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Determining Convergence among Countries in West Africa in the Digital Era

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Achieving sustainable economic growth is essential for the economic development of countries. This depends on many factors, including technological progress and capital accumulation, which are both inevitable. Although researchers have explored the roles of technological progress and capital accumulation in the economic growth of countries, understanding how these countries converge in their steady states remains relatively under-researched. This paper analyzes convergence in the context of West Africa using the Solow growth model with a specific focus on the Cobb-Douglas production function. The paper utilizes a balanced panel methodology with a dataset spanning from 2000 to 2019, based on a sample of 11 West African countries. The findings reveal that Mauritania has the highest GDP per capita, while Niger has the lowest. Furthermore, Nigeria recorded the highest growth rate in per capita GDP over this period at 9.16%, which is twice as high as that of its counterparts and some developed economies, such as the USA and Germany, in 2019. Additionally, Mauritania has the highest GDP per unit of effective worker, and Sierra Leone has the lowest. Also, digitalization impacts economic growth. Overall, the paper provides evidence of conditional convergence among countries in West Africa.

Keywords: Growth Rates, Conditional Convergence, West Africa, Panel Analysis

1. Introduction

Achieving long-run and sustainable economic growth is the priority of every economy in the world, especially in recent times when uncertainties abound. Globally, many countries, especially developing countries, have been embarking on capital investment activities as well as technical efficiency improvement to achieve a higher GDP per capita to improve the standard of living of the people (Alkathiri 2024). As indicated by AlKathiri (2022), capital accumulation is seen as the main driver of unconditional convergence in the area of manufacturing. This motive of countries has been greatly fuelled by the United Nations' Sustainable Development Goals (SDGs), which aim at helping the global economy to converge of which countries in West Africa are no exception.

However, it can be emphasized that, though countries are striving to converge to their long-run growth paths, there are differences in terms of incomes among them, which makes it difficult to achieve the desired common goal. This is more obvious in terms of income per capita and output per worker. According to Acemoglu (2007), today, there are significant differences between countries both in the income per capita and the output per worker. Thus, the wealthiest nations in the world are more than thirty times wealthier than the poorest. For instance, the US GDP (or income) per capita in 2000 was over $34,000. Contrarily, income per capita is far lower in many other nations, including Mexico ($8,000), China ($4,000), India

($2,500), Nigeria ($1,000), and several sub-Saharan African nations like Chad, Ethiopia, and Mali ($Much Lower). Furthermore, in a different pattern, while the major economies in the Western world suffered their greatest economic crisis since in 2008–2009 global financial crisis, emerging countries briefly paused in their ongoing economic catch-up game, which had been going on since the end of the 1990s (Rey–Deisting 2019).

During this time, according to Rey and Deisting (2019), countries in Asia, the Middle East, Africa, and Latin America all had steady growth, helping emerging nations weather the financial crisis better than they had before. Even though these improvements have occurred, empirical research is still primarily concerned with convergence between rich and developing nations without considering how convergence might work as a development process, as well as being achieved in developing countries. This is specifically worth analyzing in the context of countries in West Africa. Moreover, in achieving convergence through steady or long-term growth, digitalization of an economy is also crucial (Habibi–Zabardast 2020, Myovella et al. 2020). Studies have shown that the use of ICT is causing leapfrogging effects that are bringing lower-income countries closer to high-income ones. One example of this phenomenon is the rapid growth of mobile communications technology in Africa, particularly in the early 2000s, compared to developed countries where sophisticated telecommunications infrastructure has long been in place (Myovella et al. 2020, Arendt 2015, Negroponte 1998, Steinmueller 2001).

Thus, more technologically advanced and innovative countries frequently achieve greater economic performance and competitiveness (Lopes et al. 2021). By affecting the social welfare and economic growth of groups that can swiftly adjust to these changes, the employment of digital technology helps to alter the economic and social structure (Yoo−Yi 2022). Therefore, digitalization has a profound influence on the economic growth of countries, of which the West African sub-region is no exception. This paper thus examines 11 West African countries' actual convergence between 2000 and 2019, as well as how digitization impacts economic growth.

The choice of the 11 countries was due to the unavailability of data for some countries. By doing this, the paper tries to answer the following important questions: 1) To what extent have West African countries' income levels converged with one another or those of more industrialized countries? 2) Does digitalization influence economic growth in the context of West Africa? As a result, this paper reviews literature on the convergence of countries as well as the impact of digitalization on economic growth in the second section. It also presents material and methods in the third section, and the results in the fourth section encompass the comparison of GDP per capita among the countries in West Africa, as well as the interactions among the digitalization indicators (i.e., ICT indicators), including fixed telephone subscriptions, internet users and mobile cellular subscriptions. The fifth section deals with the comparison of real GDP per worker and average growth rates among the countries, the sixth section indicates the steady states of the countries, and the last section examines the estimated conditional convergence among the countries using graphs and regression analysis.

2. Literature Review

2.1. Theoretical Underpinning

This section presents a brief theoretical and empirical review that serves as a foundation for this current paper. It sets out to first indicate the theoretical underpinning, which is rooted in the Solow model with a specific focus on the Cobb-Douglas production function (Solow 1956). The following assumptions are made under the Solow model: (a) constant factor shares-constant returns to scale; (b), we assume an economy consisting of two (2) sectors: household and production sector, where households own capital (K), labor (L) and firms and rent these inputs to firms and receive interest payments, wages, and profits. Also, households use their incomes to buy output (Y), which is either invested (I) or consumed (C). Producers in return rent capital and labor, sell output, and pay for factors. Mathematically,

$$Y = F(K, L) = K^{\alpha} L^{1-\alpha} \quad (1)$$

Where Y is output, K is capital, L is labor, and α and $1 - \alpha$ are the factors share which assume a constant return to scale. From here, to sustain growth in per capita income in the simple Solow model, technological progress is important, and for that matter, the technology variable, A, is introduced in equation (1), which gives equation (2).

$$Y = F(K, AL) = K^{\alpha} (AL)^{1-\alpha} \quad (2)$$

With this, A is said to be "labor augmenting" or "Harrod-Neutral". According to Jones and Vollrath (2013), technological progress occurs when A increases over time. It is assumed in the Solow model that, technological progress is exogenous and grows at a constant rate. That is,

$$\frac{\dot{A}}{A} = g \Leftrightarrow A = A0^{egt} \quad (3)$$

Where g is a parameter representing the growth rate of technology. From equation (3), with capital accumulation, we have:

$$\frac{\dot{K}}{K} = s\frac{Y}{K} - \delta \quad (4)$$

According to Jones and Vollrath (2013), to realize the implication of growth in the Solow model with the technology variable, equation (1) can be rewritten in terms of output per worker as:

$$y = K^{\alpha} L^{1-\alpha} \quad (5)$$

Taking log and differentiating equation (5), we arrive at:

$$\frac{\dot{y}}{y} = \alpha\frac{\dot{k}}{k} + (1-\alpha)\frac{\dot{A}}{A} \quad (6)$$

From equation (4), it can be seen that, as indicated by Jones and Vollrath (2013), the growth rate of K will be constant if and only if Y>K is constant. Also, Y>K is constant, y>k is also constant, and most importantly, y and k will be growing at the same rate, and this situation is termed as a balanced growth path or steady-state. With Cobb-Douglas production function at the steady-state, where

$$f(k) = k^{\alpha},\ k = \frac{\sigma}{\delta+g+n}k^{\alpha} \quad (7)$$

$$\text{therefore, } k = \left[\frac{\sigma}{\delta+g+n}\right]^{\frac{\alpha}{1-}}\alpha \quad (8)$$

These terms are explained in the results section of the paper. It can be emphasized that, with the Solow model, global stability of the steady-state equilibrium implies that countries with the same technology should converge to the same steady-state income per effective worker levels (conditional convergence).

2.2. Empirical studies on convergence among countries

On the empirical side, Alkathiri (2024) analyzed the drivers of unconditional convergence by decomposing economic growth into technical efficiency change, technological change, and capital accumulation across developed and developing countries for the period 1970–1995 and 1995–2019. The study concluded that technical efficiency improvement and capital accumulation are the main drivers of the observed unconditional convergence. Jamilu et al. (2024) investigated the income convergence of some selected countries in SSA for the period 2000–2020 by applying the α and β convergence methods based on 42 countries. The study concluded a convergence of income among the countries.

Bako–Sisman (2022) investigated structural convergence in selected African countries over the period 1994–2019. The study employed methods such as Panel Corrected Standard Errors (PCSE), Feasible Generalized Least Squares (FGLS), Tobit model, instrumental variables, and Granger non-causality based on a sample size of 48 African countries. By using a panel dataset, the study revealed the existence of sectoral structural convergence in Africa.

Garang–Erkekoglu (2021) examined convergence triggers in Africa with a focus on convergence clubs using a panel model, specifically, the Generalized Method of Moments (GMM). By making use of the log t-test, the study revealed four core convergence clubs. Baafi (2018) also examined convergence among countries in Sub-Saharan Africa (SSA) and high-income economies by employing the difference and system GMM approach by Arellano-Bond and Arellano-Bover together using variables such as Gini index, trade, GDP per capita, investment, foreign direct investment, government expenditure, merchandise export to SSA, merchandise imports to SSA, merchandise export to high-income economies, and merchandise imports from high-income economies. The results revealed that countries in Sub-Saharan Africa (SSA) and high-income economies do converge.

Similarly, Dohmen et al. (2018) examined convergence among countries in Sub-Saharan Africa using Ordinary Least Squares methods for the period 1990 and 2015. The study revealed convergence among the countries.

Djennas–Ferouani (2014) also examined whether African countries converge by using variables such as GDP per capita, GDP per capita growth rate, gross capital formation, population growth, domestic investments, government expenditures, and exports based on a sample size of 52 African countries. between 1980 and 2011. The study used the Generalized Gini coefficient approach within the period between 1980 and 2011 and provided evidence of weak convergence.

However, Kumo (2011) also examined convergence among SADC regions by using the Generalised Least Squares (GLS) approach for the period 1990 and 2009. The study provided evidence for the lack of convergence in the region. Despite this, these empirical studies in the case of the West Africa sub-region are limited, hence the need for this research.

2.3. Digitization and Economic Growth

The Solow model states that the only way to account for the steady increase in living standards is through technological progress. ICT has been emphasized as being essential to promoting economic growth in both developed and developing nations (Arendt 2015). Hofman et al. (2016) assert that, as indicated by Habibi–Zabardast (2020), technology advancements support economic growth by (a) meeting consumer demand for digital goods, including computers, software, and communication equipment and (b) boosting output and investments in ICT-using industries. Applying a time series dataset covering the years 1994–2021, Mwananziche et al. (2023) utilize the autoregressive distributed lag (ARDL) technique to investigate the impact of digitization on Tanzania's economic growth. In both short- and long-term dynamics, the study discovered a causal link between Tanzania's GDP growth and ICT availability and infrastructure. Thus, in Tanzania, the expansion of mobile phone subscriptions has a notable effect on economic growth over the long and short terms.

Employing a dynamic panel threshold regression technique, Abdulqadir–Asongu (2022) examined the asymmetric effect of internet access on economic growth for 42 Sub-Saharan African (SSA) countries for the period 2008−2018. The results showed that the internet threshold effect for growth was a substantial 3.55 percent.

Using a panel of 123 countries, comprising 45 high-income, 58 middle-income, and 20 low-income countries, Appiah-Otoo–Song (2021) compares rich and poor countries to investigate the effect of ICT on economic growth between 2002 and 2017. The study concluded that ICT boosts economic growth in both countries using the ICT index, which includes mobile, internet, and fixed broadband. However, the study further indicated that poorer countries often benefit more from the ICT revolution.

Myovella et al. (2020) examine the relationship between digitalization and economic growth by comparing Sub-Saharan Africa and OECD economies, applying the Generalized Method of Moments (GMM), using a panel dataset for

the period 2006–2016. The findings demonstrate that digitization boosts economic growth in both sets of economies. Compared to OECD countries, SSA experiences a negligible impact from broadband internet, but SSA experiences a greater impact from mobile telecommunications.

3. Materials and Methods

This paper employed the Solow growth model to examine the conditional convergence among the countries understudy comprising Burkina Faso (BFA), Benin (BEN), Cote d'Ivoire (CIV), Cape Verde (CPV), Guinea (GIN), Niger (NER), Nigeria (NGA), Senegal (SEN), Sierra Leone (SLE), Togo (TGO) and Mauritania (MRT) with specific focus on the Cobb-Douglas production function. In addition, the study applied the β convergence method to empirically examine the conditional convergence among the countries. The West African sub-region is made up of 16 countries, and due to data unavailability for some countries, such as Ghana, Gambia, Guinea-Bissau, Mali, and Liberia, only 11 of them were considered, as indicated above. This paper employed variables such as real GDP per person (rgdpe) measured as expenditure-side real GDP at chained PPPs (in mil. 2017US$).

The paper also employed current GDP per person (cgdpe) measured as expenditure-side real GDP at current PPPs (in million 2017 USD), capital stock measured as capital stock at current PPPs (in mil. 2011US$), employment (emp) measured as the number of persons engaged (in mil.), labor share (labsh) measured as the share of labour compensation in GDP at current national prices, and capital share (csh_i) measured as the share of gross capital formation at current PPPs and data analyses were based on descriptive analysis such as graphs. Further, this paper used a balanced panel methodology with a panel annual dataset spanning from 2000-2019 from the Penn World Tables 10 and World Bank Sustainable Development Goals Indicators based on a sample size of 11 countries in West Africa.

3.1. Empirical Model

To empirically examine the conditional convergence, the β convergence method is employed, and following the works of Alkathiri (2024), Garang–Erkekoglu (2021), Barro et al. (1991), Jamilu et al. (2024), the model is stated as:

$$\Delta\log(GDPPC_{it}) = \alpha + \beta\log(GDPPC_{it-1}) + \delta X_{it} + \gamma D_{it} + \in_{it} \quad (9)$$

Where $\Delta\log GDPPC_{it}$ is the change in logGDP per capita, Δ is the change operator, α is the constant term, $\log GDPPC_{it-1}$ is the lagged of logGDP per capita, X_{it} are the auxiliary conditional variables, comprising fertility rate (FET) measured as total births per woman, life expectancy (EXPC) measured as life expectancy at birth, total in years and school enrolment (SCHL) measured as primary education (gross) based on gender parity index, fixed telephone subscriptions (FTS) measured as the sum of active number of analogue fixed

telephone lines, internet users (INTU)measured as individuals who used the internet as a percentage of the population and mobile cellular subscriptions (MCS) as subscriptions to a public mobile telephone service. D_{it} is a set of dummy variables capturing latent characteristics of the i = 1, 2…+, thus, countries in the sample, t is the time period, δ and γ are the coefficients of the control and dummy variables. β is the coefficient of lagged of logGDP per capita, which measures the speed of convergence, and requires that, the speed of convergence is negative, i.e. $\beta < 0$, and $\in_{it}$ is the error term.

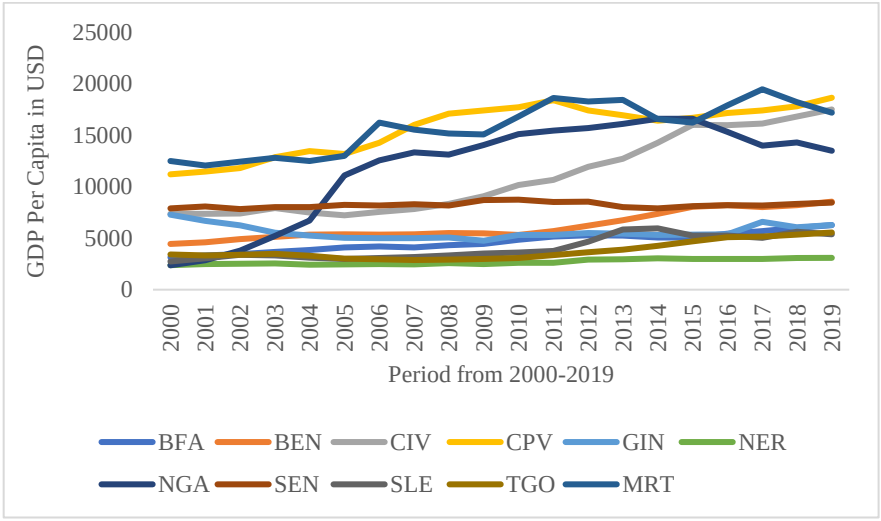
4. Results and Discussion

This section presents the results of the analyses of the data based on the distribution of GDP per capita in countries in West Africa, comparison of GDP per capita and average growth rates among the countries, comparison of real GDP per worker and average real GDP per worker growth from 2000–2019, steady-states of the countries, interactions of digitalization indicators and economic growth and estimated conditional convergence among the countries.

4.1. Comparison of GDP per capita among the countries in West Africa

This section presents the trend of GDP per capita among the 11 countries in West Africa comprising Burkina Faso (BFA), Benin (BEN), Cote d'Ivoire (CIV), Cape Verde (CPV), Guinea (GIN), Niger (NER), Nigeria (NGA), Senegal (SEN), Sierra Leone (SLE), Togo (TGO) and Mauritania (MRT) for the period 2000-2019 as depicted in Figure 1. The picture depicted in Figure 1 shows that, right from 2000 to 20004, almost all the countries were experiencing an increasing trend in their GDP per capita, however, Cape Verde, Mauritania, Nigeria, and Senegal were growing faster than the other countries. Between 2005 and 2010, some countries started experiencing a fall in their GDP per capita, especially Mauritania, Cote d'Ivoire, Senegal, Niger, Nigeria, Benin, Togo and Sierra Leone. It can be indicated that, beyond 2010, almost all the countries experienced up and downward trend in their GDP per capita. However, Cape Verde, Côte d'Ivoire, Senegal, and Benin experienced an uptrend beyond 2017. Benin is said to have experienced quite stable GDP per capita throughout the period. In all, it can be pointed out that, Mauritania has had the highest GDP per capita followed by Cape Verde and then Cote d'Ivoire and the least is Niger. From Figure 1, the countries seem to move in the same direction along growth paths.

Figure 1. Comparison of GDP per Capita among West African Countries, 2000–2019



Source: author's Computation based on a dataset from Penn World Tables 10

4.2. Comparison of GDP per capita and average growth rates of the countries

This section presents the results of the GPD per capita and average growth rates among the countries under study. as depicted in Table 1 between 2000 and 2019.

Table 1. Comparison of GDP per capita (in PPP-Adjusted 2017 USD) and average growth rates among West African countries from 2000-2019

Country	2000 (in USD)	2019 (in USD)	Average Growth Rates (in %)
BFA	3,135.22	6,266.72	3.65
BEN	4,439.77	8,543.76	3.45
CIV	7,361.13	17,491.38	4.56
CPV	11,195.16	18,631.26	2.68
GIN	7,279.21	6,278.42	-0.78
NER	2,379.42	3,089.09	1.38
NGA	2,367.64	13,468.78	9.16
SEN	7,876.76	8,464.54	0.38
SLE	2,737.10	5,372.50	3.55
TGO	3,416.29	5,551.50	2.56
MRT	12,495.87	17,168.31	1.66

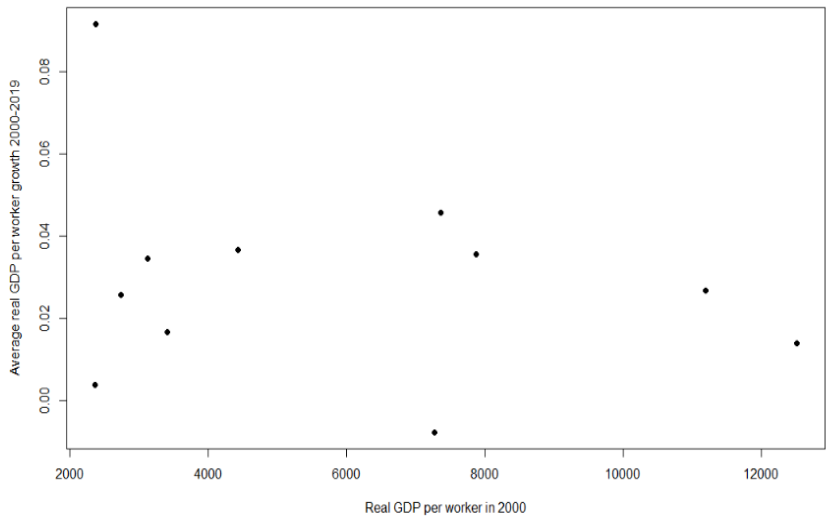
Source: author's computation based on a dataset from Penn World Tables 10

From Table 1, it can be seen that, as evident in Figure 1, in 2000, Mauritania had the highest GDP per capita, followed by Cape Verde, then Senegal, and so on, with the least GDP per capita recorded by Nigeria. In 2019, the highest GDP per capita was recorded by Cape Verde followed by Cote d'Ivoire, then Mauritania, and so on,

and the least being Niger. It can be emphasized that all the countries experienced an increase in their GDP per capita in 2019, except Guinea, which recorded a decrease in its GDP per capita, which is also clearly evident in its negative average growth rate (-0.78%). In addition, the results tend to be different in terms of the average growth rates among the countries. Here, Nigeria recorded the highest growth rate in per capita GDP over the period at 9.16%, which is 2 times higher than its counterparts and that of some developed economies such as the USA and Germany in 2019. This can be attributed partly to the increase in GDP per capita from USD2,367.64 to USD13,468.78 (USD11,100.14) higher than all of them.

Further, the relationship between average real GDP per worker growth and real GDP per worker is depicted in Figure 2. The results in Figure 1 show that some of the countries are clustering as a result of their closeness in real GDP per capita and average real GDP per worker growth. However, some are distant, for instance, Nigeria is much more distant from them. Also, Burkina Faso, Benin, Côte d'Ivoire, and Sierra Leone are distant, and Guinea is at the bottom. Nevertheless, there is some evidence of them moving to a particular path. Thus, these differences can be attributed to their differences in GDP per capita as indicated above. As depicted by the Solow model, countries at different points relative to their steady-state will grow at different rates. This also confirms one of Kaldor's stylized facts.

Figure 2. Average real GDP per worker growth and real GDP per worker among West African countries



Source: author's Computation based on a dataset from Penn World Tables 10

4.3. Comparison of GDP Per Unit of Effective Worker of the Countries (Steady-State GDP Per Effective Worker)

This section presents the results of the steady-state GDP per effective worker among the countries as depicted in Table 2. Here, the following formula developed by Solow

was used to compute the steady-state GDP per effective worker represented as (y*) for each of the countries, and the formula is stated as:

$$y^* = \left[\frac{\sigma}{\delta+g+n}\right]^{\frac{\alpha}{1-\alpha}} \quad (10)$$

Where y^* is the steady-state GDP per effective worker, σ is the average of capital share, α is the share capital stock, 1−α is the average of labsh, $\delta + g$ is technological progress and population growth rate defined as 0.075, n is the employment growth defined as the average of the growth rate of employment. Based on the computation, the following results are presented in Table 2. It is assumed in the Solow model that countries with the same technology should converge to the same steady-state income per effective worker levels (conditional convergence). Here, the speed of convergence for the individual countries is also presented to determine how countries can grow relative to their steady-states, which is given as: $t = \frac{Log2}{\lambda}$, where $\lambda = [1 - \alpha](n + g + \delta)$,

To determine the conditional convergence among the countries, the Solow model steady-state per capita output is adopted:

y*A(t), where $A(t) = (\frac{Y(t)}{K(t)})^{\frac{\alpha}{1-\alpha}}\frac{Y(t)}{L(t)}$, here, A(t) is the level of technology, Y(t) is the output for the period, K(t) is the capital stock for the period L(t) is the labor in employment, and α is the share of capital stock. The results of this computation are also presented in Table 2. Here, it is assumed that the countries are endowed with some level of technology.

Moreover, the results in Table 2 show that Mauritania has the highest y*, which can be attributed to its capital accumulation or investment rate, which was about 20% larger than some of its counterparts in the sub-region during the 2000–2019 period. One interesting aspect of the results is that Nigeria had the highest investment rate (90%) during 2000–2019, yet its y* is small. Cote d'Ivoire also invested about 50% during the period, yet its y* is small. The least of them is Sierra Leone with y* of 1.02, even though its investment rate was about 40%. These mismatches can be attributed to some country-specific factors, such as an increase in the depreciation rate, population, etc. This also happened in other countries in the sub-region. In the case of how the countries will move faster to their steady-states when further away, the results indicate that it will take both Côte d'Ivoire and Mauritania 24 years to move halfway to their steady-states. In addition, it will take both Senegal and Burkina Faso 19 years, 18 years respectively to move halfway to their steady-states. Here, if we take Mauritania as our measure of steady-state in this paper, it is found that all the other countries' (Burkina Faso, Benin, Cote d'Ivoire, Cape Verde, Guinea, Niger, Nigeria, Senegal, Sierra Leone, Togo) GDP per capita converge to its level of GDP per capita. This evidence is found in appendices 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10.

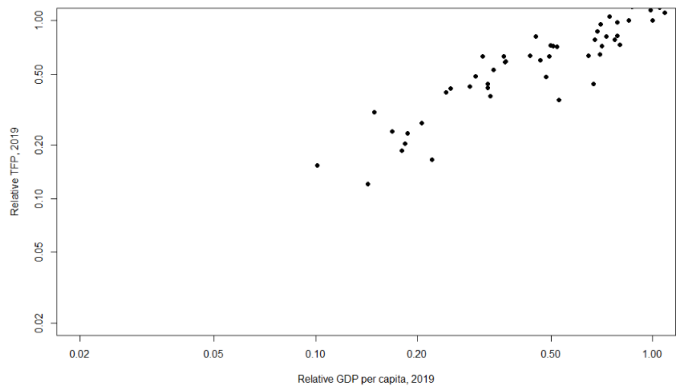
Table 2. Steady-state GDP per effective worker among West African countries in 2019

Country	GDP per Capita (2019)	y*	2019A(t)	y*A(t)	Half_life in years
BFA	6,266.72	1.68	3,053.52	5,140.43	18
BEN	8,543.76	1.36	4,949.73	6,708.21	12
CIV	17,491.38	1.30	5,923.05	7,682.76	24
CPV	18,631.26	2.50	6,351.42	15,883.90	NA
GIN	6,278.42	2.07	1,680.39	3,477.37	NA
NER	3,089.09	1.68	760.18	1,275.27	17
NGA	13,468.78	1.39	5,421.34	7,542.91	13
SEN	8,464.54	2.06	2,543.51	5,234.29	19
SLE	5,372.50	1.02	4,456.05	4,549.43	12
TGO	5,551.50	1.12	4,362.92	4,883.92	10
MRT	17,168.31	3.18	2,027.92	6,457.27	24

Source: author's Computation based on a dataset from Penn World Tables 10

Regarding Benin, Niger, Nigeria, Sierra Leone and Togo, it will take them 12 years, 17 years, 13 years, 12 years and 10 years each to move halfway to their steady-states. From Table 2, in comparing the steady-state level of GDP per capita using A(2019) with the actual GDP per capita for each of the countries, it can be pointed out that the countries are not all far from their steady-state in 2019. The results revealed that almost all the countries had their actual GDP per capita in 2019 higher than their steady-state values, with the technology level. However, the difference between the steady-state level of GDP per capita using A(2019) and the actual GDP per capita is quite high for Côte d'Ivoire, Cape Verde, Nigeria, Senegal, and Mauritania. Further, Figure 3 indicates the level of technology relative to GDP per capita among the countries. The results show that the total factor productivity (A(t)) that is found in the Cobb-Douglas production function can augment the output level of the countries under study. Thus, the level of technology plays a crucial role in the convergence among the countries.

Figure 3. Relative TFP and relative GDP per capita in 2019 among West African countries



Source: author's Computation based on a dataset from Penn World Tables 10

4.4. Determining the Evidence of Convergence Among the Countries Based on the Ratio of the Steady-state Level of GDP Per Capita Using A(2019) and the Actual GDP Per Capita Relative to the Growth Rates

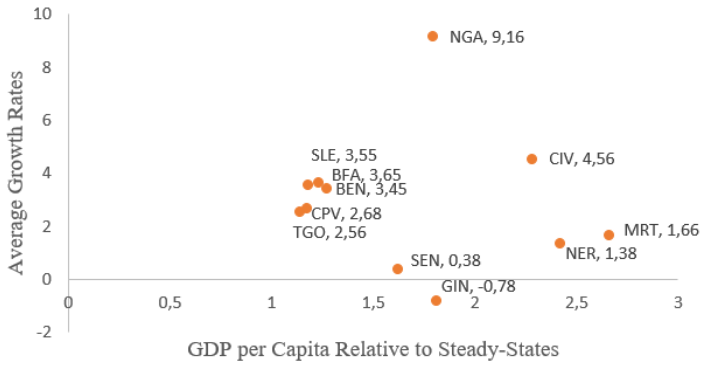
This section presents the results in terms of the evidence of convergence among the countries under study. Here, the actual GDP per capita in 2019 for the countries was divided by the steady-state level of GDP per capita and compared with the growth rates of the countries as depicted in Table 3. The results revealed that there is evidence of the countries converging to their steady-states. Additionally, the scatter plot result shown in Figure 4 indicates that there is evidence of convergence of the countries. The result implied that countries with the same level of technology will establish equilibrium in their steady-states. The results confirm the findings by Alkathiri (2024), Garang–Erkekoglu (2021), Rey–Deisting (2019), Baafi (2018), and Djennas–Ferouani (2014) as well as the Solow growth model.

Table 3. GDP per capita relative to steady-state GDP per capita and average growth rates among West African countries

Country	Actual GDP per Capita/Steady-state GDP per Capita	Average Growth Rates
BFA	1.23	3.65
BEN	1.27	3.45
CIV	2.28	4.56
CPV	1.17	2.68
GIN	1.81	–0.78
NER	2.42	1.38
NGA	1.79	9.16
SEN	1.62	0.38
SLE	1.18	3.55
TGO	1.14	2.56
MRT	2.66	1.66

Source: author's Computation based on a dataset from Penn World Tables 10

Figure 4. GDP per capita relative to steady-state GDP per capita and average growth rates among West African countries in 2019



Source: author's Computation based on a dataset from Penn World Tables 10

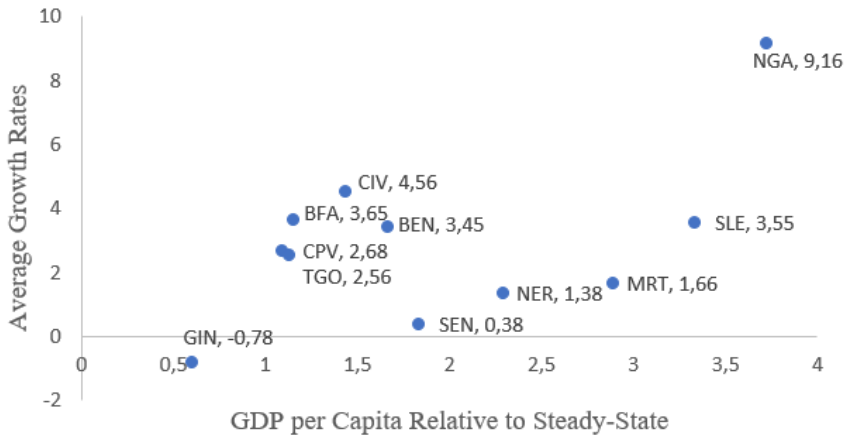
To test convergence in 2000 for the countries, this section presents the results. Here, too, the actual GDP per capita in 2000 for the countries was divided by the steady-state level of GDP per capita and compared with the growth rates of the countries as depicted in Table 4. The results revealed that there is evidence of the countries converging to their steady-states. Additionally, the scatter plot result shown in Figure 5 also confirms the evidence of convergence among the countries. So, the results here confirm that of 2019.

Table 4. GDP per capita relative to steady-state GDP per capita and average growth Rates among West African countries

Country	GDP per Capita (2000)	y*	2000A(t)	y*A(t)	Actual GDP per Capita/ y*A(t)	Average Growth Rates
BFA	3,135.22	1.68	1,615.62	2,719.80	1.15	3.65
BEN	4,439.77	1.36	1,968.13	2,667.34	1.66	3.45
CIV	7,361.13	1.30	3,982.21	5,165.31	1.43	4.56
CPV	11,195.16	2.50	4,098.31	1,0249.22	1.09	2.68
GIN	7,279.21	2.07	5,890.51	1,2189.70	0.60	-0.78
NER	2,379.42	1.68	6,18.80	1,038.12	2.29	1.38
NGA	2,367.64	1.39	457.86	637.04	3.72	9.16
SEN	7,876.76	2.06	2,090.90	4,302.85	1.83	0.38
SLE	2,737.10	1.02	806.12	823.01	3.33	3.55
TGO	3,416.29	1.12	2,700.10	3,022.54	1.13	2.56
MRT	12,495.87	3.18	1,356.94	4,320.77	2.89	1.66

Source: author's Computation based on a dataset from Penn World Tables 10

Figure 5. GDP per capita relative to steady-state GDP per capita and average growth rates among West African countries in 2000

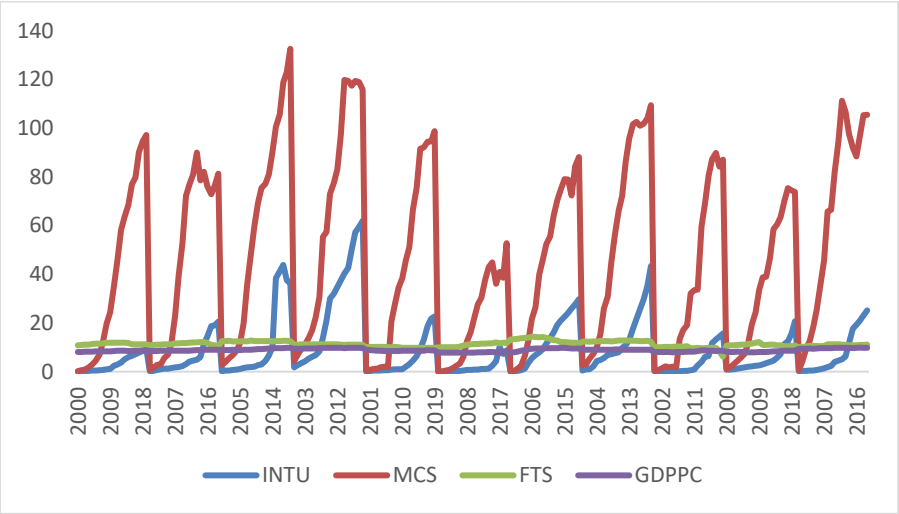


Source: author's Computation based on a dataset from Penn World Tables 10

4.5. Relationship Between Digitalization and Economic Growth

This section presents a trend analysis of how digitalization indicators, including fixed telephone subscriptions (FTS), internet users (INTU), and mobile cellular subscriptions (MCS), relate to economic growth (GDPPCC). The purpose is to determine how digitalization influences economic growth in the context of the West African sub-region. Figure 6 presents the result, which indicates that among the digitalization indicators, there are fluctuations during the period. Thus, these fluctuations are seen to influence economic growth, albeit at minimal levels. As shown in Figure 6, it is evident that digitalization, in the form of ICT, has a profound relationship with output growth. Moreover, Table 5 presents the actual impact of digitalization on economic growth since this relationship cannot be fully analyzed using a graph.

Figure 6. Trend analysis of the interactions of digitalization indicators and economic growth



Source: author's Computation based on a dataset from the World Bank World Development Indicators

4.6. Determining Conditional Convergence Using the β Convergence Method

To empirically determine the conditional convergence among the countries under study, the paper applied the *β convergence method* and the results are presented in Table 5. From Table 5, the coefficient of the lagged log of GDP per capita is statistically significant and negative, indicating conditional convergence among the countries in West Africa. The result confirmed the findings Alkathiri (2024), Garang–Erkekoglu (2021), Barro et al. (1991) as well as Jamilu et al. (2024) in SSA.

Table 5. Conditional convergence

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.492096	0.154544	3.184184	0.0017
EXPC	–0.004456	0.001237	–3.603170	0.0004
FET	–0.018379	0.007599	–2.418796	0.0166
SCHL	0.074219	0.041716	1.779179	0.0769
INTU	0.003485	0.002013	1.731419	0.0851
MCS	0.000502	0.000917	0.547766	0.5845
FTS	0.043865	0.026954	1.627380	0.1054
LGDPPC(-1)	–0.019911	0.011120	–1.790604	0.0750
Root MSE	0.067862	R-squared		0.094483
Mean dependent var	0.028678	Adjusted R-squared		0.059655
S.D. dependent var	0.071503	S.E. of regression		0.069337
Akaike info criterion	–2.458477	Sum squared resid		0.874992
Schwarz criterion	–2.321760	Log likelihood		241.5553
Hannan-Quinn criter.	–2.403095	F-statistic		2.712875
Durbin-Watson stat	1.109669	Prob(F-statistic)		0.010653

Source: author's computation based on data Penn World Table 10 and World Bank World Development Indicators
Note: Dependent variable: $\Delta \log \mathrm{GDPPC}$

The result also confirmed the theoretical basis of convergence, indicating that initially poorer countries have the tendency to grow faster than richer countries. Life expectancy and fertility rate are also statistically significant and negative. The results indicate that life expectancy and fertility rate have a negative influence on GDP per capita in West Africa. The result of the fertility rate is expected since an increase in fertility rate reduces GDP per capita, as confirmed by Jamilu et al. (2024). However, the result for life expectancy is counterintuitive. Further, school enrolment is positive and statistically significant, indicating that school enrolment has a profound influence on the GDP per capita in the sub-region. In addition, internet usage has a positive and statistically significant impact on GDP per capita, indicating that expansion in internet access improves economic growth in the sub-region, all other things being equal. This finding supports the results of Appiah-Otoo–Song (2021) and Abdulqadir–Asongu (2022). Fixed telephone subscriptions and mobile cellular subscriptions are both positive, however, they are statistically insignificant.

5. Conclusions and Recommendations

This paper examined the conditional convergence among 11 countries in West Africa comprising Burkina Faso (BFA), Benin (BEN), Cote d'Ivoire (CIV), Cape Verde (CPV), Guinea (GIN), Niger (NER), Nigeria (NGA), Senegal (SEN), Sierra Leone (SLE), Togo (TGO) and Mauritania (MRT). The paper employed the Solow growth model with a specific focus on the Cobb-Douglas production function the use of panel analysis for the period 2000–2019 using a panel dataset. The paper was based on a hypothesis that countries with income differences and that are far from their steady-

states grow faster and converge in their steady-states. The paper specifically compared the GDP per capita among the countries, as well as comparing the GDP per capita and average growth rates of the countries. It also compared the GDP per unit of effective worker (steady-states), technology level relative to GDP per capita, and convergence among the countries. Regarding the comparison of GDP per capita among the countries, the paper revealed that Mauritania has had the highest GDP per capita followed by Cape Verde and then Cote d'Ivoire and the least is Niger.

Further, the paper revealed that Nigeria recorded the highest growth rate in per capita GDP over the period at 9.16%, which is 2 times higher than its counterparts and that of some developed economies such as the USA and Germany in 2019. In terms of comparing the GDP per unit effective worker (y*), the results indicated that Mauritania has the highest y*, which may be a result of its capital accumulation or investment rate, and the lowest was Sierra Leone. Furthermore, the paper revealed evidence of conditional convergence among the countries. The results also show that life expectancy and fertility rate have a negative influence on GDP per capita in West Africa. Furthermore, school enrolment has a positive and statistically significant effect on GDP per capita, indicating that school enrolment has a profound influence on the GDP per capita in the sub-region. In addition, internet usage has a positive and statistically significant impact on GDP per capita, indicating that expansion in internet access improves economic growth in the sub-region. Fixed telephone subscriptions and mobile cellular subscriptions are both positive, however, they are statistically insignificant.

The results imply that countries in West Africa have the potential for further convergence on their growth paths if capital accumulation becomes the priority. Also, the findings imply that providing people with more access to education significantly improves GDP per capita in the sub-region. Another implication of the findings is that digitalization has a profound impact on economic growth. Specifically, the expansion of internet access across the sub-region increases GDP per capita. Also, the Solow growth model will work for countries in West Africa if investment or savings increase and are put into effective use. That is, if resources are allocated effectively and efficiently. Therefore, governments and policymakers in the sub-region must prioritise capital accumulation or investment and savings activities for sustainable economic growth.

The study also recommends that policymakers in these regions should prioritize policies that encourage regional trade, investment, and cooperation. This can include reducing trade barriers, harmonizing regulations, and developing regional infrastructure projects. Governments in the sub-region must also prioritize education and digitalization to improve economic growth. This study treated technology as an endogenous factor in the growth model; thus, future studies could focus on analyzing convergence among countries by treating technology as an exogenous factor to see how it fits in the growth model.

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Appendix

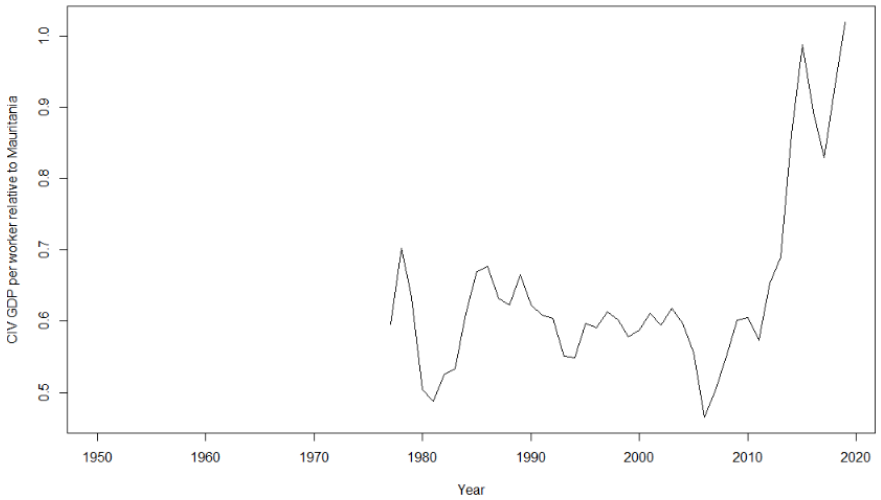
Appendix 1. Benin's GDP per worker relative to Mauritania

Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 2. Burkina Faso's GDP per worker relative to Mauritania

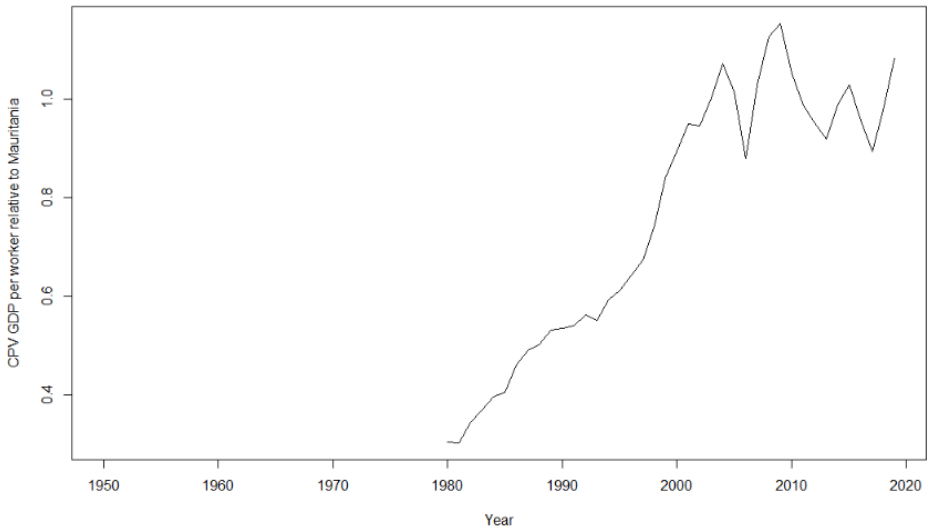
Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 3. Cote d'Ivoire's GDP per worker relative to Mauritania



Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 4. Cape Verde's GDP per worker relative to Mauritania



Source: author's Computation based on a dataset from Penn World Tables 10

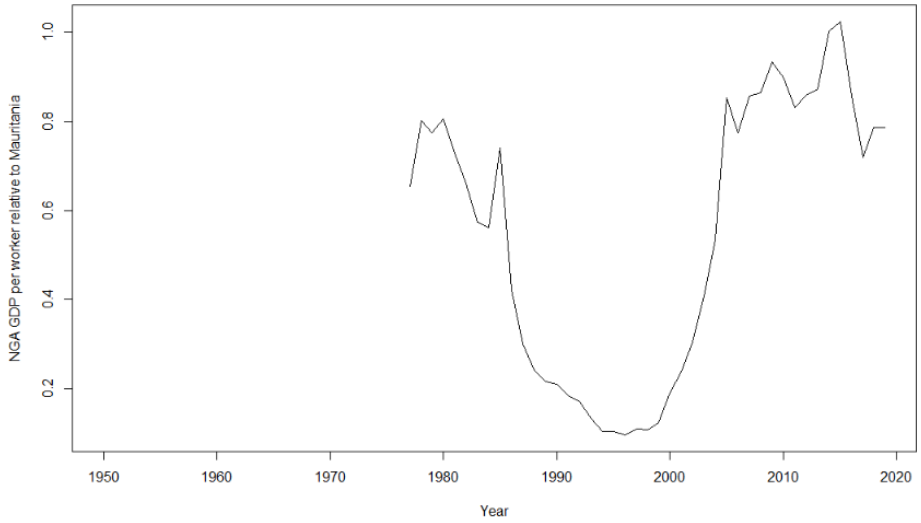
Appendix 5. Guinea's GDP per worker relative to Mauritania

Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 6. Niger's GDP per worker relative to Mauritania

Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 7. Nigeria's GDP per worker relative to Mauritania

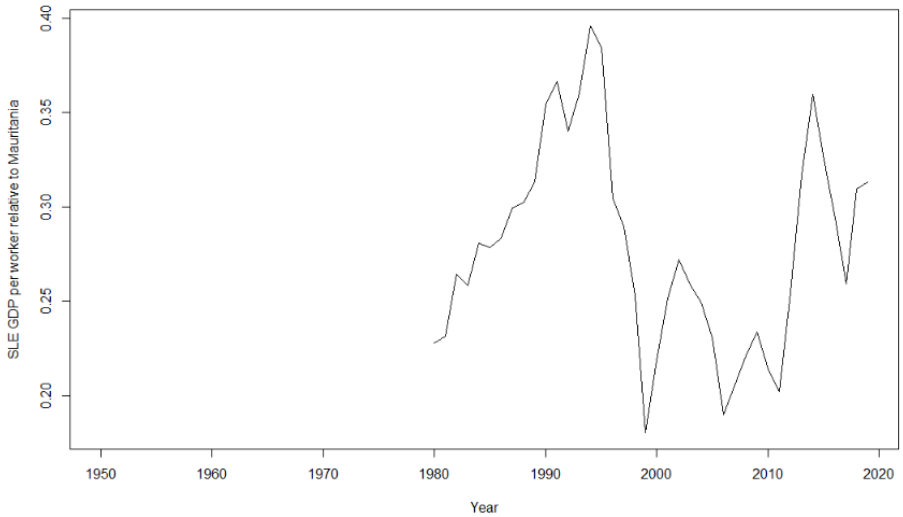


Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 8. Senegal's GDP per worker relative to Mauritania

Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 9. Sierra Leone's GDP per worker relative to Mauritania



Source: author's Computation based on a dataset from Penn World Tables 10

Appendix 10. Togo's GDP per worker relative to Mauritania

Source: author's Computation based on a dataset from Penn World Tables 10