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Impact of Information and Communication Technology on Economic Growth: Evidence from Developing Countries

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Abstract: The present study aims to evaluate the impact of information and communication technology (ICT) on the economic growth of selected developing countries in the Middle East and North Africa (MENA) region and the Sub-Saharan Africa (SSA) region by using a panel Generalized Method of Moment (GMM) growth model over the period 2007–2016. The results extracted from the econometric model show that except fixed telephone, other information and communication technologies such as mobile phone, Internet usage, and broadband adoption are the main drivers of economic growth in MENA and SSA developing countries over the recent period 2007–2016. In addition, our findings confirm the superiority of MENA countries over SSA countries in the areas of Internet usage and broadband adoption. From a policy perspective, the results suggest that authorities in MENA and SSA countries should increase investments in ICT infrastructure. To benefit from the ICT drivers of economic growth, policymakers should enact several important policies that permit the development of financial sectors, provide a more convenient regulatory and institutional environment, increase economy openness, prioritize the allocation of resources to the development of ICT infrastructure, and contain the negative effects of inflation and government consumption.

Keywords: economic growth; ICT; developing countries; MENA; SSA; panel GMM

JEL Classification: C33; O30; O47

1. Introduction

Over the last decades, the great diffusion of information and communication technology (ICT) has caused a dramatic transformation of the world into an information society. Thanks to ICT infrastructure such as fixed-line telephones, mobile phones, Internet, and broadband, people, firms, and governments now have much better access to information, knowledge, and wisdom than before in terms of scale, scope, and speed. ICT diffusion has substantially improved the efficiency of resources allocation, enormously reduced production costs, and promoted much greater demand and investment in all economic sectors (Jorgenson and Stiroh 1999; Vu 2011; Lee et al. 2012; Grimes et al. 2012; Pradhan et al. 2015).

Regarding the growing importance of ICT and the way it is transforming the world, many academicians and researchers have focused on studying the impact of ICT on economic growth at the industry level, at the national level, and at the cross-country level. Several theoretical and empirical works have been conducted to answer the following question: what is ICT's impact on economic growth?

The literature shows that many theories recognize that ICT plays an increasingly key role in speeding up economic growth, but empirical studies on this relationship have produced mixed

results (Vu 2011; Sassi and Goaied 2013). While a number of empirical studies confirmed that ICT diffusion plays a positive and significant role in improving economic growth, especially in developed countries (Roller and Waverman 2001; Inklaar et al. 2005; Koutroumpis 2009), other studies found that economic growth in many countries and regions of the world is negatively affected by ICT diffusion (Dewan and Kraemer 2000; Pohjola 2002; Papaioannou and Dimelis 2007; Yousefi 2011; Pradhan et al. 2015; etc.).

Focusing on developing countries, many previous studies have conducted empirical works employing different econometric models and using cross-country data to understand the relationship between ICT diffusion and economic growth (Nasab and Aghaei 2009; Andrianaivo and Kpodar 2011; Sassi and Goaied 2013; Pradhan et al. 2015, 2018; Aghaei and Rezagholizadeh 2017). These studies produced ambiguous results, and there was a great disagreement between researchers about the question of a strong growth-enhancing effect of ICT diffusion in the context of developing countries. Therefore, this issue is still open to investigation.

Among developing countries under investigation, some recent studies showed a particular interest in studying the effect of ICT diffusion on the economic growth of developing countries in the Middle East and North Africa (MENA) region (Hassan 2005; Sassi and Goaied 2013) and the Sub-Saharan Africa (SSA) region (Andrianaivo and Kpodar 2011; Lee et al. 2012; Wamboye et al. 2015; Albiman and Sulong 2016). This interest has developed due to the fact that in recent years most MENA and SSA countries have experienced a dramatic surge in the usage of ICTs; this is measured by several indicators such as fixed-line telephone and mobile cellular subscriptions, number of Internet users, and number of broadband subscriptions (World Bank 2017; International Telecommunications Union 2017). In addition, a literature review shows that compared to developed and Asian countries, research on ICT in MENA and SSA regions is still in its infancy stage and needs further exploration and discussions to produce a clear idea on the effect of ICT diffusion on economic growth in these regions.

Given this, the purpose of this paper is to investigate the effect of ICT diffusion on the economic growth of 45 developing countries in the MENA and SSA regions by employing a two-stage panel Generalized Method of Moment (GMM) growth model over the period 2007–2016. The remainder of this paper is organized as follows: Section 2 presents a brief literature review of the subject. Section 3 describes the methodology applied to the MENA and SSA countries. Section 4 reports and discusses the results found. Section 5 concludes and provides policy implications and recommendations.

2. Literature Review

The worldwide rapid progress of ICT in the last three decades has attracted increasing attention among many economists and researchers who have focused on studying the impact of ICT diffusion on the economic growth of developed and developing economies.

Prominent contemporary theories such as neo-Schumpeterian theories (Schumpeter 1934; Pyka and Andersen 2012) and neoclassical growth theory (Solow 1956) have highlighted the existence of a significant positive relationship between ICT and economic growth. These theories suggest that ICT enters as an input into the economic supply in the form of capital and causes the improvement of the production process through deepening capital and making advancements in technology and labor force quality. As a result, ICT creates added value at the firm level and at the sectoral level and therefore leads to the improvement of productivity and economic growth at the country level (Quah 2002; Aghaei and Rezagholizadeh 2017).

While theoretical works have shown a positive effect of ICT on economic growth, several empirical studies on this relationship have produced mixed results. On the one hand, numerous studies have confirmed the presence of a significant positive impact of ICT diffusion on economic growth. Early cross-country studies focused on the effect of telecommunication technologies such as fixed-line telephones on economic growth in developed countries. Hardy (1980), using data on 60 countries over the period 1968–1976; Roller and Waverman (2001), using data on

21 OECD (Organisation for Economic Co-operation and Development) countries over a 20-year period (1970–1990); and Madden and Savage (1998), examining a sample of 27 Central and Eastern European countries during the period 1990–1995, among others, revealed a strong positive relationship between telecommunication infrastructure investments and economic growth. Some recent studies have confirmed the strong contribution of newer telecommunication technologies such as mobile phones, personal computers, and the Internet to the economic growth of many countries around the world, especially developed countries. (Inklaar et al. 2005; Koutroumpis 2009; Gruber and Koutroumpis 2010; Vu 2011).

Among the cross-country studies that have focused on developing countries, an increasing number of empirical works have argued that ICT diffusion and investment positively and significantly affects economic growth in these countries. Using a wide range of ICT indicators, including mobile phone and fixed telephone penetration rates and the cost of local calls, Andrianaivo and Kpodar (2011) confirmed that ICT contributed significantly to the economic growth of African countries over the period 1988–2007.

Similarly, Lee et al. (2012) examined the relationship between economic growth and telecommunication infrastructure investments such as land line telephony and mobile phones in the SSA region. They applied a linear GMM estimator on data from 44 Sub-Saharan countries over the period 1975–2006. The results confirmed that mobile phone expansion is an important determinant of the rate of economic growth in Sub-Saharan Africa. Focusing on data from a cross section of 17 MENA countries, Sassi and Goaied (2013) found a positive and statistically significant impact of ICT diffusion measured by three indicators, namely, mobile phone, fixed-line telephone, and Internet, on economic growth between 1960 and 2009. Using panel cointegration techniques, Pradhan et al. (2015) investigated the nature of causal relationships between ICT infrastructure, financial development, and economic growth in 21 Asian countries over the period 2001–2012. They concluded that both ICT infrastructure and financial development matter in the determination of the long-run economic growth of Asian countries.

By applying dynamic and static panel data approaches within a framework of a growth model, Aghaei and Rezagholizadeh (2017) found that every 1 percent increase in ICT investment led to 0.52 percent economic growth in the Organization of Islamic Cooperation (OIC) countries over the time period of 1990–2014. Pradhan et al. (2018) applied panel cointegration approaches and the Granger causality test to determine the nature and direction of causal relationships existing between ICT infrastructure (both broadband and Internet users) and economic growth. They used data from G-20 countries over the period 2001–2012, and they considered some important control variables that could affect economic growth, such as consumer price index, labor force participation rate, and gross domestic fixed capital formation. The estimation analyses reveal a positive association between ICT infrastructure (both broadband and Internet) and economic growth. Following these authors, particular attention should be paid to broadband adoption and Internet users in order to enhance economic growth in developed countries. Sepehrdoust (2018) conducted an empirical study using a panel generalized method of moment (GMM) growth model to investigate the impact of ICT and financial development on the economic growth of petroleum exporting countries (OPEC) during the period 2002–2015. The results showed that 1 percent increases in the financial development index and ICT variables increased economic growth by 0.048 and 0.050 percent, respectively. These findings are consistent with earlier results found by Nasab and Aghaei (2009) on OPEC countries over the period 1990–2007.

On the other hand, some empirical studies that investigated the relationship between ICT diffusion and economic growth in developing countries have not find conclusive results. Freeman and Soete (1997) and Aghion and Howitt (1998), among others, showed that ICT diffusion could affect economic growth in a negative way, especially in developing countries. They explain this negative relationship by the fact that ICT could negatively affect employment and the labor market through the reduction or elimination of positions for unskilled workers, increasing unemployment.

In addition, ICT facilitates attracting and opening new markets for developed countries at the expense of developing countries. It allows developed countries to raise their domination on the international markets by exploiting their competitive advantage over developing countries which are less competitive.

Dewan and Kraemer (2000) used data from 36 countries over the period of 1985–1993; they found that only developed countries have benefitted from the positive effect of ICT investment on economic growth. They explain this result by the low level of ICT investment and the lack of right environmental conditions such as basic infrastructure, business practices, and appropriate government policies in developing countries.

Pohjola (2002) did not find any statistically significant correlation between ICT investment and economic growth in the case of 43 countries from 1985 to 1999. According to the author, this result is due to the poor accessibility and availability of communications technology and technology-based products in many developing countries. In another study, Lee et al. (2005) found that ICT had a positive impact on economic growth only for newly industrialized countries but not for East Asian developing countries.

Similar results were found by Papaioannou and Dimelis (2007) and Yousefi (2011) using a panel generalized method of moments (GMM) and a fixed effect model for 42 developing and developed countries over the period (1993–2001). They found that ICT investments boost growth only in developed countries. Given this, the authors suggest that developing countries should undertake appropriate measures to benefit from the positive role of ICT in driving economic growth such as liberalizing the trade regime, improving human capital, and adopting favorable government policies. Pradhan et al. (2015) confirmed that neither ICT infrastructure nor financial development plays a significant role in the long-term economic growth of western Asian countries, which includes rich Arab oil producers. This was explained by the great dependence of these economies on oil revenues.

More recently, Albiman and Sulong (2016) examined the long-run impact of ICT on economic growth in the SSA region for a 27-year period (1990–2014). They found that ICT proxies, such as fixed telephone lines, mobile phones, and Internet, have a positive and statistically significant direct linear impact on economic growth. However, when they considered a nonlinear effect analysis, they found that mass penetration of ICT proxies seems to slow economic growth in the SSA region.

3. Methodology

3.1. Model Specification

This study aims to evaluate the impact of ICT diffusion on the economic growth of 45 developing countries in the MENA and SSA regions during the period 2007–2016. To do this, we estimated a standard growth model based on the growth framework for panel data from Barro and Sala-i-Martin (1995) and Barro (1998). In addition, this model was applied by several previous empirical studies such as Vu (2011); Sassi and Goaied (2013); Ward and Zheng (2016); and Albiman and Sulong (2016). The following equation describes the growth model adopted in this study:

$$GDPPC_{it} = \beta_0 + \beta_1 GDPPC_{it-1} + \beta_2 ICT_{it} + \beta_3 Z_{it} + \delta_i + \varepsilon_{it} \quad (1)$$

where i represents each country in the panel and t indicates the time period. $GDPPC_{it}$ refers to the real Gross Domestic Product (GDP) per capita of country i over the period t. Following Barro (1998), we include lagged real GDP per capita ($GDPPC_{it-1}$) in the model in order to capture the convergence effect. β_0 is a constant. β_1 is the coefficient to be estimated in order to assess any potential effect of the lagged real GDP per capita on its current level; it is expected to be statistically significant to verify the dynamic specification of our model. β_2 is the coefficient to be estimated in order to evaluate any significant impact of ICT variables on economic growth in MENA and SSA countries during the study period. β_3 represents the coefficient to be estimated for each control variable Z_{it} Finally, δ_i terms

represent unobserved specific terms for each country in the sample, and the error terms are denoted by ε_{it}.

To estimate the coefficients of the variables introduced in the model in Equation (1) we use the GMM method instead of the traditional panel methods, such as the fixed-effect and the random-effect panel models, because of many reasons. With reference to Arellano and Bond (1991) and Arellano and Bover (1995), using the GMM method can allow us to avoid all the problems of country-specific effects, serial correlation, and endogeneity. Indeed, traditional panel methods can lead to the problem of country-specific effects with a sample of many countries like that used in this study.

Moreover, the growth model adopted in our study (Equation (1)) includes a lagged dependent variable that verifies the dynamic process of this model; that is, the previous real GDP per capita ($GDPPC_{it-1}$) may affect current real GDP per capita. In addition to that, the independent variables used in our model may have the problem of endogeneity, which is difficult to tackle using traditional panel methods.

Furthermore, it is worth mentioning that the method of a GMM estimator can be applied in either a one-step or two-step process (Arellano and Bond 1991). A two-step estimator uses residuals obtained from the first-step estimation to construct a weighted consistent variance–covariance matrix when the assumptions of independence and homoscedasticity to the estimated parameters do not hold. In our study we follow previous examples in the literature that commonly preferred using a two-step GMM estimator instead of a one-step GMM estimator (Andrianaivo and Kpodar 2011; Lee et al. 2012; Wamboye et al. 2015; Albiman and Sulong 2016; etc.).

3.2. Data and Variables

The dataset used in this study was extracted from the World Development Indicators published by the World Bank. The analysis was based on yearly data from a cross section of 45 developing countries. We particularly focus on data from 14 countries in the MENA region and 31 countries in the SSA region over the recent period 2007–2016.

The dependent variable included in the model presented above in Equation (1) is the GDPPC, which is the real Gross Domestic Product per capita used as a proxy for economic growth. As a first explanatory variable, we introduce in this model the lagged real GDP per capita ($GDPPC_{it-1}$) to test for convergence. The second explanatory variable is ICT. Following previous studies (Andrianaivo and Kpodar 2011; Sassi and Goaied 2013; Wamboye et al. 2015; Albiman and Sulong 2016; etc.), we examine the nature of the relationship between ICT and economic growth by including ICT proxies, namely, TEL, which is the number of fixed telephone subscriptions per 100 inhabitants; MOB, which is the number of mobile cellular subscriptions per 100 inhabitants; and INT, which is the number of Internet users per 100 inhabitants. Following recent empirical works, we add a fourth ICT proxy called BBA, which is the number of fixed broadband subscriptions per 100 inhabitants. In fact, it is important to introduce BBA in the estimations because many recent studies have demonstrated that broadband adoption has a profound influence on economic growth, employment, and firm competitiveness. Thus, countries with wide broadband availability have seen higher economic growth and lower unemployment rates (Kolko 2012; Jayakar and Park 2013; Kumar et al. 2015; Pradhan et al. 2018).

A number of control variables were included in the model to control for any significant contribution of these variables to the economic growth of developing countries in the MENA and SSA regions over the period of study. With reference to previous studies in the literature, the control variables included in the empirical estimations are FIND, which is financial development proxied by domestic credit to the private sector; GOV, which is general government final consumption expenditure as a percentage of GDP; TRADE, which is a country's trade volume used as a proxy for the degree of openness of a country's economy; and INVEST, which is domestic investment proxied by gross fixed capital formation. All these values are expressed as a percentage of GDP. In addition, we included inflation rate (INF) as another control variable measured by the consumer price index. It is worth

mentioning also that the independent variable and the explanatory variables were converted into their natural logarithms for use in the econometric analysis.

Table 1 below describes the sample of selected developing countries used in this study. It shows that the list of sample countries consists of 45 developing countries, of which 14 countries are in the MENA region and 31 countries are in the SSA region.

Table 1. List of sample countries.

Middle East and North Africa (MENA) Region	Sub-Saharan Africa SSA Region	
Algeria	Angola	Malawi
Bahrain	Botswana	Madagascar
Egypt, Arab Rep.	Burundi	Mali
Iran, Islamic Rep.	Cameroon	Mozambique
Jordan	Benin	Mauritius
Kuwait	Burkina Faso	Namibia
Morocco	Cabo Verde	Niger
Oman	Chad	Rwanda
Qatar	Cote d'Ivoire	Nigeria
Saudi Arabia	Gambia, The	Senegal
Sudan	Gabon	Seychelles
Tunisia	Ghana	South Africa
Turkey	Kenya	Swaziland
United Arab Emirates	Lesotho	Tanzania
	Liberia	Uganda
		Togo

Note: The number of countries in this sample is conditioned by data availability.

Descriptive statistics for the main sample (ALL) and for the subsamples MENA and SSA are presented in Table 2 below. The number of countries included in our study is similar to that in most previous studies (see Sassi and Goaied 2013; Wamboye et al. 2015; etc.). It is clear from this table that MENA countries have the largest GDPPC mean value, which is evident because this sample includes the six oil-rich Gulf Cooperation Council (GCC) countries and other middle-income countries from Asia and north Africa (World Bank 2017). Table 2 also reveals that standard deviations are higher compared to the mean values, especially in the case of SSA countries. This indicates that the transformations in the levels of GDPPC and ICT variables (INT, BBA, TEL, and MOB) are more important in the SSA region compared to the MENA region over the period of study. This is consistent with the results of earlier studies (see Albiman and Sulong 2016).

Table 2. Descriptive statistics of the regression variables for 2007–2016.

Variable	GDPPC	FIND	INT	BBA	TEL	MOB	GOV	TRADE	INF	INVEST
ALL										
Mean	7175	34.70	23.13	2.44	7.16	82.06	17.35	83.61	7.01	24.20
SD	12887	28.63	23.08	4.16	8.95	44.45	10.18	37.91	6.22	7.50
Min	218	2.40	0.39	0.00	0.06	3.40	4.52	19.10	0.05	8.32
Max	72671	160.13	98.00	22.81	38.34	214.74	88.98	311.36	39.27	46.73
MENA										
Mean	17496	51.76	46.12	5.63	14.43	114.63	15.79	87.38	7.28	25.88
SD	18964	22.11	23.51	4.98	8.75	39.05	4.97	39.20	7.33	6.77
Min	1385	7.14	8.66	0.04	0.31	25.46	4.58	19.10	0.07	12.45
Max	72671	103.77	98.00	22.81	38.34	214.74	30.92	191.88	39.27	46.02
SSA										
Mean	2514	27.00	12.75	0.99	3.88	67.36	18.06	81.91	6.89	23.43
SD	3082	27.92	13.34	2.70	6.88	38.56	11.74	37.26	5.65	7.69
Min	218	2.40	0.39	0.00	0.06	3.40	4.52	20.72	0.05	8.32
Max	13598	160.13	56.52	16.85	31.07	162.28	88.98	311.36	36.97	46.73

Notes: GDPPC is the GDP per capita; FIND is the financial development; INT is the number of Internet users; BBA is the number of fixed broadband subscriptions; TEL is the number of fixed telephone subscriptions; MOB is the number of mobile cellular subscriptions; GOV is the general government final consumption expenditure; TRADE is the country's trade volume; INF is the inflation; INVEST is the domestic investment.

4. Results and Discussion

The present research investigated the effect of ICT diffusion on the economic growth of 45 developing countries in the MENA and SSA regions over the period 2007–2016 by employing a two-step panel GMM growth model (Equation (1)). The results concerning the main sample (ALL) and the two subsamples MENA and SSA are presented in the tables bellow (Tables 3–6). It is worth mentioning that we undertook several statistical tests to check the robustness of all the estimations that resulted from the application of the GMM growth model in this study. Firstly, the variance inflation factor (VIF) was used to detect the presence of multicollinearity problems. In all our estimations (Tables 3–6), weak VIF values (inferior to 2.5) were found, which indicates the absence of any high multicollinearity between the explanatory variables (Montgomery et al. 2001). This finding was also confirmed by running the Pearson correlation test which indicated the inexistence of high correlation between the independent variables introduced in the estimations.

Moreover, the results of the Arellano and Bond (1991) test for first- and second-order serial correlation in the first-differenced errors and the Sargan test of overidentifying restrictions are reported for all the estimations presented in Tables 3–6. We found that the Arellano and Bond (1991) test accepts the null hypothesis that the errors in the first difference regression exhibit no second-order serial correlation AR(2), meaning that there is no evidence of model misspecification. In addition, the Sargan test rejects the null hypothesis that the overidentifying restrictions are valid in our GMM model, which means that the instruments are correctly specified for all our estimations. To confirm this result, we ran the Hansen test of overidentifying restrictions, which indicated that the set of instruments in our model is valid[1].

Table 3. Impact of TEL on economic growth in developing countries over the period 2007–2016.

Variables	ALL	MENA	SSA
$GDPPC_{t-1}$	0.9371 ***	0.0424	0.9173 ***
	(0.016)	(0.095)	(0.019)
TEL	−0.0073 ***	−0.0266 **	−0.0039
	(0.001)	(0.012)	(0.003)
FIND	−0.0103 **	0.0724 **	−0.0246 ***
	(0.004)	(0.028)	(0.007)
GOV	0.0091 *	−0.1424 ***	0.0214 ***
	(0.005)	(0.034)	(0.005)
TRADE	0.0250 ***	−0.0913 ***	0.0263 **
	(0.004)	(0.013)	(0.008)
INF	−0.0075 ***	0.0009	−0.0035 **
	(0.001)	(0.007)	(0.002)
INVEST	0.0096 *	−0.0256	0.0423 ***
	(0.005)	(0.042)	(0.007)
Arellano-Bond test for:			
AR(1) *p*-value	0.0020	0.0056	0.0228
AR(2) *p*-value	0.1835	0.3344	0.6282
Sargan test *p*-value	0.2335	0.9291	0.1766
Number of countries	45	14	31
Number of observations	450	140	310

Notes: The 10%, 5%, and 1% significance levels are denoted by *, **, and ***, respectively. Standard errors are reported in parentheses next to the coefficient estimates. All values are based on a two-step Generalized Method of Moment (GMM) estimator.

[1] Details are available on request.

Table 4. Impact of MOB on economic growth in developing countries over the period 2007–2016.

Variables	ALL	MENA	SSA
$GDPPC_{t-1}$	0.6571 ***	0.0749	0.8171 ***
	(0.011)	(0.111)	(0.045)
MOB	0.0708 ***	0.0333	0.0240 *
	(0.004)	(0.051)	(0.008)
FIND	−0.0108 *	0.0753 *	−0.0279 ***
	(0.004)	(0.044)	(0.007)
GOV	−0.0018	−0.1400 ***	0.0133 **
	(0.004)	(0.019)	(0.006)
TRADE	0.0037	−0.0949 *	0.0156 *
	(0.004)	(0.053)	(0.009)
INF	−0.0060 ***	0.0052	−0.0018
	(0.001)	(0.006)	(0.001)
INVEST	0.0169 ***	−0.0195	0.0429 ***
	(0.005)	(0.021)	(0.007)
Arellano-Bond test for:			
AR(1) *p*-value	0.0151	0.0053	0.0287
AR(2) *p*-value	0.1773	0.2602	0.6395
Sargan test *p*-value	0.2192	0.9642	0.2109
Number of countries	45	14	31
Number of observations	450	140	310

Notes: The 10%, 5%, and 1% significance levels are denoted by *, **, and ***, respectively. Standard errors are reported in parentheses next to the coefficient estimates. All values are based on a two-step GMM estimator.

Table 5. Impact of INT on economic growth in developing countries over the period 2007–2016.

Variables	ALL	MENA	SSA
$GDPPC_{t-1}$	0.5379 ***	−0.1177	0.7234 ***
	(0.020)	(0.114)	(0.039)
INT	0.0396 ***	0.0487 **	0.0217 ***
	(0.002)	(0.019)	(0.005)
FIND	−0.0295 ***	0.0571 *	−0.0306 ***
	(0.004)	(0.033)	(0.008)
GOV	−0.0083 **	−0.1295 ***	0.0135 **
	(0.003)	(0.032)	(0.006)
TRADE	0.0192 ***	−0.0777 ***	0.0288 ***
	(0.004)	(0.017)	(0.008)
INF	0.0003	0.0058	−0.0028 **
	(0.001)	(0.007)	(0.001)
INVEST	0.0204 ***	−0.0136	0.0418 ***
	(0.002)	(0.029)	(0.007)
Arellano-Bond test for:			
AR(1) *p*-value	0.0215	0.0008	0.0279
AR(2) *p*-value	0.1001	0.9095	0.6637
Sargan test *p*-value	0.2510	0.9517	0.1745
Number of countries	45	14	31
Number of observations	450	140	310

Notes: The 10%, 5%, and 1% significance levels are denoted by *, **, and ***, respectively. Standard errors are reported in parentheses next to the coefficient estimates. All values are based on a two-step GMM estimator.

Table 6. Impact of BBA on economic growth in developing countries over the period 2007–2016.

Variables	ALL	MENA	SSA
$GDPPC_{t-1}$	0.7781 ***	−0.0054	0.8546 ***
	(0.015)	(0.093)	(0.027)
BBA	0.0161 ***	0.0288 ***	0.0065 ***
	(0.002)	(0.051)	(0.002)
FIND	−0.0152 ***	0.0621 **	−0.0257 ***
	(0.004)	(0.028)	(0.007)
GOV	0.0037	−0.1496 ***	0.0186 ***
	(0.004)	(0.032)	(0.005)
TRADE	0.0289 ***	−0.0872 ***	0.0289 ***
	(0.004)	(0.011)	(0.008)
INF	−0.0076 ***	0.0023	−0.0029 *
	(0.001)	(0.006)	(0.002)
INVEST	0.0125 **	−0.0105	0.0466 ***
	(0.005)	(0.032)	(0.008)
Arellano-Bond test for:			
AR(1) *p*-value	0.0043	0.0002	0.0215
AR(2) *p*-value	0.1936	0.8369	0.6318
Sargan test *p*-value	0.2373	0.9803	0.1176
Number of countries	45	14	31
Number of observations	450	140	310

Notes: The 10%, 5%, and 1% significance levels are denoted by *, **, and ***, respectively. Standard errors are reported in parentheses next to the coefficient estimates. All values are based on a two-step GMM estimator.

Table 3 shows the empirical results derived from the estimation of the model in Equation (1) when considering TEL, measured by the number of fixed telephone subscriptions per 100 inhabitants, as a proxy for the ICT variable. The results presented below concern the main sample of developing counties (ALL) as well as the subsamples MENA and SSA over the period 2007–2016.

According to Table 3, the effect of fixed telephone (TEL) is negative and statistically significant for the main panel of developing countries and the MENA panel. While it is not significant, the coefficient of the telephone variable is also negative for the SSA countries. These findings are consistent with those of Kumar (2012), Sassi and Goaied (2013), and Wamboye et al. (2015).

The negative impact of fixed telephones on economic growth could be explained by the poor economic performance of many MENA and SSA developing countries having led to a lower penetration rate of fixed telephone lines (Albiman and Sulong 2016). In addition, it is possible that, recently, fixed telephone lines were substituted by mobile telephones. Indeed, several empirical studies have shown the presence of a substitution effect, particularly in African countries. According to these works, mobile phones are substitutes for fixed telephones in Africa. The substitution effect is due to the shortage of fixed telephone lines on the African continent and results from the lack of extensive wired infrastructure (Waverman et al. 2005; Andrianaivo and Kpodar 2011).

Table 4 shows the empirical results found when considering MOB, measured by the number of mobile cellular subscriptions per 100 inhabitants as a proxy for the ICT variable. The results presented below concern the main sample and the subsamples of developing counties over the period 2007–2016. Table 4 indicates that mobile phones (MOB) have a positive effect on economic growth in all panels. However, a stronger and significant impact was found particularly in SSA countries (+2.4%). We did not find a significant effect for MENA countries. This could be explained by the fact that the MENA panel includes countries from different income levels and that have different ICT penetration degrees.

Focusing on SSA countries, our findings are consistent with those of most previous studies such as Vu (2011); Andrianaivo and Kpodar (2011); Wamboye et al. (2015); Ward and Zheng (2016); and Albiman and Sulong (2016), among others.

The results found confirm that in the recent period (2007–2016) mobile phones became an important driver of economic growth in the SSA region. These findings consolidate the efforts of many SSA countries to accelerate mobile penetration. For example, in African countries such as Kenya, Niger, and Zambia, authorities attempt to stimulate economic growth through increasing financial inclusion. They facilitate people's access to mobile technology in order to accelerate the spread and use of mobile financial services. Therefore, through higher mobile penetration, it becomes easier for customers of African banks to have access to deposits and loans and to execute various financial transactions, such as storing and transferring money and paying bills.

In addition, better information flows through mobile phones could substantially improve information acquisition for depositors and financial institutions and enhance monitoring. Higher mobile phone penetration does indeed reduce the physical constraints and costs of distance and time (Andrianaivo and Kpodar 2011; Wamboye et al. 2015).

Tables 5 and 6 show the empirical results found when considering respectively INT, which is the number of Internet users per 100 inhabitants, and BBA, which is the number of fixed broadband subscriptions per 100 inhabitants, as proxies for ICT in our model. These two tables reveal that Internet usage (INT) and broadband adoption (BBA) have strong positive and significant effects on economic growth in all our samples of developing countries.

Our results confirm previous those of theoretical studies suggesting that Internet usage should improve economic growth by accelerating the development and adoption of innovation processes and thereby fostering competition which results in the development of new products, processes, and business models (Lucas 1988; Romer 1990; Aghion and Howitt 1998; Barro 1998; etc.).

In addition, our findings are in accordance with most previous empirical studies that showed the presence of a significant positive effect of Internet on economic growth in developing countries (Andrianaivo and Kpodar 2011; Sassi and Goaied 2013; Wamboye et al. 2015; Pradhan et al. 2018; etc.). The results found are also consistent with earlier studies that confirmed that countries with wide broadband availability have seen higher economic growth (Kolko 2012; Jayakar and Park 2013; Pradhan et al. 2018).

However, Table 5 indicates that the positive impact of Internet usage on economic growth is more important in MENA countries (+4.87%) than in SSA countries (+2.17%). Moreover, Table 6 reveals that broadband adoption has a positive impact on economic growth which is stronger in MENA countries (+2.88%) than in SSA countries (+0.65%). These findings indicate the presence of a relative superiority of MENA countries in recent years (2007–2016) over SSA countries in terms of Internet usage and broadband adoption.

Considering the control variables introduced in the estimations, we found that financial development (FIND) significantly affected the economic growth of developing countries over the period of study. This effect is positive (from +5.7% to +7.5%) in MENA countries and negative in SSA countries (from −2.5% to −3%). In all estimations, government final consumption expenditure (GOV) had a negative and strongly significant impact on the GDP per capita of MENA countries (from −13% to −15%), while its impact was weak but positive for SSA countries (from +1.3% to +2.1%). The results also show that, contrary to in the MENA countries, trade openness (TRADE) triggered economic growth in SSA countries over the study period. Inflation (INF) had a very weak negative and significant effect (less than 1%) on the economic growth of all developing countries in our sample. The last control variable introduced in the estimations is domestic investment (INVEST). The results show that it had a positive and significant impact (more than 4%) on economic growth, particularly in the case of SSA countries.

5. Conclusions

In this study we investigated the effect of ICT diffusion on the economic growth of 45 developing countries from the MENA and SSA regions over the period 2007–2016. A two-step panel GMM growth

model was employed to explore the nexus between economic growth and four ICT variables: fixed telephone (TEL), mobile phone (MOB), Internet usage (INT), and broadband adoption (BBA).

Our findings show that except for fixed telephone, other information and communication technologies such as mobile phone, Internet usage, and broadband adoption were the main drivers of economic growth in MENA and SSA developing countries over the recent period 2007–2016. Indeed, the negative impact of fixed telephones on economic growth revealed that many low-income MENA and SSA developing countries in our sample failed to benefit from the growth potential of this telecommunication technology. This could be due to their inability to afford the cost of the infrastructure required to install and diffuse fixed telephone lines over all their territories (Wamboye et al. 2015; Albiman and Sulong 2016). In addition, this result could be explained by the fact that mobile phones are substitutes for fixed telephones in many developing countries. This is particularly true for SSA countries which have recently seen rapid growth in mobile phone penetration rates. This explanation is consistent with our findings. Indeed, our results show that mobile phones had the most significant positive impact on economic growth in the case of SSA countries (unlike MENA countries) over the period of study of 2007–2016. In accordance with earlier studies, our findings confirm that Internet usage and broadband adoption are among the main factors that contribute to the economic growth of developing countries. A further analysis revealed that a relative superiority of MENA countries over SSA countries exists over the period of study in the areas of Internet usage and broadband adoption.

Several policy implications and recommendations can be derived from our results. Indeed, to ensure sustainable economic growth, authorities and policymakers in MENA and SSA countries should increase investments in mobile phone infrastructure as it is more cost-effective and beneficial than fixed-line telephones. Authorities are also required to upgrade and expand existing ICT infrastructure to accelerate Internet usage and broadband adoption. They should establish e-government to promote good governance and improve efficiency in public administration. They should also stimulate the diffusion of ICT in the private sector through several policy interventions such as tax reduction, subsidies, promoting e-commerce, and developing public–private partnerships in the development of telecommunications infrastructure and services. This is very important since it was proven that these new technologies positively and strongly influence economic growth by accelerating the development and adoption of innovation processes and fostering competition.

Other policy implications related to control variables introduced in the estimations are to be considered. Many actions should be undertaken by financial authorities in both MENA and SSA countries to improve their financial sectors. Right now, financial sectors are not well developed enough to help ICT drive economic growth, particularly in many SSA countries. Furthermore, authorities in MENA and SSA developing countries should continue their efforts to increase the openness of their economies and prioritize the allocation of resources to the development of ICT infrastructure to benefit from the ICT revolution. In addition, they should enact policies that provide a more convenient regulatory and institutional environment to attract foreign investors, enhance fair competition in the ICT sector, and promote Internet-enabled services and Internet presence, including e-government and e-commerce. Finally, MENA and SSA governments should adopt the necessary policies to contain government consumption and inflation rates in order to avoid their negative impact on economic growth.

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