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Internet Adoption, Digital Divide, and Corruption: Evidence from ECOWAS Countries

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Abstract: This paper aims to extend the existing literature on Internet adoption and corruption by analyzing the factors impacting the digital divide and assessing the impact of Internet adoption on corruption reduction in the Economic Community of West African States (Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo). The study uses fixed and random effect panel data techniques covering 17 years (2003-2019), to exploit the times series nature of the relationship between the digital divide and its determinants. In addition, it aims to assess the impact of internet adoption along with other control variables on corruption. The estimation results show that per capita income, human capital, age, population density, government effectiveness, political stability, and the rule of law significantly affect the digital divide in ECOWAS. The findings reveal also that internet adoption affects positively the level of corruption control; the impact of an increase in internet users of 1% implies an increase in corruption control between 0.05% and 0.06%.

Keywords: corruption; digital divide; ECOWAS; internet adoption; panel data.

JEL classification: D73; O55; O38.

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1. INTRODUCTION

Corruption is a worldwide phenomenon that a majority of countries are still failing to tackle effectively (Transparency International, 2019). For instance, on 21 December 2001, the Economic Community of West African States (ECOWAS) signed protocol A/P3/12/01 21 on the fight against corruption in Dakar. Yet, many years later, and in 2019 Transparency International considered West Africa as the lowest-scoring region on the Corruption Perceptions Index (CPI). Except for Cape Verde which is ranked in the first quartile out of 180 countries, all West African countries[1] were and are still at the bottom of the index. This is explained by the fact that this region is truly very far from the international standards in all socio-economic indicators (Ejemeyovwi *et al.*, 2019). Thereby, it is natural to ask how these countries can improve their ranking in the CPI through these indicators.

A growing number of studies have considered corruption as one of the global issues for a long time, which is seriously affecting people, government, civil society, and media, as well as involving anyone from politicians and government officials to business people and citizens. Also, many studies highlighted that corruption is efficient in making other economic activities and social values inefficient. Corruption can weaken the efficiency of the economic system and result in higher poverty rates and income inequality (Gupta *et al.*, 2002; Park & Kim, 2020). In addition, corruption affects social values by lessening public trust and consequently being a hindrance to the legitimacy of institutions (Seligson, 2002; Swaner, 2017).

In this perspective, transparency may play a crucial role in enhancing citizens' trust in institutions by creating an environment of openness that allows people to participate in the decision-making process and monitor the performance of institutions (Grimmelikhuijsen, 2012; Burman *et al.*, 2016). Transparency can be reached by using Information and Communication Technologies (ICT) that are accessible and available to the majority of people to improve accountability (Lnenicka & Nikiforova, 2021).

The emergence of computers, and the rapid growth of the Internet and mobile phones, allow institutions to enhance their transparency. From this point, ICT has played two key roles. First, they mitigate the interaction between citizens and government officials and consequently slash the discretionary power of government officials (Elbahnasawy, 2014). Second, ICT makes easier the dissemination of information on corruption (Goel *et al.*, 2012). Nowadays, the speed of information dissemination is heavily reliant on the use of the Internet by citizens, businesses, and institutions. This was supported by the spread of several easy ways of sharing information in real-time (e.g., Social media networks).

However, the use of the internet and other tools of ICT in many countries are significantly linked to many obstacles such as the digital divide; lack of legal bases; lack of policy cycle management; lack of measurement and evaluation; lack of citizens' participation; and lack of trust and transparency (Savoldelli *et al.*, 2014). The digital divide is one of the most important obstacles (Gounopoulos *et al.*, 2020)**,** and it is qualified as a new face of inequality and disparity in the use of Information and Communication Technologies (Szeles, 2018; Elena-Bucea *et al.*, 2021). The consequence is only 18 percent of the population in Africa has internet access compared to 56.7 percent in the world (International Telecommunication Union, 2020).

The objective of this study is to contribute to the understanding of the role of ICT on corruption in 15 ECOWAS economies using panel data for the period 2003-2019, by analyzing factors impacting the digital divide and assessing the impact of internet adoption

on corruption reduction. For achieving this objective, two questions are addressed: first, what are the important determinants that significantly impact the digital divide in the ECOWAS? Second, does ICT affect corruption in these countries? This study contributes to the existing literature in two major ways: First, studies have concentrated on European, Asiatic, Latin American, and, sub-Saharan African countries, this study will therefore extend the results on the corruption-ICT nexus to the developing setting, especially ECOWAS that is prone to a high level of corruption. Second, previous studies had studied corruption-ICT without including determinants of the digital divide, this study assesses the impact of ICT on corruption reduction along with determinants of the digital divide. In this perspective, this research fills this gap by re-investigating which drivers of the digital divide impact e-government in the ECOWAS by integrating macroeconomic factors. In addition, this study explores the impact of ICT on corruption reduction in ECOWAS.

Despite the existence of several studies about the corruption-ICT nexus in Africa, there is a dearth of studies covering regional economic communities (RECs). So, it is crucial to focus on studies targeting regions such as ECOWAS, AMU, EAC, SADC, and so on.

This paper is organized as follows: Section 2 reviews related literature review. Section 3 reveals data and the empirical model. Section 4 presents results and discussions and Section 5 concludes with some policy implications.

2. LITERATURE REVIEW

2.1 Digital Divide and ICT

According to UNESCO[2]: "Digital divide refers to the distinction between those who have internet access and can make use of new services offered on the World Wide Web, and those who are excluded from these services". In the same way, the Organization for Economic Co-operation and Development (OECD) provides a more detailed definition of the digital divide: "The gap between individuals, households, businesses, and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities" (Van Panhuys *et al.*, 1968).

Despite the rapid evolution and the strong trend in digital indicators in the world, Africa is marginalized in terms of digital penetration and it has a higher digital divide around the globe. The majority of people who don't have access to digital channels such as the Internet, mobile telephony, and fixed phone are located in the African continent (Mignamissi & Djijo T, 2021). This is mainly explained by a lack of telecom infrastructure (Mutula, 2008; International Telecommunication Union, 2020).

Researchers exploring the digital divide by using different approaches and many dimensions have found that gender, age, education, income, location, population density, government effectiveness, political stability, and rule of law are the main causes of the digital divide (Table no. 1). Older, less educated, and poor people have would have more difficulties in access to digital channels than younger, educated, and rich people (van Deursen *et al.*, 2015; Botrić & Božić, 2021; Myovella *et al.*, 2021). Furthermore, a recent study conducted by Lembani *et al.* (2020), sheds light that students who lived in rural areas have more difficulties in open-distance learning than those who live in urban areas due to the problem of access to digital technologies. This is justified by the concentration of internet service providers in

urban areas and by the availability of public internet access in these areas than the rural areas (Okunola *et al.*, 2017). Yet other researchers, have pointed out that the digital divide is a consequence of a lack of the skills to use technology, called: digital skills (Gounopoulos *et al.*, 2020; Niyigena *et al.*, 2020; Maji & Laha, 2022). Moreover, other strands of literature have revealed other variables such as the cost of the internet, access to electricity, ethnicity, societal openness, civilian liberties, political rights governance, and R&D expenditure that explain the digital disparities (Chinn & Fairlie, 2006; J. B. Pick *et al.*, 2015; Krishnan *et al.*, 2017; Ma, 2018; Szeles, 2018; J. Pick *et al.*, 2021). According to Song *et al.* (2020), there are three levels of the digital divide: the first level is about ICT access, and it is measured by: computer penetration, mobile phone penetration, and internet access price. The second level is ICT use, which is measured by "Internet users per capita", broadband subscribers per capita, and time online. The third level is linked to ICT outcomes, it is measured by the E-commerce economy, online shopping benefits, online learning outcomes, and E-government. Concerning this study, the second level is adopted and consequently, the digital divide will be measured by the "Internet users per capita" indicator (Milner, 2006; F. Zhao *et al.*, 2014; Elena-Bucea *et al.*, 2021; Myovella *et al.*, 2021).

Table no. 1 - Some selected Studies that support the chosen determinants of the digital divide

Variables	Studies
GDP per capita	Bagchi (2005); Dasgupta *et al.* (2005); Chinn and Fairlie (2006); F. Zhao *et al.* (2014); Weiss *et al.* (2015); Nishijima *et al.* (2017); Pérez-Morote *et al.* (2020); Myovella *et al.* (2021)
Human capital index	Adam (2020); Pérez-Morote *et al.* (2020); Maji and Laha (2022)
Population age	Chinn and Fairlie (2006); F. Zhao *et al.* (2014); Nishijima *et al.* (2017); Pérez-Morote *et al.* (2020)
Rural population	Chinn and Fairlie (2006); Milner (2006); Nishijima *et al.* (2017); Pérez-Morote *et al.* (2020)
Population density	Nishijima *et al.* (2017); Botrić and Božić (2021)
Government effectiveness	Dasgupta *et al.* (2005); Wijers (2010); F. Zhao *et al.* (2014)
Political stability	Dasgupta *et al.* (2005); Wijers (2010); Adam (2020); Myovella *et al.* (2021)
Rule of law	Dasgupta *et al.* (2005); Chinn and Fairlie (2006); Wijers (2010); Weiss *et al.* (2015); J. Wang *et al.* (2019)

To sum up, studies about the digital divide have focused mainly on two categories of disparities: the domestic digital divide and the international digital divide (Maji & Laha, 2022). The domestic digital divide is about disparities at the micro-level (individual, state, district, and city), and the international digital divide is related to disparities among countries. This research fits with this second category, in the context of the ECOWAS for the reason that there is scanty literature on unearthing the role of socio-economic factors (along with other important factors) to explain the digital divide in this region.

2.2 ICT and corruption

As previously indicated, it is imperative to explore the underlying positive implications of ICT in the context of ECOWAS, particularly considering the disparities at the corruption level across the member nations. The literature on ICT and corruption draws a direct

association between various determinants such as economic, political, technological, societal, and cultural factors, amongst others. In this regard, the present section reviews ICT and the issues associated with corruption from a macroeconomic perspective. Empirical studies find both direct and indirect impacts of e-government on corruption reduction (Table no. 2). For instance, a study conducted by Adam (2020) investigated whether e-government facilities would alleviate corruption through the mediating role of ICT and institutional quality. The author used secondary data from various sources. The result shows that ICT and institutional quality play the role of mediators between e-government and corruption. Yet, the direct effect of ICT on corruption has not been found. Another study based on data from 133 countries by L. Wang *et al.* (2022) also proves a non-linear relationship between ICT and corruption. But, the ICT infrastructure moderates this relationship. Similarly, Park and Kim (2020) by using longitudinal data from 2003 to 2016 across 214 countries, found that the rule of law moderates the relationship between ICT and corruption. Focusing on 120 economies over four years, a recent study by Alsaad (2022), has found an indirect effect of ICT on corruption through the variable of the enforcement of the law.

Table no. 2 – Some selected studies that support the chosen variables in the corruption-internet adoption nexus

Variables	Studies
Control of corruption	Lio *et al.* (2011); X. Zhao and Xu (2015); Lee *et al.* (2018); Nam (2018); Androniceanu and Georgescu (2021); Darusalam *et al.* (2021); Ali *et al.* (2022)
Internet users	Lio *et al.* (2011); Lee *et al.* (2018); Darusalam *et al.* (2021); Setor *et al.* (2021)
Voice and accountability	X. Zhao and Xu (2015); Lee *et al.* (2018)
Political stability	X. Zhao and Xu (2015); Androniceanu and Georgescu (2021)
Government effectiveness	X. Zhao and Xu (2015); Nam (2018); Androniceanu and Georgescu (2021); Darusalam *et al.* (2021); Ali *et al.* (2022)
Rule of law	X. Zhao and Xu (2015); Lee *et al.* (2018); Nam (2018)
Human capital index	Lio *et al.* (2011); X. Zhao and Xu (2015); Darusalam *et al.* (2021); Ali *et al.* (2022)
E-participation index	Lee *et al.* (2018); Androniceanu and Georgescu (2021)
GDP per capita	Lio *et al.* (2011); X. Zhao and Xu (2015); Darusalam *et al.* (2021); Setor *et al.* (2021)
Population density	X. Zhao and Xu (2015); Lee *et al.* (2018)
Rural population	X. Zhao and Xu (2015); Adam (2020)

Other strands of literature explored the direct effect of ICT on corruption. In this context, a recent study conducted by Ali *et al.* (2022), provided regional evidence from four South Asian countries spanning the period 2003-2018. The study revealed that ICT has a significant positive impact on corruption reduction, along with press government effectiveness and education. Mouna *et al.* (2020), by investigating the impact of corruption on economic growth for a sample of 149 countries from 2012 to 2016, have found that corruption has a weak impact on economic growth for countries with a high level of technology adoption. Using panel data from 57 countries H. Zhao *et al.* (2021), found a weak and positive impact of e-government development and corruption but this impact changes according to cultural factors. Similarly, a study by Nam (2018), which covered 179 countries, extended the ICT-corruption nexus by

exploring factors that impact the level of corruption control by considering political, economic, and cultural differences. The empirical analysis suggests that cross-country disparities in political, economic, and cultural conditions affect the impact of e-government on corruption. Focusing on the ASEAN countries from 1984 to 2016, Darusalam *et al*. (2021) investigated whether ICT development influences the control of corruption. Results show that ICT alone cannot reduce corruption but it needs to be complemented by institutional measures and education. Another study by X. Zhao and Xu (2015), made similar research by examining whether e-government reduces corruption across 80 countries from 2003 to 2010. The findings reveal that a low level of corruption is correlated with e-government development as well as other factors such as government effectiveness, gender ratio, and government size. Androniceanu and Georgescu (2021) studied the relationship between e-government and corruption covering 27 European countries for the period 2010-2019. The result reveals that countries with a high level of ICT implementation have a low level of corruption. In light of the above studies, it is clearly expressed that ICT along with other factors reduces corruption.

This research adds some evidence to the literature in the context of ECOWAS by examining the theoretical links, and whether factors that drive internet adoption will contribute to reducing corruption.

3. DATA AND EMPIRICAL MODEL

Based on the literature review, this section presents an econometric model to examine the determinants of the digital divide, and the impact of internet adoption on the alleviation of corruption in ECOWAS.

3.1 Empirical model and estimation technique

For answering the main research questions in this paper, three regression techniques were run (Fixed-Effects, Random Effects, and Double Least Squares). First, is the test of factors impacting the digital divide in ECOWAS. “Internet users per capita” was used as a measurement of the digital divide. After testing the factors of the digital divide, the assessment of the impact of internet adoption in reducing corruption is performed. Internet adoption was also measured by “Internet users per capita” indicators. For the analysis, we used the statistical software STATA version 17.

Based on the multicollinearity test[3] (Table no. 4), two models are employed for modelling the determinants of the digital divide and the relationship between internet adoption and corruption. Due to the endogeneity problem of the OLS method, two techniques of estimation (Fixed effects and random effects). According to the literature, the fixed effects regression is chosen for two reasons: first, it is considered the ultimate way of analyzing countries with different data levels and time-series variation. Second, the fixed effect regression can improve the bias emerging from unobserved heterogeneity (Myovella *et al.*, 2021). The random-effects regression supposes exogeneity of independent variables, but the errors of independent variables may be correlated.

Concerning the econometric analysis, the fixed effect is selected, based on the Hausman specification test. If the p-value is less than 0.05, the null hypothesis is rejected and the fixed effect technique is needed for the analysis. However and according to Arellano and Bond (1991), the random effects and the fixed effects regressions are biased due to autocorrelation and

heteroscedasticity problems. In this perspective, and to avoid any potential problem of endogeneity in the results, the literature suggests the use of the instrumental variable method in particular the Fully Modified Ordinary Least Squares (FMOLS) and Generalized Moments Method (GMM) of Blundell and Bond (1998). However, GMM is recommended when the number of individuals is greater than the number of periods. In our case, the number of periods is high than the number of individuals, consequently, the FMOLS is employed as a robustness test.

The FMOLS allowed us to correct for heteroscedasticity, and endogeneity bias and, above all, to check whether the results are still valid when the regression techniques are changed (Yang *et al.*, 2017).

Based on the literature review the construction of the econometric model is presented below. For determining the crucial factors that influence the digital divide in ECOWAS, the following econometric model is employed:

$$lnINU_{it} = \alpha_0 + \beta_1 lnGDPC_{it} + \beta_2 lnHCI_{it} + \beta_3 lnPOA_{it} + \beta_4 lnRUP_{it} + \beta_5 lnPOD_{it} + \beta_6 VOA_{it} + \beta_7 GOE_{it} + \beta_8 POS_{it} + \beta_9 RUL_{it} + \alpha_i + e_{it}. \quad (1)$$

where lnINU = log of internet users, lnGDPC = log of per capita real GDP, lnHCI = log of human capital index, lnPOA = log of total population, lnRUP = log of rural population, lnPOD = log of population density, lnGEN = log of gender ratio, VOA= Voice and accountability, GOE = government effectiveness ,POS =political stability and absence of violence, RUL= rule of law, i = 1,2,3,… 255 country, t = 1,2,3,… 15 time period, α_i = the unobserved effects for i^{th} country observation, and e_{it}= the idiosyncratic error term for i^{th} country on the t^{th} year. We except that: per capita income, human capital index, population size, population density, gender ratio, voice and accountability, government effectiveness, political stability, and rule of law are positively associated with internet users, whereas the rural population is expected to have a negative relationship with internet users.

To analyze the impact of internet adoption on corruption in ECOWAS, the following econometric model is specified:

$$COR_{it} = \alpha_0 + ln\beta_1 lnINU_{it} + \beta_2 VOA_{it} + \beta_3 POS_{it} + \beta_4 GOE_{it} + \beta_5 RUL_{it} + \beta_6 lnHCI_{it} + \beta_7 lnEPI_{it} + \beta_8 lnGDPC_{it} + \beta_8 lnPOD_{it} + \beta_9 lnPOA_{it} + \beta_{10} lnRUP_{it} + \alpha_i + e_{it} \quad (2)$$

where COR = control of corruption, lnEPI = log of E-participation index, and the other specifications are similar to the econometric model (1). Here, internet users is expected to be positively associated with control of corruption because higher access to internet services helps the government to share information and to deliver better services to citizens and businesses. The other specifications are expected to have a positive relationship with the control of corruption to the above equations. Except for the rural population which is expected to have a negative impact on the control of corruption.

3.2 Data and variables

This research aims to investigate the relationship between E-government and Corruption. For this purpose, the empirical analysis uses a cross-sectional and longitudinal study on data spanning the period 2003–2019, collected for 15 ECOWAS member states[4]. By using the linear interpolation technique for dealing with missing data, these data become a

balanced panel since the countries in the sample have the same number of time-series observations. The values of both the dependent and independent variables were sourced from secondary sources. The variables selected for this study were selected based on previous studies and the availability of data. Table no. 3 shows the variables used in this empirical section, as well as their measurements and sources.

Table no. 3 – Variables, measurement, and data source

Variables	Measurement	Data source
E-participation Index (EPI)	It is focused on the use of online services to facilitate the provision of information by governments to citizens.	UN E-government knowledge-base
Human Capital Index (HCI)	It consists of four components: (i) adult literacy rate; (ii) the combined primary; secondary and tertiary gross enrolment ratio; (iii) expected years of schooling; and (iv) average years of schooling	
GDP per capita (GDPC)	It is gross domestic product divided by midyear population. Data are in current U.S. dollars.	World Development Indicators
Population Age (POA)	The total population between the ages of 15 to 64 is a percentage of the total population.	
Rural Population (RUP)	It refers to people living in rural areas. It is calculated as the difference between the total population and the urban population.	
Rule of Law (RUL)	It reflects the extent to which agents have abided by the rules of society (estimate ranges from − 2.5 (weak) to 2.5 (strong))	
Political stability and absence of violence (POS)	It measures perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism (estimate ranges from − 2.5 (weak) to 2.5 (strong))	
Voice and Accountability (VOA)	Perceptions of the extent to which a country's citizens can participate in selecting their government (estimate ranges from − 2.5 (weak) to 2.5 (strong))	
Internet Users (INU)	They are individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, or digital TV.	
Control of Corruption (COR)	it captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption (estimate ranges from − 2.5 (high level of corruption) to 2.5 (low level of corruption))	
Population Density (POD)	It is a midyear population divided by land area in square kilometers.	
Government Effectiveness GOE	Perceptions of the quality of public services, and the degree of its independence from political pressures (estimate ranges from − 2.5 (weak) to 2.5 (strong))	

Table no. 4 – Multicollinearity test

	EPI	HCI	GDPC	POA	RUP	RUL	POS	VOA	INU	COR	POD	GOE
EPI	1.000											
HCI	-0.037	1.000										
GDPC	0.443***	0.426***	1.000									
POA	0.334***	0.687***	0..603***	1.000								
RUP	-0.236***	-0.661***	-0.639***	-0.775***	1.000							
RUL	0.273***	0.174***	0.464***	0.422***	-0.402***	1.000						
POS	0.117	0.328***	0.498***	0.378***	-0.362***	0.452***	1.000					
VOA	0.339***	0.150**	0.467***	0.478***	-0.343***	0.813***	0.504***	1.000				
INU	0.664***	0.173***	0.728***	0.510***	-0.604***	0.347***	0.209*	0.309***	1.000			
COR	0.298***	0.196***	0.505***	0.516***	-0.448***	0.907***	0.552***	0.783***	0.360***	1.000		
POD	0.198***	0.622***	0.483***	0.626***	-0.643***	0.146**	0.031	0.024	0.492***	0.158**	1.000	
GOE	0.239***	0.148**	0.535***	0.366***	-0.370***	0.882***	0.316***	0.742***	0.308***	0.852***	0.161***	1.00

Notes: ***, **, and * refer to significance at 1%, 5% and 10%, respectively.
Source: author compilation

4. RESULTS AND DISCUSSION

This section shows the empirical finding and discussions. First, it presents the results on the crucial factors that impact the digital divide in ECOWAS. Second, it reports the results on the influence of internet adoption on corruption reduction.

Table no. 5 presents the descriptive statistics of the data used for the econometric models. From this table, we can notice that the standard deviation compared to the mean is high for corruption, internet users, political stability, and voice and accountability variables. This indicates that it is inequality among ECOWAS at the level of corruption, internet adoption, political stability, and accountability. For other variables, we can observe that there is no disparity because the standard deviation is less than their mean values.

Table no. 5 – Descriptive statistics

	Obs.	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
EPI	255	0.14	0.14	0	0.63	1.32	4.05
HCI	255	0.38	0.15	0	0.78	0.17	2.92
GDPC	255	1050.88	788.50	243.08	3740.37	1.77	5.61
POA	255	53.55	3.46	47.18	66.89	1.29	6.42
RUP	255	58.13	11.39	33.80	83.79	0.40	3.15
RUL	255	-0.65	0.52	-1.64	0.65	0.43	2.75
POS	255	-0.53	0.79	-2.40	1.03	-0.43	2.47
VOA	255	-0.31	0.59	-1.46	0.979	0.20	2.42
INU	255	10.55	12.85	0.03	61.94	1.74	5.67
COR	255	-0.61	0.52	-1.55	0.95	1.12	4.44
POD	255	83.98	52.40	9.82	231.98	0.72	2.98
GOE	255	-0.79	0.45	-1.760	0.353	0.400	2.484

Source: author compilation

The Pesaran LM test reveals the presence of cross-sectional dependency, as the null hypothesis for all variables is rejected at the 1% level of significance (Table no. 6).

Table no. 6 – Cross-sectional dependence

	Pesaran LM
EPI	73.69***
HCI	48.62***
GDPC	72.40***
POA	74.08***
RUP	105.45***
RUL	19.48***
POS	19.43***
VOA	23.56***
INU	100.03***
COR	15.56***
POD	115.55***
GOE	8.16***

Source: author compilation

Moreover, the results reveal that variables HCI, RUL, POS, VOA, and GOE are stationary at a level. When the first difference is added, all the variables become stationary (Table no. 7). Hence, all the variables are incorporated in order I(1).

Table no. 7 – Panel unit root test Im, Pesaran, and Shin (CIPS)

Variables	Level		First difference		Order of integration
	Constant	Constant and trend	Constant	Constant and trend	
EPI	3.71	-1.74**	-7.13***	-4.49***	I (1)
HCI	-3.61***	-2.13**	-	-	I (0)
GDPC	-0.78	1.09	-9.11***	-6.99***	I (1)
POA	5.73	4.94	1.21	-3.06***	I (1)
RUP	13.39	7.97	-9.01	-6.06***	I (1)
RUL	-3.54***	-2.87***	-	-	I (0)
POS	-3.00***	-2.15***	-	-	I (0)
VOA	-1.25	-3.95***	-	-	I (0)
INU	26.05	17.04	4.52	-2.61***	I (1)
COR	-1.86**	-1.02	-8.65***	-6.24***	I (1)
POD	15.71	2.25	-4.16***	-11.78***	I (1)
GOE	-2.66***	-3.15***	-	-	I (0)

Notes: ***, **, and * refer to significance at 1%, 5% and 10%, respectively.
Source: author compilation

The results of the Kao (1999) cointegration test, which is conducted to test the association among the variables in the long run. The test has a null hypothesis of no cointegration. The results indicate that the null hypothesis is rejected at the 1% and 5% level of significance, revealing the long-run relationship among the variables for the four models of this study (Table no. 8).

Table no. 8 – Kao cointegration test

Models	**1**	**2**	**3**	**4**
T-statistic	-4.081***	-3.913***	-2.146**	-2.097**

Notes: ***, **, and * refer to significance at 1%, 5% and 10%, respectively.
Source: author compilation

4.1 Results on the determinants of the digital divide

The two models tested by fixed effect and FMOLS regressions indicate that per capita income, human capital, age, population density, government effectiveness, political stability, and the rule of law are the determinants of the digital divide in ECOWAS (Table no. 9). Per capita income has a significant and positive impact on internet use. This implies that high income allows people to have internet access. The impact is between 0.66% and 0.54%. This means that when per capita income grows by 1% enlarges users of the internet between 0.66% and 0.54%. This result is consistent with Botrić and Božić (2021); Myovella *et al.* (2021).

Table no. 9 – Determinants of the digital divide

Dependent variable: lnINU	FE		RE		FMOLS	
Independent variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
lnGDPC	0.663***	0.540***	1.460***	1.387***	0.803***	0.641***
lnHCI	-0.387***	-0.373***	-1.900***	-1.977***	-0.422**	-0.350*
lnPOA	9.542***	9.625***	4.875***	5.441***	11.766***	12.038***
lnRUP	2.011	1.804	-3.510	-3.688	2.711	2.860
lnPOD	6.961***	6.893***	0.863***	0.857***	6.712***	6.969***
VOA	0.151	-	0.506	-	-0.109	-
GOE	-0.200	-	-0.778***	-	-0.382	-
POS	0.062	-0.075***	-0.202***	-0.271**	0.075	-0.085
RUL	-	0.686***	-	0.318	-	0.651**
Cons	-78.305***	-76.607***	-19.643*	-20.102*	-	-
R-squared	0.910	0.915	0.818	0.816	0.937	0.939
No. of obs.	250	250	250	250	236	236
No. of groups	15	15	15	15	15	15
Prob.>F	0.000	0.000	0.000	0.000	-	-
Hausman test	441.97	289.96	-	-	-	-
Prob (Hausman test)	0.000	0.000	-	-	-	-

Notes: ***, **, and * refer to significance at 1%, 5%, and 10%, respectively.
Source: author compilation

Another finding is that the human capital index shows a significant negative impact on internet adoption, although the expected sign was positive. It can be explained by the low qualification of human capital in this region. This finding is not consistent with van Deursen *et al.* (2015); Botrić and Božić (2021); Myovella *et al.* (2021). Population age is another determinant of internet adoption. The influence of this variable is significant and positive. The coefficient is between 9.54% and 9.62%. This suggests that a rise of 1% in this population segment leads to expand the number of internet users between 9.54% and 9.62%. This enhances the argument that younger people use more internet than others. This result is similar to Elena-Bucea *et al.* (2021).

Population density is another factor that affects the digital divide in ECOWAS. The estimate shows a significant and positive impact on users of the internet. The interpretation is that people in dense areas use more internet services to save time commuting. this finding is similar to Botrić and Božić (2021). Government effectiveness and political stability are important to explain the digital divide. It is widely proven that the quality of government

policy, political stability, and no violence play a crucial role in the development of the internet across the world. However, our estimates indicate a negative effect of government effectiveness and political stability on internet adoption in ECOWAS. This suggests that internet users is affected by the low level of institutional quality and political stability in this region. The possible explanation is because of politicians who have a short-term vision, and focus their effort on investment with a rapid impact to win another mandate. While investment in telecom infrastructures needs huge budgets and their impact is not clear in the short term. This result is consistent with Myovella *et al.* (2021).

The impact of Rule of law is significant and positive on internet adoption. This shows that an increase of 1% affects the number of internet users by 0.68%. This implies that there is an improvement in the application of law equally to citizens and legal transparency. The possible explanation is that countries with high rule of law index are more interested in the digitalization of the justice system and people are using internet services to be engaged in this judicial system.

For the rural population, voice and accountability variables their impact on internet users is not significant statistically. The estimates following the FE are in contradiction with the FMOLS estimates.

4.2 Results on the impact of internet adoption on corruption

Table no. 10 presents the findings of the cross-section panel data models. Based on the Hausman test, model 1 is compiled with the fixed effect method while model 2 follows the random effect compilation. For the robustness check, we use the FMOLS method for avoiding the endogeneity problem of the FE and RE methods. The coefficient of internet users is significant and positive in both models. Hence, an enlargement in internet users in ECOWAS leads to a higher perception of corruption control. This suggests that an increase of 1% in internet users increases control of corruption by 0.05% and 0.06%. This weak impact is an indication of the poor level of telecom infrastructure and factors of the digital divide in ECOWAS countries. This finding is in line with the findings of Lio *et al.* (2011); X. Zhao and Xu (2015); Lee *et al.* (2018); Nam (2018); Androniceanu and Georgescu (2021); Darusalam *et al.* (2021); Setor *et al.* (2021); Ali *et al.* (2022). This result is robust with the FMOLS estimates.

The coefficient of voice and accountability is positively signed and achieves statistical significance at the 1% level. Invariably, a higher level of freedom of expression and involvement of citizens in governmental decisions leads to a high level of corruption control. An increase of 1% in voice and accountability stimulates corruption control by 0.22%. The estimate of government effectiveness has a positive sign and is significant at the 1% level. Thus, a higher perception of the quality of public services, as well as the degree of its independence from political pressures contributes significantly to increasing the perception of corruption control. A 1% rise in government effectiveness enhances corruption control by 0.48% and 0.53%. Rule of law shows a positive and significant impact on controlling corruption. This suggests that the intensification of law enforcement and the enhancement of the legal system increase the perception of corruption control. These findings are similar to X. Zhao and Xu (2015); Nam (2018); Androniceanu and Georgescu (2021); Darusalam *et al.* (2021); Ali *et al.* (2022). These results are robust with the FMOLS estimates.

Human capital is another variable that alleviates the level of corruption in the ECOWAS. The estimate is significant at 10% and it indicates that a rise of 1% in this index leads to an improvement in the control of corruption by 0.09%. This indicates that the educated public

can detect the violation of law and unethical practices, for this reason, education can be a powerful tool for tackling corruption in this region. This finding is consistent with Lio *et al.* (2011); X. Zhao and Xu (2015); Darusalam *et al.* (2021); Ali *et al.* (2022). For the robustness check, the FMOLS estimator shows also a positive and significant impact.

Other control variables such as political stability, E-participation index, per capita income, population density, and rural population are not significant statistically and the estimates are not robust with the FMOLS regression. Consequently, they are not impacting corruption in this study.

Table no. 10 – Impact of internet adoption on corruption

Dependent variable: COR	FE		RE		FMOLS	
Independent variables	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4
lnINU	0.058***	0.078***	0.054**	0.061***	0.052*	0.087***
VOA		0.229***	-	0.227***	-	0.319***
POS	-0.016	-0.018	-0.017	-0.004	-0.018	-0.002
GOE	0.481***	0.503***	0.482***	0.539***	0.401***	0.443***
RUL	0.315***	-	0.359***	-	0.468***	-
lnHCI	0.064	0.083	0.056	0.092*	-0.136**	0.179***
lnEPI	-0.012	-0.021	-0.010	-0.025*	-0.031	-0.036
lnGDPC	-0.061	-0.031	-0.058	-0.033	-0.131	-0.080
lnPOD	-0.010	-0.206	0.068	-0.062	0.333	0.126
lnRUP	-0.206	-0.029	-0.363	-0.107	0.654	0.404
Constant	1.203	0.639	2.096*	0.650	-	-
R-squared	0.522	0.521	0.520	0.519	0.961	0.961
No. of obs.	225	225	225	225	194	194
No. of groups	15	15	15	15	15	15
Prob.>F	0.000	0.000	0.000	0.000	0.000	0.000
Hausman test	385.10	-	-	7.53	-	-
Prob (Hausman test)	0.000	-	-	0.674	-	-

Notes: ***, **, and * refer to significance at 1%, 5%, and 10%, respectively.
Source: author compilation

5. CONCLUSIONS

The core aim of this study is to reinvestigate the role of ICT on corruption in 15 ECOWAS economies using panel data for the period 2003-2019, by analyzing factors impacting the digital divide and assessing the impact of internet adoption on corruption reduction. To answer some key questions regarding the role of ICT, the factors that significantly affect internet adoption were examined. Empirical results confirm the importance of per capita income, human capital, age, population density, government effectiveness, political stability, and rule of law affecting the digital divide in ECOWAS. Then the test of the impact of internet adoption on corruption for ECOWAS was performed. The results indicate a significant and positive impact of internet adoption on corruption reduction.

Based on the findings, this study suggests the following thoughts for policy consideration. First, economic factors, demographic factors, and institutional factors are determinants of the digital divide. Countries with a high-income per capita income, the

youngest population, population density, political stability, and rule of law tend to have more access to internet services, while those with low human capital index, government effectiveness, and political stability have lower access to internet services. For these countries, a good educational system, political stability, governance, and the quality of institutions lead to reducing the digital divide by providing more access for people to internet services.

Finally, the results show evidence of a positive impact of the internet on corruption alleviation. In this regard, ECOWAS's policymakers should enlarge internet access and ICT infrastructure to further accelerate corruption reduction. ICT infrastructures in ECOWAS contribute to make easier the availability of the Internet for the whole population and consequently improve their efforts to tackle all types of corruption. However, investing in ICT infrastructure is not enough, ECOWAS leaders should have political well by enhancing education and investing in institutions.

The limit of this study is related to the selection of one variable as a measure of internet adoption, future studies are invited to employ other measures such as social media users or the E-government index as a measure of ICT in this region. Moreover, for future research, a comparative and country-specific study among ECOWAS is needed to investigate the determinants of the digital divide and corruption-ICT nexus. Future studies can also investigate the impact of ICT infrastructures on corruption.

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Notes

[1] Since 2012, Senegal and Ivory Coast have made a significant improvement.

[2]https://unevoc.unesco.org/home/TVETipedia+Glossary/filt=all/id=704 (accessed: 16/10/2021)

[3]Correlations of above 0.8 or 0.9 are often interpreted as excessively collinear (Franke, 2010)

[4]ECOWAS are an area of more than 5 million km^2 and, they are a home of 349 million people whose major languages are English, French, and Portuguese with a GDP per capita (current international dollar) of $4618. They include :Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.