countries such as Thailand, Vietnam, and India. (CSEA-CIRES-IPAR, 2015). In 2018, Africa imported 31.46% of the world's rice exports, which totaled 34.234 million metric tons, and West Africa was responsible for more than half of these imports (Faye et al., 2022; Arumugan et al., 2020). Rice production in West Africa averaged 10.1 million tons per year over the 2009–2019 period (FAOSTAT, 2021). Therefore, this study aims to fill the gaps in previous research and contribute to the existing literature by identifying the productive, and unproductive factors that affect rice output. The study also provides policy analysts, researchers, and the subregion with guidance on how to allocate resources to maximize production, increase efficiency and productivity at their economies of scope and potentially become exporters. The following research questions guide the study:

- How can ECOWAS best use its factor inputs to produce rice at its full capacity?
- What are the factors that have been misused or underused in the production process?

6. Objectives of the Study

The study aims to achieve the following objective:

- To examine the trends and patterns of rice productivity growth in the countries of the Economic Community of West African States (ECOWAS).

III. SAMPLING OF METHODS

1. Methodological Background and Empirical Procedure

The concept of total factor productivity, which was proposed by Solow and is often referred to as the Solow Residual, describes the rate of economic growth that occurs in addition to labor and capital investment as a result of the development of new technologies (Solow, 1957). To put it another way, total factor productivity refers to the proportion of output in economic growth that cannot be explained by the quantity of inputs. It is recommended that total factor productivity be used as an indication of the development of new technologies (Zuo & Bao, 2008). To determine whether or not there has been a shift in rice productivity, we will use the Malmquist Index (MI) methodology and look at total factor productivity (TFP) scores.

2. Total Factor Productivity

The MI method was used in this research project in order to arrive at the TFP scores, which represent the increase in rice

production throughout the time period under consideration. The total factor productivity (TFP) ($t + 1$) is a measure that indicates the typical output in relation to the amount of input. The change in total factor productivity (TFP) from one period (t) to the next ($t + 1$) is what is meant by "TFP growth."

$$\frac{TFP[t+1]}{TFP[t]} = \frac{y^{t+1}/f(x^{t+1})}{y^t/f(x^t)} \quad (1)$$

$$= \frac{y^{t+1}/y^t}{f(x^{t+1})/f(x^t)} \quad (2)$$

$$= \frac{A[t+1]}{A(t)} \quad (3)$$

TFP is the ratio of output to input, which can be expressed as an index number. For example, if $y^t = A(t) x^t$ and $y^{t+1} = A(t+1) x^{t+1}$ where both input and output are scalar, then the index in Equation (3) becomes $TFP(t+1)/TFP(t) = (y^{t+1}/y^t)(x^t/x^{t+1})$, which is a simple way to measure TFP using an index number.

Malmquist Productivity Index (Mpi)

Using the nonparametric Malmquist productivity index (MPI) technique, the goal of this study is to determine how the total factor productivity (TFP) increase of rice production differs across nations. The MPI technique has the benefit of being able to decompose the rise in TFP into two different components, which are referred to as the change in technical efficiency and the technical advancement, respectively. Using the period (t) technology, the following is one way to represent the change in TFP that was measured by the MPI between period t and period $t+1$:

$$M_0^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \quad (4)$$

Similarly, we can define the MPI that uses the technology of period $t + 1$ as;

$$M_0^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \quad (5)$$

According to Fare et al. (1994), the MPI formula can be expressed as follows:

$$M_0^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \sqrt{\frac{D_0^t(x^{t+1}) D_0^t(x^t, y^t)}{D_0^{t+1}(x^{t+1}) D_0^{t+1}(x^t, y^t)}} \quad (6)$$

The right-hand side of the equation shown above has two terms. The first term determines how the level of technological efficiency shifts between time t and time $t+1$ as

a direct consequence of getting closer to the frontier. The second phrase describes the change in production technique (also known as "technical change"), which is often shown by a movement in the frontier itself.

- Technical efficiency change = $EC = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}$
- Technological change = $TC = \sqrt{\frac{D_0^t(x^{t+1}) D_0^t(x^t, y^t)}{D_0^{t+1}(x^{t+1}) D_0^{t+1}(x^t, y^t)}}$

4. Data Description

For the purpose of estimating productivity in ECOWAS countries in order to analyse their influence on the technological environment in terms of the quantity of rice produced in tonnes as a desired output. The inputs include harvested area in hectares, number of labor force employed in agriculture, total kg of fertilisers in three category Nutrient nitrogen N, Nutrient phosphate P2O5, and Nutrient potash K2O, and energy (electricity) in terajoule (TJ) were considered. The study uses secondary data from Food and Agriculture Organization (FAO) covering the period from 2011 to 2020.

5. Tools

The study applies the Malmquist Productivity Index (MPI) as the analytical method. The software packages Deep and R were used to estimate the model which provided useful information for the productivity analysis of rice production in several ECOWAS countries.

IV. RESULTS AND DISCUSSION

1. Total Factor Productivity

The findings of this study are shown in table 1, and it details the Malmquist productivity index (MI) for the main ECOWAS countries when it comes of rice production. Rice is the most widely eaten staple grain in the region. The MI is a measure of the change in productivity over time based on the ratio of output to input. This ratio is calculated using the ratio of output to input.

The MI may be broken down into its two constituent parts, which are the technical change (TECHCH) and the efficiency change (EFFCH). Changes in efficiency represent how efficiently a nation utilises its inputs, while changes in technology show how well a country absorbs new technologies or improves its manufacturing techniques. Both of these aspects of change are reflected in GDP. The EFFCH may be further broken down into the pure efficiency change, also known as the PECH, as well as the scale efficiency change (SECH). PECH evaluates how a nation adapts its level of output to attain optimum efficiency, while SECH measures how a country adjusts its level of production in order to move closer to or farther away from the best practise frontier.

Table 1: Malmquist Index Summary of Firm Means

Country	EFFCH	TECHCH	PECH	SECH	TFPCH
Benin	1	0.875	1	1	0.875
Burkina Faso	1.038	0.99	1.047	0.991	1.027
Cote d'Ivoire	1.016	1.036	1.015	1.002	1.053
Ghana	1	0.989	1	1	0.989
Guinea	1	0.971	1	1	0.971
Mali	1	0.985	1	1	0.985
Niger	1.019	1.018	1	1.019	1.037
Nigeria	1.001	0.987	1	1.001	0.988
Senegal	1	1.047	1	1	1.047
The Gambia	1.107	0.969	1	1.107	1.072
Togo	1.002	0.998	1	1.002	1
Mean	1.016	0.987	1.006	1.011	1.003

The result shows that most countries have an MI close to 1, which means that their productivity has not changed much over the period. Only The Gambia and Burkina Faso have an MI greater than 1, which means that they have improved their productivity. The Gambia has the highest MI of 1.072, which is mainly due to a large increase in EFFCH (1.107), especially PECH (1). This means that The Gambia has improved its input utilization and moved closer to the best practice frontier. Burkina Faso has an MI of 1.027, which is mainly due to a small increase in EFFCH (1.038), also driven by PECH (1.047). The result that The Gambia and Burkina Faso have improved their productivity of rice production rely to Ceesay (2011), reported that the System of Rice Intensification (SRI) practices in The Gambia increased grain yield and water productivity significantly compared to conventional methods. Similarly, the Food and Agriculture Organization of the United Nations (FAO) stated that rice production in Burkina Faso was encouraged by the policy environment, which provided protection and support to producers. Furthermore, the World Bank (2016) noted that project support for rainfed lowland rice production in Burkina Faso helped clear land and provide income for thousands of producers. This confirming that both countries have made progress in enhancing their rice production efficiency and competitiveness.

On the other hand, some countries have an MI less than 1, which means that they have declined in their productivity. Benin has the lowest MI of 0.875, which is mainly due to a large decrease in TECHCH (0.875). This means that Benin has lagged behind in adopting new technologies or improving its production methods. Guinea has an MI of 0.971, which is also mainly due to a decrease in TECHCH (0.971). This means that Guinea has also lagged behind in adopting new technologies or improving its production methods, but to a lesser extent than Benin. This is consistent with the findings

of previous studies that have identified various constraints and challenges faced by rice farmers in Benin and Guinea. For example, Loko et al. (2022) characterized the rice farming systems in Benin and found that most farmers practice subsistence rice cultivation with low adoption of improved varieties and technologies. They also reported that farmers face difficulties in accessing agricultural credit, mechanization, and extension services. Similarly, Miassi et al. (2023) evaluated the technical efficiency of rice production in Benin and found that it was only 51%. They also identified factors such as age, household size, credit, and inputs that influence the efficiency of rice producers. These studies suggest that there is a need for more technological and policy interventions to boost rice production in Benin and Guinea. The other countries have an MI close to 1, which means that their productivity has not changed much over the period. However, some of them have different patterns of EFFCH and TECHCH. For example, Senegal has an MI of 1.047, which is mainly due to an increase in TECHCH (1.047), while its EFFCH is 1. This means that Senegal has improved its production technology, but its input utilization has not changed much. Senegal is known to have a highly productive irrigated rice farming system in the Senegal River Valley, with an average yield of nearly 5 tons per ha and a widespread adoption of modern seed-fertilizer technology (Diagne et al., 2013). Senegal also benefits from renewable energy and energy efficient solutions that reduce the costs and environmental impacts of rice processing (WE4F, 2021). Niger has an MI of 1.037, which is mainly due to an increase in both EFFCH (1.019) and TECHCH (1.018), but both are small. This means that Niger has slightly improved both its input utilization and its production technology. The result of Niger having an MI of 1.037 for rice production can be explained by various factors related to the country's economic, climatic and technological conditions. According to the Observatory of Economic Complexity OEC (2021), Niger is the 33rd largest importer of rice in the world, mainly from India, Thailand and China. However, the country also has some potential for domestic rice cultivation, especially in the hydro-agricultural areas along the Niger River and its tributaries. Sido et al (2021) showed that the application of mineral fertilisers, improved seeds, irrigation techniques and crop rotation can enhance the efficiency and productivity of rice farming in Niger.

2. Malmquist Index Summary of Annual Means

Table 2 shows the Malmquist productivity index (MI) for rice production in different years. The MI is a measure of the change in productivity over time, based on the concept of the production function. The MI can be decomposed into four components: efficiency change (EFFCH), technical change (TECHCH), pure efficiency change (PECH), and scale efficiency change (SECH). The last component, total factor productivity change (TFPCH), is the product of EFFCH and TECHCH.

- EFFCH measures how efficiently the inputs are used to produce the output. A value greater than 1 indicates an improvement in efficiency, while a value less than 1 indicates a decline in efficiency.
- TECHCH measures how the production technology changes over time. A value greater than 1 indicates an innovation or advancement in technology, while a value less than 1 indicates a regression or deterioration in technology.
- PECH measures how efficiently the inputs are used to produce the output at an optimal scale. If the number is larger than 1, it indicates that the level of pure efficiency has increased, whereas if the value is less than 1, it suggests that the level of pure efficiency has decreased.
- SECH measures how efficiently the inputs are used to produce the output given the scale of production. A scale efficiency gain is indicated by a number larger than 1, while a scale efficiency fall is indicated by a value less than 1.
- The total factor productivity change over time is what is measured by TFPCH. If the number is larger than 1, it suggests that productivity is increasing, however if the value is less than 1, it indicates that productivity is decreasing.

Table 2: Malmquist Index Summary of Annual Means

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
2011 - 2012	1.078	1.02	1.056	1.021	1.099
2012 - 2013	1.068	1.054	1.002	1.067	1.126
2013 - 2014	1.011	0.989	1.016	0.996	1.001
2014 - 2015	0.967	1.121	0.994	0.973	1.085
2015 - 2016	0.987	0.911	0.985	1.002	0.9
2016 - 2017	0.956	1.009	0.989	0.967	0.965
2017 - 2018	0.954	0.799	1.019	0.936	0.762
2018 - 2019	1	1.014	0.986	1.015	1.014
2019 - 2020	1.139	0.998	1.006	1.132	1.137
Mean	1.016	0.987	1.006	1.011	1.003

According to the result, rice production has experienced an increase in productivity from 2011 to 2013, and from 2014 to 2015, mainly due to improvements in efficiency and technical change. However, rice production has experienced a decrease in productivity from 2015 to 2018, mainly due to declines in technical change and scale efficiency. Rice production has recovered slightly in 2019 and 2020, mainly due to

improvements in efficiency and scale efficiency. The mean values of EFFCH, TECHCH, PECH, SECH, and TFPCH indicate that rice production has been slightly efficient, slightly regressive in technology, slightly pure efficient, slightly scale efficient, and slightly productive on average over the period of analysis. The result of the analysis is consistent with some previous studies on rice production in ECOWAS. For example, Soullier et al. (2020) analyzed farm household data from three donor-funded project surveys in Ghana, Burkina Faso and Niger, and found that alternative water-management options and policy interventions improved the profitability of rice production in West Africa. The eco-efficiency of rice production was evaluated by Huang et al. (2022) using life cycle assessment and data envelopment analysis methodologies.

They discovered that water toxicity, soil toxicity, and eutrophication were the primary elements that had an impact on the eco-efficiency of rice production. They also indicated that decreasing the use of fertilisers and pesticides as well as increasing the efficiency of usage were efficient approaches to boost the production of green rice. Furthermore, past research in West Africa has evaluated the differences in rice yields, as well as the factors that contribute to those differences, across a variety of production methods and climate zones (Niang et al., 2017; Adjah et al., 2022). Rice yields were found to be greatest in the semi-arid zone for irrigated and rainfed lowland systems, whereas there was no discernible variation in yields across climatic zones for upland rice, as stated by Niang et al. (2017). They also discovered that high solar radiation, high maximum temperature, intermediate air humidity, multiple split nitrogen application, high frequency of weeding operations, the use of certified seeds, and well-leveled fields in the irrigated lowland system were all associated with high rice yields. A comprehensive method for breeding drought-resistant rice varieties in ECOWAS was proposed by Adjah et al. (2022). This technique includes profiling of known QTLs and discovery of novel ones, marker-assisted selection, genomic selection, and large multi-locational yield experiments. They suggested that yield stability might be obtained via the process of breeding drought-tolerant varieties of crops using these methods.

V. CONCLUSION

In a nutshell, the ECOWAS member states' rice production is approaching its ideal size of production, but this is happening at widely varied rates throughout the region. The effectiveness of rice production in twelve main ECOWAS nations is the subject of this research, which covers the period of time from 2011 to 2020. We assessed the difference in TFP in the rice output of a few chosen ECOWAS nations using MPI. The result shows that there is a variation in the productivity change of rice production among the top ECOWAS countries in rice production over the period. The Gambia and Burkina

Faso have improved their productivity, while Benin and Guinea have declined their productivity. The other countries have not changed their productivity much as the result shows.

1. Implications

This study contributes to the theoretical framework of agricultural economics by offering insights into the mechanisms affecting productivity in rice production across ECOWAS countries. This study was conducted in order to provide insights into factors affecting productivity in rice production. This has the potential to expand upon the knowledge base that already exists on agricultural economics ideas. The results have the potential to contribute to the formulation of agriculture policy across the ECOWAS region. The discovered variables that influence productivity in rice production provide the basis for the theoretical implications, which may include suggestions for policy modifications or novel interventions based on those aspects. The theoretical framework of this research has the potential to offer light on the generalizability of some agricultural economic theories across the many cultural, geographical, and economic settings that exist within the ECOWAS area. This may help contribute to a more comprehensive knowledge of the ways in which ideas can be used in a variety of contexts. In terms of their practical consequences, the findings may have particular policy suggestions for each ECOWAS nation to implement in order to boost rice yield. This may include individualised treatments, incentives, or laws that are based on the discovered variables that have an effect on productivity. It may entail devising plans for the ECOWAS nations to exchange technological know-how and information with one another. This could make it easier for less productive areas to acquire best practises from more productive regions, which would ultimately contribute to an increase in rice output overall. The research may provide suggestions for concrete interventions relating to capacity building. These may include training programmes for farmers, extension services, and the construction of infrastructure.

2. Limitations

The agricultural industry is often affected by temporal and geographical variability, including the circumstances of the climate and the physical characteristics of the landscape. The findings may not be as accurate as they might be because of the constraints of this research, which prevent it from capturing the entire spectrum of these changes. This study has the potential to find correlations between many parameters and rice production; however, in order to demonstrate a causal link, more research or the design of experiments may be required. The socio-political issues that have the potential to affect agricultural practices have not been taken into account in this research. There is a possibility that our research does not take into account all of the factors that can have an effect on rice production, such as changes in government policy, trade agreements, or societal dynamics. The agricultural industry is a dynamic sector that is characterised by constantly

developing technology, changing market dynamics, and shifting environmental circumstances. Because this thesis is static, it may not represent the current changes that are taking place, and its suggestions may need regular revision depending on the latest developments

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