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The Mediating Role of Internet Adoption on Gender Equality and Economic Development in West Africa

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Abstract- ***This study examines the role of gender equality and internet adoption in driving human development in West African countries, with the Human Development Index (HDI) serving as the measure of economic development. The primary objective is to assess how gender equality and internet penetration adoption interactively influence human development in the West Africa region. Using a panel data set of West African countries, multiple econometric models were applied, including Panel Ordinary Least Squares (OLS), Fixed Effect Model (FEM), Random Effect Model (REM), and Panel-Corrected Standard Errors (PCSE) to ensure robustness and address potential heteroscedasticity and cross-sectional dependency issues. Findings indicate that gender equality and income levels are consistently positive contributors to economic development, while internet adoption generally supports human development, though its impact varies across models. The interaction terms reveal that combining broadband access with gender equality significantly enhances human development outcomes. The study concludes that policies promoting both gender inclusivity and digital infrastructure are essential for fostering economic growth in West Africa. Recommendations include investing in broadband infrastructure, implementing gender-inclusive policies, fostering public-private partnerships, and adopting inclusive digital policy frameworks to support women's access to internet-based economic opportunities. These strategies are critical for harnessing the synergistic potential of gender equality and internet access to drive inclusive development in the region.***

Keywords: Gender Equality, Internet Adoption, Economic Development, Human Development Index, Fixed effect, Random effect, Panel-Corrected Standard Errors.
JEL Classification Numbers: O1, O33, C23, J16.

I. INTRODUCTION

In recent years, the role of gender equality in economic development has gained recognition as a key factor for sustainable growth. Gender equality is widely accepted as both a fundamental human right and a crucial factor in accelerating economic development, with many studies suggesting that societies with greater gender equality enjoy higher economic growth rates (World Bank, 2018). In West Africa, persistent gender disparities present ongoing challenges, hindering women's full participation in education, employment, and decision-making roles, limiting the region's development potential (African Development Bank, 2020). The region's socio-economic growth is further constrained by limited access to information and communication technology (ICT), especially internet connectivity, which remains low compared to global standards. As internet adoption rises globally, it is important to examine whether and how this technology can influence gender equality, impacting economic development in West Africa.

The economic theory shows that both gender equality and technology access contribute significantly to human capital development, labor market productivity, and innovation. Becker's (1993) Human Capital Theory argues that investing in education and health improves labor productivity, while Romer's (1986) Endogenous Growth Theory suggests that internal factors like knowledge, human capital, and innovation drive economic growth. In the case of West Africa, addressing the gender gap could maximize labor productivity and economic growth by tapping into an underutilized segment of the workforce (Becker, 1993). Similarly, increased internet adoption aligns with Technology Diffusion Theory, facilitating knowledge and skill development that can further empower women and enhance their economic contributions (Rogers, 2003). By fostering internet access and promoting gender inclusivity, West African countries could leverage a more equitable society for accelerated economic development.

Despite notable advancements, the gender digital divide remains an obstacle in West Africa. According to the International Telecommunication Union (ITU), women in sub-Saharan Africa are 25% less likely to use the internet than men, often due to socio-cultural

norms, lower literacy rates among women, and financial constraints (ITU, 2019). This digital divide limits women's ability to engage in the digital economy, which hinders their potential to contribute fully to economic development. Furthermore, internet access and gender equality are interlinked, as access to information and networking opportunities can improve educational and employment outcomes for women. For example, online platforms can facilitate access to market information, financial resources, and skill-building programs, enabling women to enhance their employability and entrepreneurial capacities (UN Women, 2021).

Several West African countries have implemented policies to promote gender equality, but structural barriers continue to restrict women's economic participation. Gender norms, limited mobility, and educational disparities worsen these challenges, resulting in West Africa ranking consistently low on the Gender Development Index (GDI) and Gender Inequality Index (GII) (UNDP, 2020). Given these ongoing issues, exploring the role of internet adoption as a potential mediator in the relationship between gender equality and economic development could reveal innovative pathways to accelerate growth in the region.

At the intersection of gender equality, internet adoption, and economic development lies the promise of an inclusive economy that benefits from diverse perspectives and capabilities. By enabling wider internet access, governments and policymakers in West Africa could not only enhance digital inclusivity but also address existing gender gaps in the labor market. When women have access to online resources, they are more likely to invest in education and skills that support high-value economic activities, creating a ripple effect that can foster broader societal development. However, empirical research in this area remains scarce, emphasizing the need to understand how gender equality, when combined with internet access, can positively influence economic development in West Africa.

This research addresses whether internet adoption can bridge the gender gap in West Africa and enhance economic development outcomes. By investigating the interaction between gender equality and internet access, this study seeks to contribute to the theoretical and empirical understanding of how digital inclusion affects economic growth. Given the rapid advancements in ICT and its potential to drive development, this research is timely and relevant for policymakers aiming to foster inclusive growth in the region. Addressing the gender digital divide through targeted internet adoption policies could unlock significant economic benefits, enabling West African countries to achieve sustainable and inclusive development.

II. RELEVANT LITERATURE

Theoretical Literature

There are several literature that show the relationship between gender equality, internet adoption, and economic development, particularly those related to human capital, endogenous growth, and technology diffusion. They emphasize the transformative role of both gender inclusivity and technology access in promoting long-term, sustainable economic growth. Therefore, the interaction between gender equality and internet adoption can serve as a facilitator, advancing economic development by enhancing productivity, labor market participation, and innovation.

Human Capital Theory and Gender Equality

The Human Capital Theory, as developed by economists like Gary Becker, suggests that investment in human capital (skills, education, and health) contributes to economic growth by enhancing labor productivity. Traditionally, gender disparities have restricted women's access to education and employment, limiting the effective accumulation and utilization of human capital (Becker, 1993). Nevertheless, when gender equality is prioritized, the economy benefits from a larger, more skilled workforce, maximizing the potential output from a society's human capital. The internet adoption however plays a crucial role in this process by facilitating access to education and skill-building resources, particularly for women who may otherwise face socio-cultural barriers to traditional learning environments. Through online platforms, women gain access to education, vocational training, and networking opportunities, which can improve their employability and productivity. This aligns with Schultz's theory of human capital, which emphasizes that investments in education lead to more productive labor and ultimately drive economic development (Schultz, 1961). By bridging gender gaps in education and labor force participation, internet adoption enables a fuller utilization of the economy's

human capital, translating into higher productivity and growth (Becker, 1993).

Endogenous Growth Theory and Innovation through Internet Adoption

The Endogenous Growth Theory, developed by Romer (1986) and Lucas (1988), emphasizes that economic growth is a result of internal factors—such as innovation, knowledge spillovers, and technology—rather than external factors like foreign investment alone. This theory places a strong emphasis on human capital, suggesting that a knowledgeable and skilled population fosters innovation and sustained growth. Internet access plays a significant role in this model by facilitating the dissemination of knowledge, increasing access to information, and enabling research and development (Romer, 1986). For women, internet access often serves as an entry point into fields historically dominated by men, such as technology, business, and finance, leading to a more inclusive economy where diverse perspectives contribute to innovation (Lucas, 1988).

As women become more connected to the Internet, they participate more actively in economic activities, driving innovation and entrepreneurial ventures (Romer, 1986). This alignment with endogenous growth theory means that economies with higher gender equality in internet access and utilization experience enhanced growth rates due to a broader base of knowledge workers and innovators. Knowledge spillovers—where skills and ideas transfer from one part of the economy to another—are facilitated by the internet, amplifying the positive impacts of gender equality on economic development (Lucas, 1988).

Technology Diffusion and Gender Equality

The theory of technology diffusion explains how innovations spread across populations and enhance productivity. Rogers (2003), in his Diffusion of Innovations Theory, describes how the adoption of new technologies, like the internet, spreads over time, influencing economic development. When internet access reaches traditionally underserved groups, such as women in developing economies, it leads to a wider diffusion of technology across society. This shows that internet adoption contributes to gender equality by granting women access to markets, financial resources, and entrepreneurial opportunities (Rogers, 2003).

By enabling remote work and access to global networks, the Internet allows women to overcome barriers to traditional employment, such as family obligations or restrictive societal norms. This increase in female labor force participation enhances the aggregate productivity of an economy, consistent with theories that link labor productivity growth to technology diffusion. Moreover, when women adopt and utilize internet technologies, they often bring unique insights into market needs and consumer behavior, which can lead to new products, services, and market segments, fostering economic diversification and growth (Rogers, 2003).

The Role of Internet Adoption on Gender Equality in Driving Development

The interaction between internet adoption and gender equality can be understood as a virtuous cycle driving economic development. As internet adoption rises, particularly among women, gender disparities in education, employment, and entrepreneurship tend to decrease. This shift not only improves individual welfare but also stimulates macroeconomic growth by diversifying the labor force and enhancing productivity (Schultz, 1961; Becker, 1993). When more women have access to the Internet, they gain financial independence, contribute to household income, and can make investment decisions, which can foster a consumption-led growth model as outlined in Keynesian economic theories of aggregate demand (Keynes, 1936).

Increased female labor participation supported by internet access aligns with the Solow Growth Model, where an expanded labor force enhances the capital-labor ratio, promoting economic growth (Solow, 1956). As women integrate into the economy more fully, economies also benefit from what economists term “total factor productivity,” the increased output not solely tied to labor or capital but rather to improved efficiency and innovation within the workforce (Solow, 1956).

By integrating more women into the workforce and enabling their entrepreneurial activities, economies can leverage a larger pool of human capital, enhancing innovation and productivity. The theories of human capital, endogenous growth, and technology diffusion collectively highlight that when internet adoption supports gender equality, it facilitates a more inclusive growth model that is

crucial for sustainable economic development (Becker, 1993; Romer, 1986; Rogers, 2003).

Empirical Literature

Haftu (2019) conducted an empirical analysis of the impact of mobile phones and the Internet on per capita income in Sub-Saharan Africa (SSA) from 2006 to 2015, utilizing a panel dataset from 40 countries and applying a two-step system GMM method. The study found that mobile phone penetration significantly contributed to GDP per capita growth, where a 10% rise in mobile phone penetration led to a 1.2% increase in GDP per capita, emphasizing the role of mobile access in reducing poverty. However, Internet penetration showed no significant effect on GDP per capita, attributed to low penetration rates and limited ICT skills in SSA.

Asamoah et al. (2019) examined the role of institutions in the relationship between FDI, trade, and economic growth in SSA, using Structural Equation Modelling with data from 34 SSA countries (1996–2016). The study found that while FDI had a decreasing effect on growth without institutional intervention, institutions positively influenced the trade-growth nexus. The authors highlighted that institutional quality is crucial to enhancing SSA's economic growth, as it strengthens trade's impact on growth. Following this, Asongu and Odhiambo (2020) examined how ICT influences the effect of FDI on growth in 25 SSA countries from 1980 to 2014, using the GMM approach. They found that internet and mobile penetration enhanced FDI's positive effects on economic growth, with internet adoption yielding the strongest positive outcomes. The study pointed out that ICT policies should be complemented by additional initiatives to maximize growth.

Sani et al. (2019) explored institutional quality's moderating role on public debt's effect on economic growth in SSA, utilizing GMM analysis on data from 46 countries (2000–2014). The study revealed that institutional quality mitigated debt's adverse impact on growth, highlighting government effectiveness, regulatory quality, and corruption control as critical factors. This underscores the need for strong institutions to maximize the benefits of government borrowing in SSA. Focusing on fiscal dynamics, Awolaja and Esefo (2020) analyzed budget deficits and growth in SSA from 1991 to 2018, using the PMG estimation technique. The results indicated that in the long term, budget deficits negatively impacted growth, while in the short term, deficits were positively associated with growth. The authors recommended reducing recurrent expenditures to prevent excessive deficits and increase developmental spending.

Donou-Adonsou et al. (2016) found that telecommunications infrastructure, particularly internet and mobile usage, had a positive impact on economic growth in SSA. Employing IV-GMM with data from 47 countries (1993–2012), the study concluded that enhancing telecommunications infrastructure would substantially boost growth, advising policymakers to support internet expansion and reduce usage costs. While Nyasha et al. (2021) examined tourism development's effect on SSA's economic growth from 2002 to 2018. Dividing SSA into low- and middle-income countries, they found that tourism expenditure negatively affected growth, whereas tourism receipts had a positive effect. The study observed that low-income countries benefited more from tourism receipts, revealing variations in tourism's impact across income groups.

Adegboye et al. (2020) investigated FDI's relationship with institutional quality and economic development in SSA using pooled data from 30 SSA countries (2000–2018). The study found that FDI positively impacted growth, but institutional quality was crucial in attracting FDI. Weak institutions hindered resource use and domestic sector investment, reducing SSA's potential for optimal growth. Akinlo and Dada (2022) examined how real sector output moderated the relationship between information technology and growth in 26 SSA countries (2000–2019), using pooled OLS/WLS, fixed effects, and GLS. Their findings showed that agricultural output and IT combined positively influenced growth, while industrial output's interaction with IT had a negative effect. This suggested that different sectors contribute variably to its impact on growth.

Adeleye and Eboagu (2019) explored ICT's role in Africa's economic growth from 54 countries (2005–2015). Using various estimation models, they found that ICT development, particularly mobile technology, significantly impacted growth, with mobile subscriptions showing the highest output elasticity. This supports the "leapfrogging" hypothesis, suggesting mobile technology can enable Africa to bypass traditional growth stages.

The reviewed literature emphasizes the role of infrastructure and institutional quality in facilitating SSA's economic growth. However, critical areas remain underexplored, particularly in how gender equality and internet penetration collectively affect development. While previous studies have examined internet adoption or gender inclusivity separately, the combined impact of these factors on growth in SSA has yet to be investigated. Examining this intersection could uncover new insights into inclusive growth, allowing for the optimization of technological adoption and the economic potential of a more gender-diverse workforce.

III. METHODOLOGY

Theoretical Framework

The theoretical framework for this study is endogenous growth theory. The Endogenous Growth Theory, introduced by Romer (1986) and further developed by Lucas (1988), posits that economic growth stems primarily from internal factors, notably human capital, innovation, and technology, rather than external factors such as foreign investment. Central to this theory is the role of human capital specifically, that a skilled and knowledgeable population enhances innovation and promotes sustained growth (Grossman & Helpman, 1991; Aghion & Howitt, 1998). Internet access becomes integral in this framework, facilitating knowledge dissemination, increasing access to information, and enabling research and development (Geroski et al., 2001; Romer, 1986). Internet access has an empowering effect, often serving as a gateway to traditionally male-dominated fields like technology, business, and finance, which diversifies and enriches the economy (Lucas, 1988; Arestis & Demetriades, 2020). As women increasingly utilize the Internet, their economic participation expands, driving both innovation and entrepreneurial activity within various industries (Barro & Lee, 2015; Goldin, 2014). This dynamic aligns with the Endogenous Growth Theory, suggesting that economies with higher gender parity in internet access experience enhanced growth due to a more inclusive base of knowledge workers and innovators (Klasen & Lamanna, 2009).

Internet access amplifies knowledge spillovers which is a key element of endogenous growth whereby skills and ideas transfer across sectors and creates a feedback loop where increased gender equality strengthens economic development (Becker, 1994; Lucas, 1988; Voitchovsky, 2014). This model thus suggests that internet adoption and digital inclusion serve as conduits for translating gender equality into measurable economic gains (Romer, 1986; Ferrant & Kolev, 2016), affirming that endogenous growth is furthered by accessible digital infrastructure that benefits both genders equitably (Jorgenson, 2001).

Model Specifications

To investigate the role of gender equality and internet adoption in driving human development across West African countries, using the Human Development Index (HDI) as a measure of economic development. The study draws its foundation from the endogenous growth model which helps the choice of explanatory variables for the study and links the theoretical and empirical frameworks. As a sequel to this, the model of economic development with gender equality and internet adoption as well as broadband as drivers is given thus in equation I:

$HDI = (GDI_{it}, GNIPC_{it}, INT_{it}, FBB_{it}, INTGDI_{it}, FBBGDI_{it})$ ---------------------- (I)

By suggesting a linear econometric relationship between human development and the determinants, and after adding the intercept and error terms α_0 and μ_{it} respectively. Thus, the econometric model specified for estimation is as shown in Equation 2 below:

$$HDI_{it} = \propto_0 + \propto_1 GDI_{it} + \propto_2 GNIPC_{it} + \propto_3 INT_{it} + \propto_4 FBB_{it} + \propto_5 INTGDI_{it} + \propto_6 FBBGDI_{it} + \mu_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (II)$$

Where:

HDI = Human Development Index

GDI = Gender Development Index

GNIPC = Gross National Income Per Capita

INT = Internet Adoption

FBB = Fixed Broadband

INTGDI = Internet interaction with gender development

FBBGDI = Fixed broadband with gender development

$\propto_1$ to $\propto_6$ = coefficient of the independent variables

μ_{it} = Error term

i = country in the panel;

t = year in the panel

The apriori expectations of each of the parameters of the model are

$\propto_1 > 0$ or < 0, $\propto_2 > 0$ or < 0, $\propto_3 > 0$ or < 0, $\propto_4 > 0$ or < 0, $\propto_5 > 0$ or , and $\propto_6 > 0$ or < 0.

Variables Description and Measurement.

Numerous scholars have utilized a variety of variables to represent indicators of economic development and others as determinants of economic development. This section presents the variables selected for this study along with their corresponding measurement methods.

Human Development Index (HDI)

The Human Development Index (HDI) is a composite measure developed by the United Nations to assess a country's average achievements in three basic aspects of human development: health (life expectancy), education (mean years of schooling and expected years of schooling), and standard of living (gross national income per capita). The HDI is scored between 0 and 1, where higher values indicate better development outcomes. It combines these dimensions to provide a single index that reflects overall human development beyond merely economic performance (UNDP, 2023; Smits & Permanyer, 2022).

Gender Development Index (GDI)

The Gender Development Index (GDI) measures gender disparities in human development achievements across three dimensions: health (life expectancy at birth), education (mean and expected years of schooling), and economic status (estimated earned income). The GDI is the ratio of female to male HDI values, highlighting gaps between genders in development outcomes; a GDI score closer to 1 suggests greater gender equality (UNDP, 2023; Ferrant & Kolev, 2021).

Gross National Income Per Capita

Gross National Income (GNI) per capita represents the average income earned by a country's residents, including earnings from international sources, divided by its population. It is used as an indicator of economic development, reflecting the average income level and economic health of a nation. GNI per capita is often adjusted for purchasing power parity (PPP) to facilitate international comparisons, and it forms part of the Human Development Index to provide a broader perspective on human well-being (World Bank, 2022; UNDP, 2023).

Internet Adoption (INT)

Internet adoption proxy by individuals using the Internet (% of the population) measures the percentage of a country's population that has used the Internet at least once in a specified period, typically within a year. It serves as a critical measure of digital access and inclusion, reflecting the reach of information and communication technology (ICT) infrastructure within a country. This metric is often used to gauge technological progress, economic development, and the potential for digital-driven growth (International Telecommunication Union, 2022; World Bank, 2023).

Internet Adoption-Gender Development Index (INTGDI)

The interaction between Internet adoption and the Gender Development Index (GDI) is calculated by multiplying the rate of Internet adoption by the GDI score. This combined measure reflects how internet access relates to gender equality in development outcomes. A higher value suggests that greater internet adoption aligns with more equitable development between genders, potentially enhancing opportunities for both men and women to participate equally in economic, educational, and social domains. This interaction term can help illustrate how digital access impacts gender-based development dynamics within a society.

Fixed Broadband-Gender Development Index (FBBGDI)

The interaction between fixed broadband adoption and the Gender Development Index (GDI) is calculated by multiplying the rate of fixed broadband subscriptions by the GDI score. This measure captures the relationship between broadband internet access and gender equality in development outcomes. A higher interaction value suggests that widespread broadband access correlates with more balanced development between genders, potentially providing equal opportunities for men and women in areas such as education, employment, and access to information. This interaction term highlights the influence of reliable internet infrastructure on promoting gender-equitable development.

Analytical Techniques

The analysis begins with a descriptive examination of the key variables using descriptive statistics to assess their characteristics and interrelationships. This includes estimates of the number of observations, mean, standard deviation, minimum, and maximum values across countries and over time. Pearson correlation will be employed to measure linear relationships, with values near +1 indicating a strong

positive correlation and those near -1 indicating a strong negative correlation (Gujarati & Porter, 2009). The study will utilize static panel analysis to explore data collected over time from multiple entities. This method is commonly used in econometrics to examine relationships between variables while accounting for individual and time-specific effects (Gujarati & Porter, 2009). The analysis will include three primary models: Ordinary Least Squares (OLS), Fixed Effect Model (FEM), and Random Effect Model (REM). OLS estimates relationships between dependent and independent variables, while the FEM accounts for individual-specific effects using dummy variables. The REM assumes individual effects are random and uncorrelated with the independent variables.

Key tests, including the Poolability test, Hausman test, and Breusch-Pagan Lagrange Multiplier (LM) test, will guide the choice among the three methods (Pooled OLS, FEM, and REM). The Poolability test evaluates whether a constant should be treated as homogeneous or heterogeneous, informing the choice between pooled regression and FEM. The F-test will be used to assess the validity of fixed effects by determining if constants differ across units, with a low F-test value favoring FEM (Gujarati & Porter, 2009).

The Hausman test will check the correlation between individual-specific effects and independent variables, estimating both FEM and REM and performing a Wald test based on the covariance matrix of the estimates. A p-value below the significance level will lead to the rejection of the null hypothesis, indicating FEM is more suitable (Gujarati & Porter, 2009). The Breusch-Pagan LM test will help distinguish between REM and pooled OLS models, with a p-value below the significance level indicating a preference for REM (Kalita & India, 2013). To enhance model robustness, the analysis will also incorporate Panel-Corrected Standard Errors (PCSE) to address cross-sectional dependence in panel data, which can result in biased estimates in the FEM and REM frameworks (Kalita & India, 2013).

V. DATA AND RESULTS ANALYSIS

Stylized Analysis

The Human Development Index (HDI) trends in figure 1 for various West African countries reveal a general pattern of gradual improvement, though at varying rates. Countries like Benin, Burkina Faso, Cameroon, Ghana, Mauritania, Senegal, and Togo display consistent upward trends, indicating steady advancements in health, education, and income levels. Cape Verde shows an overall increase in HDI with some fluctuations, suggesting progress with occasional instability. Cote d'Ivoire and Gambia also reflect gradual improvement, while Guinea Bissau and Mali show slower, steady progress. Countries with more historical volatility, such as Liberia and Sierra Leone, exhibit fluctuations in their HDI trends due to past conflicts, though they have resumed positive paths in recent years. Niger started with one of the lowest HDI values but showed gradual improvement over time. These HDI trends suggest that while all countries are experiencing growth in human development, the pace and consistency differ, with some nations progressing more steadily than others.

In Figure 2, the Gender Development Index (GDI) trends for selected West African countries expose diverse growth in gender equality across the region. From the figure, Benin and Burkina Faso's GDI shows upward trends with slight oscillations, signifying gradual improvements in gender equality in education, health, and income. Cape Verde shows a sharp increase followed by a steep decline, indicating instability in gender equality, potentially due to social or economic shifts that affected men and women differently. Cameroon shows a steady improvement with minor fluctuations, signaling consistent efforts toward gender balance. Cote d'Ivoire presents a highly volatile trend with notable drops and recoveries, suggesting that gender development has been uneven, possibly influenced by economic or political changes impacting gender roles differently.

Gambia and Ghana display upward trends in GDI, with Ghana showing more consistent improvement, reflecting progress in gender-focused policies. Guinea Bissau has a relatively stable trend with gradual increases, indicating slow yet steady progress. In Liberia, the GDI trend reflects fluctuations but ultimately an upward trajectory, likely recovering from the impacts of past conflicts on gender development. Mali and Mauritania exhibit high variability, with some steep declines, suggesting challenges in achieving sustained gender parity due to sociocultural or economic factors. Niger shows some fluctuation but generally trends upward,

showing incremental progress. Senegal shows an upward trend with occasional dips, reflecting ongoing efforts in gender equality despite some setbacks. Sierra Leone and Togo both present relatively steady upward trends with minor fluctuations, indicating gradual improvements in gender development over time.

GDI trends in West Africa highlight that while there is a positive movement toward gender equality in most countries, the rate of progress and stability varies. Countries like Ghana, Senegal, and Gambia show more consistent improvements, while others, such as Cape Verde, Cote d'Ivoire, and Mali, demonstrate significant fluctuations. This variability suggests that the journey toward gender equality in West Africa is complex, influenced by factors such as political stability, economic conditions, and cultural norms that can either advance or hinder gender development.

Figure 3 shows the percentage of individuals using the Internet in selected West African countries over time, highlighting the digital transformation in the region. Across all countries, internet usage has grown significantly in recent years, although the pace and extent of this growth vary. Benin, Burkina Faso, and Cameroon demonstrate gradual increases in internet penetration, with sharper growth in recent years, indicating rising digital adoption. Cape Verde shows a steady upward trend, likely due to its relatively developed infrastructure, which supports higher internet penetration rates compared to some other countries in the region. Cote d'Ivoire exhibits a notable spike in internet usage, especially after the mid-2000s, reflecting improvements in telecommunications infrastructure and possibly more affordable internet access.

Gambia and Ghana show consistent growth, with Ghana experiencing rapid increases in internet penetration, possibly due to supportive government policies and investments in digital infrastructure. Guinea Bissau and Liberia start from low levels but also show significant growth, though at a slower pace than some of their neighbors, which could reflect infrastructural or economic constraints. In Mali and Mauritania, internet usage has risen gradually, with noticeable increases in the past decade. These trends suggest ongoing efforts to improve internet access, though there may be limitations due to geographic or economic challenges. Niger has one of the lowest internet penetration rates initially but shows a marked increase over time, reflecting efforts to expand connectivity in a challenging environment. Senegal and Sierra Leone display strong upward trends, with recent rapid growth suggesting that digital access is becoming increasingly widespread. Togo shows a similar pattern, with a steep rise in internet usage in recent years, likely driven by increased investments in digital infrastructure and growing public demand.

These trends suggest a positive trend in internet adoption across West Africa, with internet usage becoming more widespread. However, the degree of access varies significantly by country, influenced by factors like infrastructure development, economic resources, and government policies. Countries like Ghana, Cape Verde, and Senegal lead in terms of digital adoption, while others, like Guinea Bissau and Niger, are progressing but at a slower rate. Expanding internet access remains critical for fostering digital inclusion and supporting economic and social development across the region.

The analysis of the Gender Development Index (GDI), internet usage, and Human Development Index (HDI) across selected West African countries provides understandings into the interconnected relationships between gender equality, internet access, and human development in the region. These three indicators HDI, GDI, and internet penetration are interdependent, as progress in one can drive or reflect improvements in the others. Gender equality and human development show a correlation in most countries. Higher GDI scores, indicating better gender parity, often align with upward trends in HDI, which measures overall development through health, education, and income indicators. For instance, countries like Ghana, Senegal, and Cape Verde exhibit steady increases in both GDI and HDI, reflecting how gender-inclusive development policies contribute to overall human progress. In these countries, progress in gender equality likely enhances workforce participation, boosts productivity, and promotes educational access for both men and women, which in turn elevates HDI.

Internet access serves as a significant facilitator for both gender equality and human development, as demonstrated by the rising trends in internet penetration across these West African countries. Countries with higher internet penetration, such as Ghana and Senegal, also show substantial gains in

GDI and HDI. Increased internet access enables individuals, especially women, to access information, education, job opportunities, and social networks that were previously unavailable, contributing to empowerment and economic inclusion. Digital access can support flexible work arrangements, remote learning, and entrepreneurship, which are critical for enhancing women's participation in economic activities and reducing gender gaps. The data also highlight challenges where gender inequality and limited internet access inhibit human development. In countries with lower internet penetration rates, such as Niger and Guinea Bissau, GDI and HDI improvements are relatively slower. These countries face substantial barriers to digital connectivity, which may be tied to socioeconomic constraints, underdeveloped infrastructure, or cultural norms that limit women's digital access and participation. As a result, limited internet penetration restricts opportunities for educational advancement and economic engagement, especially for women, slowing overall human development.

What can be deduced from the analysis is that internet adoption can act as a bridge between gender equality and human development. Digital tools empower women by increasing their access to education, healthcare, financial services, and employment, all of which contribute to gender parity and improve living standards, thereby raising HDI. For example, Mauritania and Togo show rising trends in both internet usage and GDI, suggesting that increasing internet access can support gender equality initiatives, which in turn positively impact human development. The analysis highlights a jointly supporting relationship between gender equality, internet access, and human development in West Africa. Increased internet access supports gender equality by providing opportunities for women's empowerment and inclusion, which in turn drives human development. Countries with stronger internet infrastructure and gender-inclusive policies, such as Ghana and Senegal, exhibit better HDI and GDI outcomes, indicating that prioritizing digital inclusion and gender equity is essential for achieving sustainable human development in West Africa.

Results Analysis

The descriptive statistics from table 1 provide insight into the key variables in the study, which examines the mediating role of internet adoption on gender equality and economic development in West Africa, with the Human Development Index (HDI) as a proxy for economic development. The mean HDI is 0.4774, with a standard deviation of 0.0744, reflecting moderate variation in development across the sample. HDI values range from 0.296 to 0.668, indicating that countries in the study span from low to medium levels of human development. The Gender Development Index (GDI) has a mean of 0.8615 and a smaller standard deviation of 0.0450, suggesting that gender equality levels are relatively stable, though there is some disparity, with GDI values ranging from 0.767 to 1.015.

Gross National Income per Capita (GNIPC) shows significant variation, with a mean of 2872.1 and a standard deviation of 1451.5, highlighting economic disparity across the region. The income ranges from 820.2 to 7646.2, demonstrating the wide gap in economic conditions between the poorest and wealthiest countries. Internet penetration (INT) has a mean of 12.005%, but a high standard deviation of 14.932, showing considerable differences in internet access across the region, with penetration rates ranging from a minimal 0.018% to a high of 71.37%. Fixed broadband (FBB) penetration is extremely low, with a mean of 0.4478 and a standard deviation of 0.8974, ranging from 0.0003 to 5.909, reflecting limited broadband access across most countries in West Africa.

The interaction term between internet penetration and gender equality (INTGDI) has a mean of 10.157, with a standard deviation of 14.076, showing wide variability in the influence of internet access on gender equality. The interaction between fixed broadband and gender equality (FBBGDI) has a mean of 0.2877 and a standard deviation of 0.7668, indicating that while fixed broadband's role in gender equality is generally small, it can be higher in certain cases. These statistics suggest that internet access, both mobile and fixed broadband, plays an important but varying role in shaping gender equality and economic development outcomes across West Africa.

The correlation results from table 2 reveal significant relationships between human development, gender equality, economic indicators, and internet penetration in West Africa. Starting with the Human Development Index (HDI), shows a strong positive correlation with the Gender Development Index (GDI) (0.6989), indicating that countries with higher

gender equality tend to have better overall development outcomes. The HDI has a very strong association with Gross National Income per Capita (GNIPC) (0.7997), suggesting that as income levels increase, so do human development levels. There is also a notable positive relationship between HDI and Internet Penetration (INT) (0.6152) as well as Fixed Broadband Penetration (FBB) (0.6263), reflecting that better access to digital infrastructure supports human development.

The interaction terms further emphasize this connection. The correlation between HDI and INT*GDI (0.6057) and between HDI and FBB*GDI (0.5699) suggests that internet access, when combined with improved gender equality, significantly contributes to human development. This highlights the dual importance of digital access and gender equality in driving progress. Looking at the GDI, its positive correlations with both GNIPC (0.5888) and internet-related variables—INT (0.6428) and FBB (0.6820)—indicate that countries with higher income levels and better digital access tend to exhibit stronger gender equality. Moreover, the interaction terms INT*GDI (0.6818) and FBB*GDI (0.6775) demonstrate that the influence of internet access on gender equality is more pronounced when combined with factors promoting gender equality, reinforcing the importance of integrating both aspects in development strategies.

The GNIPC shows a positive correlation with INT (0.5483) and FBB (0.5672), meaning that wealthier countries tend to have better internet and broadband infrastructure. This also extends to the interaction terms INT*GDI (0.5493) and FBB*GDI (0.5383), suggesting that higher incomes can enhance the impact of internet penetration on gender equality outcomes. The strong correlation between INT and FBB (0.6156) indicates that countries with better internet access tend to also have stronger broadband infrastructure. The interaction terms INT*GDI and FBB*GDI are almost perfectly correlated with their respective internet variables, showing that the effects of internet and broadband access on human development and gender equality are closely intertwined.

The above results suggest that internet penetration and broadband access play a crucial role in advancing both human development and gender equality in West Africa. These effects are enhanced when combined with income levels and gender equality, pointing to the importance of integrated policies that address digital access and gender empowerment for achieving broader development goals.

The regression results from table 3 for the four models—Panel Ordinary Least Squares (OLS), Fixed Effect Model (FEM), Random Effect Model (REM), and Panel-Corrected Standard Errors (PCSE) provide insights into how internet penetration and gender equality influence human development (HDI) in West Africa.

The Panel OLS results show a strong positive impact of the Gender Development Index on HDI, with a coefficient of 0.692, significant at the 1% level. This suggests that improvements in gender equality are associated with higher human development. GNIPC (Gross National Income per Capita) also has a significant positive effect on HDI, with a very small coefficient (0.00002), reflecting that rising income levels contribute positively to human development. Internet penetration (INT) is also positively associated with HDI (0.008), indicating that increased internet access boosts development. The interaction terms FBB*GDI (0.111) and FBB*INT (-0.009) are significant, highlighting that the role of the internet and fixed broadband in promoting development is stronger when considering gender equality. The R-square value of 0.718 indicates that 71.8% of the variation in HDI is explained by the model, showing a good fit.

The FEM results are similar to the OLS, with GDI remaining highly significant (0.694), showing a strong link between gender equality and human development. GNIPC remains positively associated with HDI, with the same coefficient (0.00002). INT is again positively significant (0.008), reaffirming the role of internet access in promoting development. However, the interaction term FBB*GDI (-0.009) remains significant but negative, suggesting that while broadband access interacts with gender equality, its influence on development can be complex, with certain negative effects observed. The FEM's F-test value is highly significant (73.93), supporting the overall model's effectiveness.

The REM results are nearly identical to those of the OLS and FEM, with GDI (0.692), GNIPC (0.00002), and INT (0.008) all showing significant positive effects on HDI. The interaction terms show a slightly

different behavior: FBB*GDI is negatively significant (-0.106), implying that the combination of broadband access and gender equality can sometimes have a diminishing impact on human development. The Hausman test (8.02, p = 0.091) suggests that the difference between the fixed and random effects models is not statistically significant, making REM a viable alternative to FEM in this context.

The PCSE results adjust for heteroscedasticity and cross-sectional dependency, providing robust estimates. Here, GDI (0.501) remains significant but with a smaller coefficient compared to the previous models, reflecting the persistent positive relationship between gender equality and human development. GNIPC remains highly significant (0.00002), and the interaction term FBB*GDI (0.231) is positive and significant, indicating that fixed broadband access, when combined with gender equality, enhances human development. Interestingly, INT becomes insignificant (0.0006), suggesting that when correcting for potential biases, the role of internet penetration in development becomes less pronounced. The overall model fit improves slightly with an R-square of 0.729.

The model performance reveals that both the Panel OLS and Random Effects Model (REM) yield similar results, highlighting the positive impacts of gender equality, income, and internet penetration on human development. The Fixed Effects Model (FEM), by accounting for individual country-specific effects, provides a more detailed view, especially in terms of the interaction between broadband access and gender equality. Meanwhile, the Panel-Corrected Standard Errors (PCSE) model offers more robust estimates by addressing heteroscedasticity and cross-sectional dependencies, emphasizing the significant interaction effects between broadband access and gender equality. Across all models, gender equality and income consistently emerge as strong drivers of human development, while the impact of internet penetration varies by model. The interaction terms across the models suggest that internet and broadband access, when combined with gender equality, have an amplified effect on development consequences in West Africa.

VI. CONCLUSION AND RECOMMENDATIONS

This study investigated the role of gender equality and internet adoption in driving human development across West African countries, using the Human Development Index (HDI) as a measure of economic development. The findings affirm that gender equality and income levels are consistently significant drivers of human development, aligning with established human capital theories. Internet penetration generally contributes positively to HDI, yet its effects vary depending on the model applied, indicating that digital connectivity's impact may be sensitive to underlying regional and structural factors. Notably, the interaction between broadband access and gender equality suggests an amplified impact on development when both factors are present, highlighting that digital inclusion combined with gender equality can provide a robust pathway to economic progress. This research thus highlights the transformative potential of advancing gender inclusivity alongside internet penetration to support sustainable economic growth in West Africa.

To fully leverage the developmental benefits of internet access and gender equality, the following recommendations are proposed:

1. Governments and policymakers should prioritize investments in broadband infrastructure, particularly in underserved and rural areas. This would enable more equitable internet access and enhance development outcomes by enabling both men and women to participate in the digital economy.
2. Creating and enforcing policies that support gender equality in education, employment, and internet accessibility is crucial. Encouraging women's participation in technology sectors and offering digital literacy programs can help close gender gaps in ICT access and use, further strengthening the impact of internet adoption on economic development.
3. Governments should consider integrating gender-sensitive approaches in their ICT and economic development policies. This involves incorporating gender-based needs and barriers into digital policies to ensure that women, particularly those in rural areas, can access digital resources for education, employment, and entrepreneurship.

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APPENDIX

TABLES

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
hdi	322	0.4774	0.0744	0.296	0.668
gdi	258	0.8615	0.0450	0.767	1.015
gnipc	330	2872.1	1451.5	820.2	7646.2
int	328	12.005	14.932	0.018	71.37
fbb	237	0.4478	0.8974	0.0003	5.909
intgdi	330	10.157	14.076	0.000	70.01
fbbgdi	330	0.2877	0.7668	0.000	5.797

Source: Author's Computation, 2024.

Table 2: Correlation Results

Variable	hdi	gdi	gnipc	int	fbb	Int*gdi	fbb*gdi
hdi	1						
gdi	0.6989	1					
	(0.000)						
gnipc	0.7997	0.5888	1				
	(0.000)	(0.000)					
Int	0.6152	0.6428	0.5483	1			
	(0.000)	(0.000)	(0.000)				
fbb	0.6263	0.6820	0.5672	0.6156	1		
	(0.000)	(0.000)	(0.000)	(0.000)			
Int*gdi	0.6057	0.6818	0.5493	0.9912	0.6475	1	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
fbb*gdi	0.5699	0.6775	0.5383	0.6352	0.9917	0.6739	1
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

Source: Author's Computation, 2024.

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Table 3: The Regression Results

Variables	Static Model			
	Panel OLS	FEM	REM	PCSE
gdi	0.692***	0.694***	0.692***	0.501***
	[11.83]	[11.69]	[11.83]	[5.14]
	(0.000)	(0.000)	(0.000)	(0.000)
gnipc	0.00002***	0.00002***	0.00002***	0.00002
	[6.29]	[5.07]	[6.29]	[23.46]
	(0.000)	(0.000)	(0.000)	(0.000)
int	0.008***	0.008***	0.008***	0.0006
	[4.53]	[4.57]	[4.53]	[0.21]
	(0.000)	(0.000)	(0.000)	(0.833)
fbb	0.111**	0.118**	0.111***	0.231***
	[2.23]	[2.23]	[2.23]	[2.75]
	(0.026)	(0.027)	(0.000)	(0.006)
Int*gdi	-0.009***	-0.009***	-0.008***	-0.0004
	[-4.44]	[-4.48]	[-4.44]	[-0.12]
	(0.000)	(0.000)	(0.000)	(0.904)
Fbb*gdi	-0.106*	-0.114**	-0.106**	-0.229***
	[-1.97]	[-1.99]	[-1.97]	[-2.63]
	(0.049)	(0.049)	(0.049)	(0.009)
Constant	-0.183-***	-0.183***	-0.182***	-0.032
	[-3.62]	[-3.59)	[-3.62]	[-0.39]
	(0.000)	(0.000)	(0.000)	(0.697)
Total Panel Observation	209	209	209	209
R-square	0.718	0.716	0.718	0.729
F-statistics	527.5***			
	(0.000)			
F-Test		73.93***		
		(0.000)		
Wald χ^2 –stat.			527.49***	1818.76***
			(0.000)	(0.000)
Hausman Test		8.02*		
		(0.0910)		
LM Test			188.541***	
			(0.000)	
Heteroscedasticity Tests		36392.6***		
		(0.000)		
Cross-sectional dependency			4.191***	
Test			(0.000)	

Source: Author's Computation, 2024.

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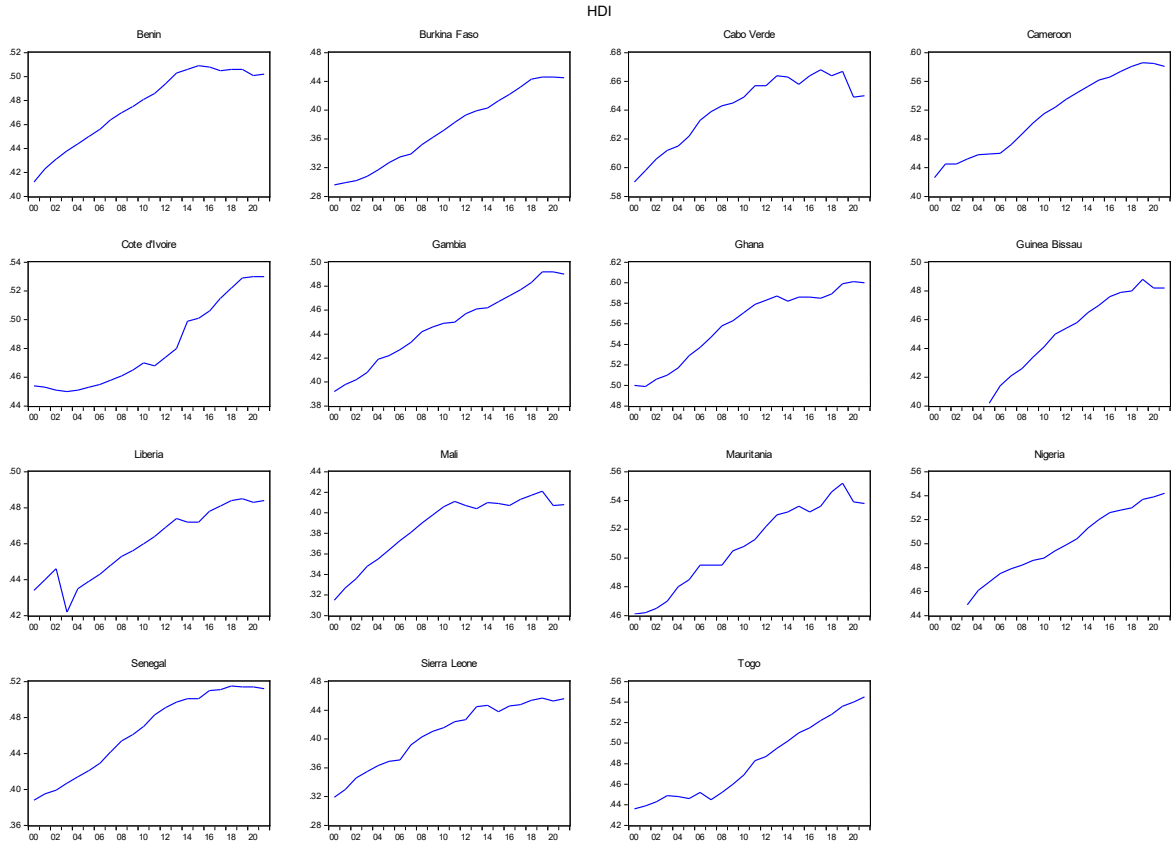
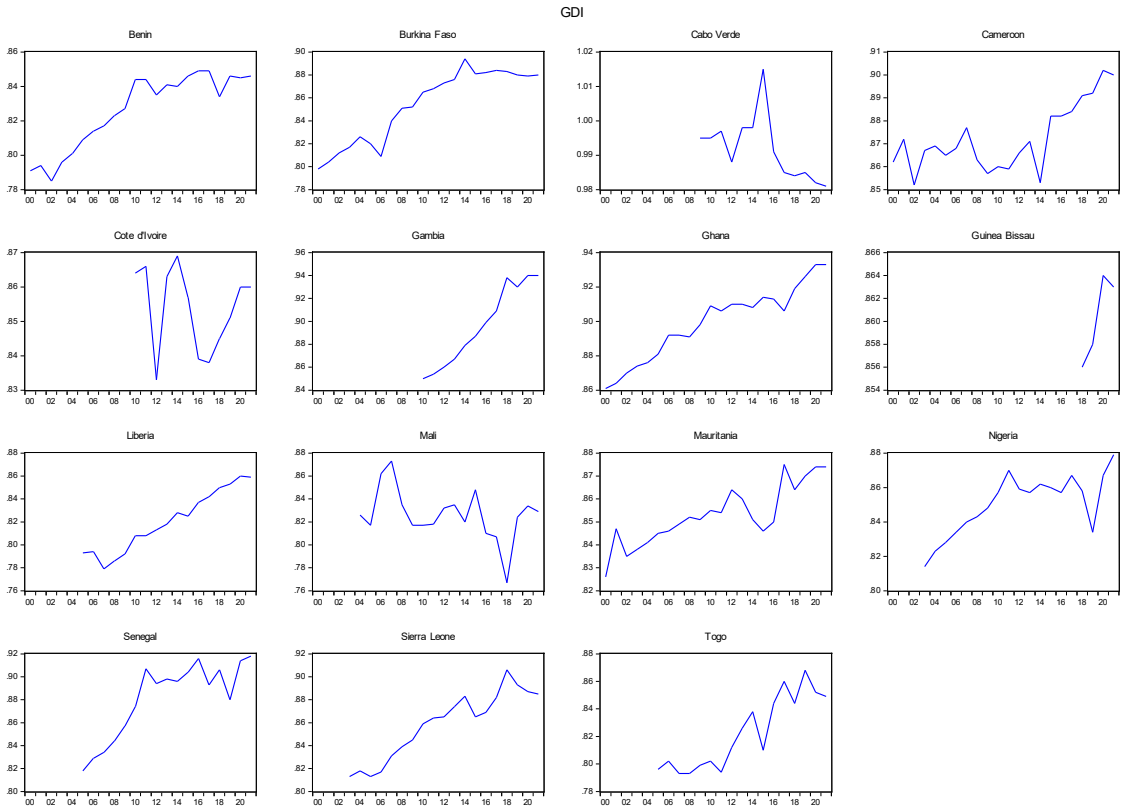
FIGURES

Fig 1: Human Development Index of Selected West African Countries.



Source: Authors' Computation via Eviews, 2024.

Fig 2: Gender Development Index of Selected West African Countries.



Source: Authors' Computation via Eviews, 2024.

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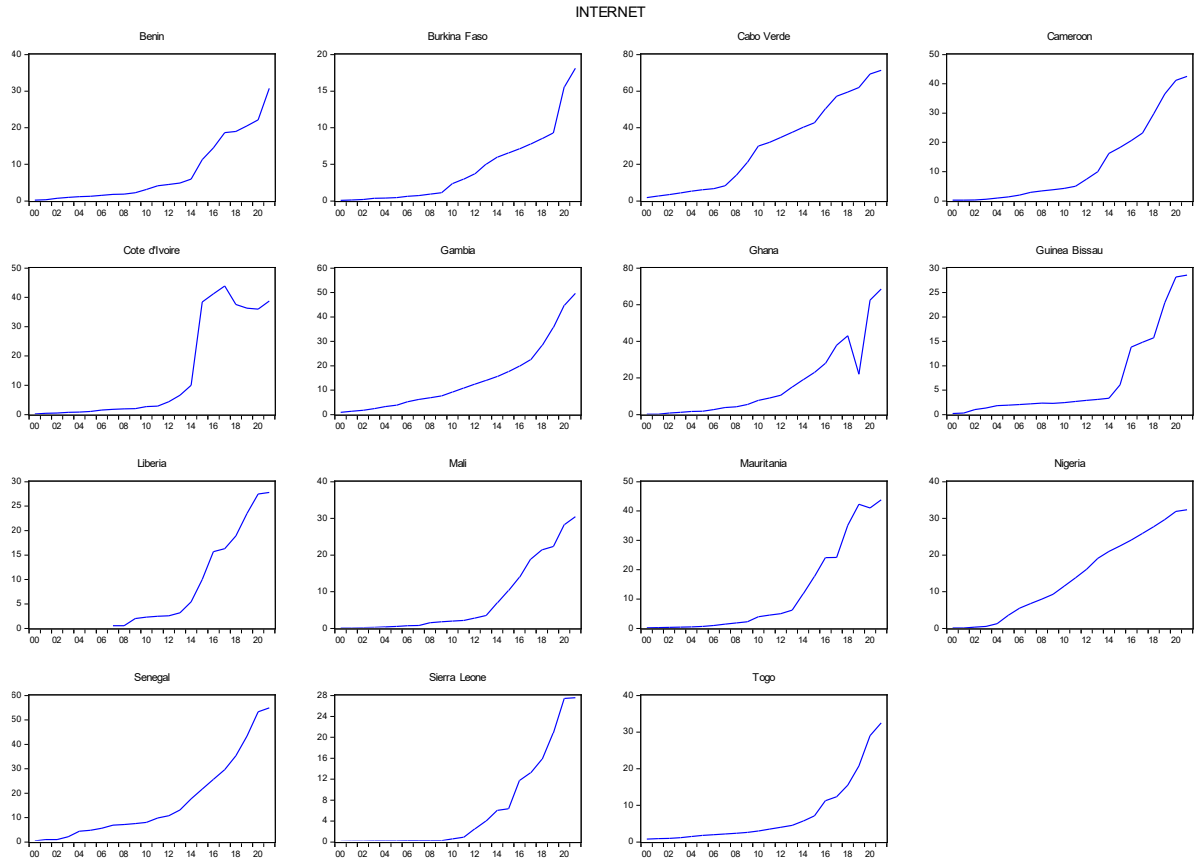
Fig 3: Individuals Using the Internet (% of the population) in Some Selected West African Countries.



Source: Authors' Computation via Eviews, 2024.