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Modeling broadband, mobile telephone and economic growth on a macro level: Empirical evidence from G7 countries

Tekin Birinci[a*] and Dervis Kirikkaleli[b]

[a]15 Kasim University, Lefkosa, Turkish Republic of Northern Cyprus, Mersin-10, Turkey
[b]European University of Lefke, Faculty of Economic and Administrative Sciences, Department of Banking and Finance, Lefke, Northern Cyprus, TR-10 Mersin, Turkey

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A B S T R A C T

Information and Communications Technology (ICT) has played overwhelming roles in the economic and social development of nations and continents in the last two decades. This study aims to explore the impact of mobile telephone and broadband use on economic growth in G7 countries using annual data covering the period of 2000-2017. We performed Pedroni cointegration, Kao cointegration, fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and panel Granger causality tests to investigate the causal and long-run effects. The empirical findings reveal that (i) mobile telephone and broadband use contribute to economic growth in the long-run; (ii) changes in mobile telephone and broadband use significantly lead to a change in economic growth.

1. Introduction

The effect of technology on economic growth and the social-economic condition is increasingly becoming an important domain of research. The enormous spread of the use of the Internet and substantially rising ICT investments in the last two decades has encouraged studies on the various economic consequences of these substantial expansions. ICT is so affecting consumers' behavior and also producers' behavior through influencing utility function and productive function respectively which implies the effects of ICT on both demand and supply sides. Concerning the supply side, ICT along with other complementary infrastructure components; augments capital, reorganizes the economic processes and ultimately results in a gain in economic growth and increment in productivity of productive factors. Two approaches discuss the effects of ICT on national competitiveness. The first approach believes in the paradox of productivity (Carr, 2003; Parsons, Gottleb, Denny, 1990; Solow, 1987) which disaffirms the ICTs influences on national competitiveness. This approach argues that the rise in ICT capacity investment does not lead to the same deal of increase in the productivity in business, industry, and a nation and even it can result in a fall. On the other side, numerous sources claim that ICT investment and economic growth and national competitiveness are positively related; in such a way that investment in ICT can be influential through improving labor productivity or organizational efficiency. The second contradictory approach belongs to Johnson (1992) and Kraemer and Dedrick (2001). They note the significant relationships between ICT and economic growth or indeed the national development. The basis of their logical concept is called ”respectability” which specifies ”accumulated relationship between ICT investment and economic growth” and a ”virtuous circle structure.” SERI (2008) also proves that ICT investment improves productivity through ”static economies of scale (e.g., informatization of industries)” and ”dynamic economies of scale (e.g., the industrialization of information).” Static economies of scale benefit each industry and business via reducing cost and increasing flexibility of the high-quality production process. NIA (2011) also states that technological change through ICT development enhances the efficiency of the capital and

* Corresponding author.
E-mail address: tekin_birinci@yahoo.com (T. Birinci)

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labor as the input determinants of productivity. The starting point is the literature on endogenous economic growth as pioneered by Romer (1986) and Lucas (1988) which explored the endogenous factors influencing economic growth, empirically. Human capital is the main factor that influences economic growth (Lucas, 1993) but in addition to being a passive worker, everyone is also a team member, a decision-maker, and a life-long learner. Improvements in the working conditions of workers have a positive impact on the economic growth of the country. These kinds of improvements make it possible for workers to have direct or indirect contact with information, which would enhance their learning, communication, productivity, and human capital. Therefore, modern notions pointed to the importance of technology development for economic development in a country. Ever, since the invention of computers, researchers, policy-makers and international development agencies underline that technology is the engine of economic development.

Vu (2011) pointed out that the positive effect of ICT on economic development can be realized through minimizing the cost of production, optimizing resource allocation, and increasing demand. More specifically, the internet, and mobile telephone, which are the driving factors of ICT, have significantly minimized communication costs by allowing individuals and companies to send and receive information fast and cheap. Those ICT indicators are also likely to increase total output and productivity (Kolko, 2012). As its main novelty, this study constructs models to detect the long-run and causal effect of mobile telephone and broadband on economic growth in the G7 countries which have not been investigated in-depth using a single dataset, to our best knowledge. Also, numerous studies capture the effect of ICT and ICT components on economic growth and Income level for different countries. However, to date, no study has been developed to examine the direction of the long-run effect for ICT on the size of income. Therefore, the major objective of this study is to fill this gap in the literature by using the panel cointegration approach. It is crystal clear that the research is expected to open a new debate in the literature, and the outcomes of the paper spotlight remarkable economic policy modifications for policymakers in the G7 countries. It is worthy to note that those ICT indicators have also received substantial numbers of regulatory and public policy attempts in the world, especially in the last two decades. Besides, rather than many studies that have been applied to classical OLS techniques in their estimation process, this study employs panel FMOLS and panel DOLS methodologies to have “less distorted parameters from possible endogeneity and correlation” in the used dataset. This study is organized as follows. Section 2 introduces existing literature about the concept of mobile telephone and broadband uses and economic growth. Section 3 involves the data that we used in the models of this study. Section 4 presents the models and methods that we used to detect the possible effect of mobile telephone and broadband uses on economic growth. Section 5 presents the findings from the methods that we performed. Section 6 provides a summary of the results and implications for related policies.

2. Literature Review

In the last two decades, information communication technology has been playing significant roles in the economic and social development of various nations and continents. During this period, many jobs have gone extinct, and others have been substituted with better methods. Today, the world cannot be imagined without the internet, smart TVs, cell phones, and other devices that have been invented to make life easy. Amongst the efforts achieved so far by a couple of researchers to identify the impact of ICT on economic growth, many of them focused mainly on the implications of ICT investment in the production of goods and services.

Previous studies on the relationship between economic growth and information communication technology development have revealed that there is a positive correlation between information communication technology and economic growth (Hardy, 1980; Jipp, 1963; Saunders 1983; Gilling, 1975). Most of these studies were based on static data and did not address the long-run linkages among the variables involved. Hence, they did not accurately provide enough information regarding the relationship between economic growth and information communication technology development. The work done by Engle and Granger (1987) is a widely-adopted technique for exploring the long-run connections among time-series variables. The time-series analysis was first applied in ICT growth relationship studies in the 1990s. Cronin et al. (1993) applied this scheme to investigate the causal relationship between economic growth and information communication technology development in the United States. They found evidence of a bi-directional relationship between the two variables. Several types of research have been conducted with a similar technique after then, in both developing and developed countries, with most of them showing evidence of a positive relationship runs between information communication technology and economic growth (Dutta, 2001; Chakraborty & Nandi, 2003; Chu et al., 2005; Stiroh, 2005; Inklaar, Timmer &van Ark, 2008; Jorgenson, Ho, & Samuels, 2011; Vu, 2011 and 2013). However, quite a few researches showed no evidence of a relationship between information communication technology and economic growth (Shiu & Lam, 2008). The usage of investment of telecommunications on economic growth has been investigated since the beginning of the globalization period in the 1980’s-. An initial study regarding this area was conducted by Hardy (1980) who found that the effect of telecommunications investment on economic development in the least developed countries is then that in developed countries. Leff (1984) investigated the welfare effect of telecommunication investment in developing economies using cost-benefit analysis. He pointed out that arbitrage abilities are increased, and information flow is better off as a result of rising telecommunication investment.

Norton (1992) underlined the importance of the economic impacts of telecommunication on reducing transaction costs. In research investigating the effect of a mobile telephone on economic growth for 92 countries from 1980 to 2003, Waverman et al. (2005) found that economic development is positively and significantly affected by the expansion of mobile telephone. Using a special linear GMM estimator, the study of Lee et al. (2012) reports that mobile phones play a major role in the economic development of 44 sub-Saharan countries. They also underlined that the impact of the mobile phone on economic development gets stronger wherever landline phones are rare. A more recent study by Ward and Xheng (2016) reveals that mobile phone usage has a positive and significant impact on economic development in China. However, they also argue that the effect fades away as the regional economy develops more. The internet is a network of various computers, objects, and people who are remote from one another. Information is exchanged from one person to another or objects to other objects through established applications and protocols. The Internet can impact societies at different levels and in various categories of activities. The Internet makes it possible for businesses and organizations to communicate faster, cheaper, and better. This will lower the cost of production, enhance productivity, and economic growth. Internet technologies create avenues through which new products can reach consumers quickly and safely. The technologies provided by the web gives a facelift to research and development, necessary for product enhancement and market re-evaluation for better output. New knowledge about production and sales can easily get to business owners via the internet. The labor market is also influenced by the internet, making it easy for companies to recruit the right category of employees to meet customer's needs (Stevenson, 2008; Levin, 2011). As a well-known fact, access to or use of broadband encourages the use of high-speed internet. Thus, broadband use is likely to reduce the cost of sending and obtaining data which enhances efficiency, productivity, and total output in a country. Holt and Jamison (2009) clearly mentioned that "broadband applications can potentially substitute for labor, make the use of labor more efficient, and change the way work is done and the products that are produced". Another economic impact research on broadband was conducted by Roller and Waverman (2001), using a simultaneous approach, the study reveals that broadband as a main driver of ICTs contributes to the economic growth of 21 OECD countries when a critical mass of infrastructure exists. Using the FCC (Form 477) data in the US, Gillett et al. (2006) aimed to answer the question of "do broadband matter to the US economy?" They found that economic growth is positively affected by the expansion of broadband due to an increasing number of employment and business in the US, especially in IT-intensive sectors. However, the findings of Van Gaasbeck et al. (2007) are not in line with the results of Gillett et al. (2006). Although Van Gaasbeck et al. (2007) found that the explosion of broadband in 39 California counties from 2001 to 2006 stimulated economic growth and generated new jobs, they failed to find the significant effect of broadband use on the number of businesses. Also, Cleeve and Yiheyis (2014) focused on 34 African countries over the period 1995 to 2010 to explore the linkage between economic growth and mobile telephone use. Using panel econometric techniques, they concluded that mobile phone use contributes to GDP growth but the reverse effect is not detected. The impact of telecommunications on per capita income growth is investigated for 49 African countries by Chavula (2013). He employed Barros's (1991) endogenous growth model which estimates the impact of mobile, fixed telephone main lines and the use of the Internet on per capita income. He found a significant impact of the telephone main lines and mobile telephony on the growth per capita income in Africa, However, he failed to find the effect of internet usage on growth per capita income. Qureshi (2012, p. 277) underlined that" there is a sense that ICT has the potential to give people the freedom they need to lead the lives they value.`` However, due to the importance of these perspectives (ICTs adoption and human, social and economic development), little studies have been undertaken to define the link between them (Kamal Qureshi, 2009); (Malaquias et al., 2016). Therefore, against this backdrop, this study aims to identify the long-run and causal effect of mobile telephone and broadband on economic growth in the sample of G7 countries to fill the gap of long-run analyses in the existing literature of ICT-Growth nexus.

3. Data

The datasets of G7 countries, namely Canada, Germany, France, Italy, Japan, the UK, and the USA are used in this research. The annual data covers the period of 2000 - 2017 and were gathered from (i) ITU, which is the United Nations specialized agency for ICTs; (ii) World Bank; (iii) OECD. GDP growth, Gross capital formation (% of GDP), General government final consumption expenditure (% of GDP), Inflation (Consumer Price Index), Mobile-cellular telephone subscriptions per 100 inhabitants, and Fixed broadband subscriptions per 100 inhabitants are the variables used in our estimation models. The codes of the variables are presented in Table 1. It is worthy to note that all variables are expressed in their logarithmic transformation in the models.

Table 1
The sources of the information

Data	Source	Code
GDP (current US$)	World Bank	GDP
Gross capital formation (% of GDP)	OECD	INV
General government final consumption expenditure (% of GDP)	OECD	GCG
Inflation (Consumer Price Index)	World Bank	INF
Mobile-cellular telephone subscriptions per 100 inhabitants	ITU	MTS
Fixed-broadband subscriptions per 100 inhabitants	ITU	FBS

4. Model and Methodology

We hypothesize that ICT, specifically mobile telephone, and broadband uses, plays a major role in the distribution of knowledge leading to economic growth. This is consistent with Romer's (1986, 1990) endogenous growth model which states that the spread of knowledge positively affects the level of growth. It becomes obvious therefore that ICT indicators are major prerequisites to the dissemination of knowledge in an economy. In addition to the ICT indicators, we added general government final consumption expenditure (% of GDP), gross capital formation (% of GDP), and inflation (consumer price index) as explanatory variables, as recommended by Barro's (1996) growth equation. This means that the mobile-cellular subscriptions and fixed broadband subscription, government consumption, investments, and inflation are the factors that would determine the actual growth rate of the GDP of the G7 countries. The equation below is used for estimation.

$$GDP_{it} = \alpha_i + \beta_1 INV_{it} + \beta_2 INF_{it} + \beta_3 GCG_{it} + \beta_4 FBS_{it} + \beta_5 MTS_{it} + e_{it} \quad (1)$$

where $e_{it}=\eta_i+\nu_t+\varepsilon_{it}$, ηi is a country effect, and ν_t is a time effect, and ε_{it} is independently and identically distributed among countries and years. GDP_{it} is the GDP (current US$) of country $_i$ at year $_t$. It is expected that the coefficient of mobile telephone and broadband uses would be positive because they contribute to the spread of knowledge. Before performing panel cointegration techniques –Pedroni and Kai cointegration tests-, we initially detected the stationary of the time series variables. We employed IPS panel unit root test suggested by Im et al. (2003), LLC panel unit root test proposed by Levin et al. (2002) Breitung panel unit root test proposed by Breitung (2001) and ADF-Fisher and PP-Fisher panel unit root tests suggested by Maddala and Wu (1999) and Choi (2006). We assume that GDP, INV, GCG, INF, MTS, FBS variables are not stationary at the order of integration 0 but when the first difference of the variables are taken, the variables become stationary (I(1)), such that some linear combination of INV, GCG, INF, MTS, FBS, and GDP have a run equilibrium relationship. The detection of the stationary of time series variables is an important issue in panel and time series modeling. That is because the use of non-stationary series in a regression model may lead to spurious regression, implying invalid statistical conclusions. The basic equation of the LLC unit root test can be as follows;

$$\Delta y_{it} = m_{it}\alpha_i + \beta y_{it-1} + \sum_{j=1}^{pi} g_i \Delta y_{it-j} + u_{it} \quad (2)$$

where Δy_{it} represents the first difference operator, for country i, in time period t=1……T. β_i is identical for all country, m_{it} is the deterministic components, u_{it} represents the error term and pi represents the lag order. We test the null hypothesis β_i = 0 for all countries against the alternative $H_1 : \beta_i < 0$, suggesting that all variables are stationary. The unit root test of Levin et al. (2002) may loss its power if the assumption of homogenous β_i for all I ($\beta_i = \beta$) does not exist. To deal with the weak side of the LLC panel unit root test of Levin et al. (2002), Im et al. (2003) developed IPS panel unit root test which permits β to vary across all i. the simple form of the LLC unit root test equation is represented as follows;

$$\Delta y_{it} = m_{it}\alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{pi} g_i \Delta y_{it-j} + u_{it} \quad (3)$$

PP-Fisher panel unit root test, developed by Madalla and Wu (1999), are usually the type of nonparametric tests that permit test statistics indicated by the equation shown below

$$P = -2 \sum_{i=t}^{N} ln_{\beta i} \quad (4)$$

Another model for Fisher type p-test was proposed by Choi (2006) which generates more robust evidence with the equation constructed below:

$$Z = \frac{1}{\sqrt{1}} \sum_{i=1}^{N} \lambda^{-1}(\pi_i) \sim N(0,1) \quad (5)$$

where λ^{-1} is the inverse of the normal cumulative distribution function. Once the order of integration of the variables are detected, and I find that the variables are I(1), the next issue is to check the long-run equilibrium relationship from INV, GCG, INF, MTS, FBS variables to GDP variable using Pedroni and Kao panel cointegration tests developed by Pedroni (2004) and Kao (1999), correspondingly. This is because the presence of stationary linear combinations between two or more nonstationary time series variables shows that the variables are cointegrated. Pedroni (2004) developed the Pedroni cointegration test based on regression errors from the hypothesized cointegrating regression. The test is contracted with seven test statistics of the group: ADF-statistic, group rho-statistic, group PP-statistic, panel v-statistic, panel rho-statistic, panel PP-statistic, and panel ADF-statistic. The simplest version of the panel Pedroni cointegration equation is shown below;

$$Z_{i,t} = \rho_i + \eta H_{i,t} + \beta K_{i,t} + e_{i,t}, \quad (6)$$

where $e_{it} = e_i e_{i(t-1)} + \Phi_{it}$ are the estimated residuals from the panel model. The null hypothesis tested is whether e_i is unity. The long-run relationship between Z, H, K variables is detected if the null hypothesis of no cointegration can be rejected. Pedroni (1999) underlined that this can be realized if the value of t-stat is more than the critical value in Pedroni (1999). Apart from the Pedroni cointegration test, we employed the Kao panel cointegration test which was proposed by Kao (1999) to investigate the effect of mobile telephone and broadband uses on economic growth in the G7 countries. The test was constructed based on the ADF-statistics. The simple form of Kao panel cointegration is estimated using the equation below;

$$\text{ADF}=\frac{t_{ADP}+\left(\frac{\sqrt{\text{pN}}\,\mho_v}{2\mho_{ov}}\right)}{\sqrt{\left(\frac{\mho_{0v}^2}{2\mho_v^2}\right)+\left(10\mho0_v^2\right)}} \tag{7}$$

where $\mho_v^2 = \Sigma_{ue}$- $\Sigma_{ue}\Sigma_e^{-1}$, $\mho_{0v}^2$= Φ_{ue}- $\Phi_{ue}\Phi_e^{-1}$, Φ denotes the long-run covariance matric (Dogan and Seker, 2016). Based on our primary aim, within-dimensions and between-dimensions panel FMOLS and DOLS techniques were implemented employed, the main advantages of the between-dimension FMOLS and DOLS methods are; (i) to minimize size distortion in the small dataset; (ii) to permit more suppleness in hypothesis testing; (iii) to bring out an estimate of the cointegrating vectors' mean. Allowing researchers to select leads and lags by DOLS test is criticized by Maeso-Fernandez et al. (2006) for minimizing the degrees of freedom in a model. They also underlined that the FMOLS technique provides more robust estimations relative to DOLS because fewer assumptions are required (Maeso-Fernandez et al., 2006). The FMOLS estimator was initially developed by Phillips and Hansen (1990) to increase the efficiency of the Ordinary Least Squared estimator for cointegrated variables.

The last step of the study involves the implementation of a panel Granger causality test to explore the causal effect of mobile telephone and broadband uses on economic growth in the G7 countries. The test is based on the F-statistic values. The possible causal effects cannot be estimated using either the Kao panel cointegration or Pedroni panel cointegration test. The hypotheses are as follows;

H_1: Null Hypothesis: MTS does not Granger cause GDP
H_2: Null Hypothesis: FBS does not Granger cause GDP

5. Findings

We aim to investigate the effect of mobile telephone and broadband uses on economic growth in G7 countries. Initially, the order of integration of the variables, namely: GDP, INV, GCG, INF, FBS, and MTS variables, are detected using LLC, Breitung, IPS, ADF-Fisher, and PP-Fisher panel unit root tests. The outcomes of the tests are presented in Table 2 which mirrors that the null hypothesis of GDP has a unit root and cannot be rejected at the 5% level but after taking the first difference of the variable; the null hypothesis can be rejected. Therefore, the order of integration of the variable is one. This situation is not entirely different in the independent variables of the model. Obtaining I (1) integrated variables allows us to explore the effect of mobile telephone and broadband uses on economic growth. Table 3 reports the findings from the Pedroni and Kao panel cointegration tests for Eq. (1).

Table 2
Panel Unit Root Tests

Variables		LLC t-stat	Breitung t-stat	IPS W-stat	ADF - Fisher Chi-square	PP-Fisher Chi-square
Level T&C	GDP	-1.049	-0.186	1.344	8.089	1.980
		(0.146)	(0.425)	(0.910)	(0.884)	(0.999)
	INV	-1.919[a]	1.616	-0.439	18.459	18.440
		(0.027)	(0.947)	(0.330)	(0.186)	(0.187)
	GCG	-0.853	0.653	0.910	9.714	4.786
		(0.196)	(0.743)	(0.818)	(0.782)	(0.988)
	INF	0.924	0.872	-2.507*	33.456*	30.247*
		(0.822)	(0.808)	(0.006)	(0.002)	(0.007)
	FBS	-0.020	2.024	1.476	10.551	0.694
		(0.491)	(0.978)	(0.930)	(0.720)	(1.000)
	MTS	1.815	2.834	4.162	1.765	3.852
		(0.965)	(0.997)	(1.000)	(1.000)	(0.996)
First difference	GDP	-6.521*	-3.246*	-4.301*	43.167*	53.960*
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	INV	-5.672*	-5.039*	-3.587*	36.679*	50.015*
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	GCG	-6.068*	-6.434*	-3.383*	35.776*	35.729*
		(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
	INF	-6.197*	-6.447*	-6.389*	59.428*	61.471*
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	FBS	-4.248*	-3.751*	-2.712*	30.248*	24.725[a]
		(0.000)	(0.000)	(0.003)	(0.007)	(0.037)
	MTS	-5.549*	-3.556*	-1.647[a]	23.196*	59.351*
		(0.000)	(0.000)	(0.050)	(0.057)	(0.000)

Note: *, [a], and [b] denote statistical significance at the 1%, 5%, and 10% levels, respectively. T&C denotes that the model is performed with a trend and is constant. After analyzing the pattern of the variables and showing the significance of the trend coefficients in the unit root regressions, the models are applied with an intercept and deterministic trend.

The majority of the tests in Table 3 are statistically significant, implying that the null hypothesis of no cointegration can be rejected at the 5% level. This presents the long-run equilibrium linkage among the variables. In other words, the variables (GDP, INV, GCG, INF, FBS, and MTS) move together in the long-run. The subsequent stage is to estimate this linkage using the FMOLS and DOLS techniques.

Table 3

Panel Cointegration Tests

	Alternative hypothesis: common AR coefs. (within-dimension)				Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.	Weighted Statistic	Prob.			
Panel v-Statistic	-2.164	0.984	-2.488	0.993	Group rho-Statistic	5.155	1.000
Panel rho-Statistic	4.768	1.000	4.389	1.000	Group PP-Statistic	-7.036*	0.000
Panel PP-Statistic	-3.506*	0.000	-6.114*	0.000	Group ADF-Statistic	-4.744*	0.000
Panel ADF-Statistic	-4.185*	0.000	-5.276*	0.000			
			Kao Residual Cointegration Test				
	t-Statistic				Prob.		
ADF	-6.928*				0.000		

Note: *, [a], and [b] denote statistical significance at the 1%, 5%, and 10% levels, respectively.

The long-run mobile telephone and broadband use for economic growth are obtained through FMOLS and DOLS estimators. Estimation findings from FMOLS and DOLS are based on annual data for the period 2000-2017. Table 4 demonstrates the outcomes from the FMOLS and DOLS estimators. The second and fourth columns of Table 4 provide homogeneous (within-dimension) parameter estimates of FMOLS and DOLS, respectively while the third and fifth columns of the table bring heterogeneously (between-dimension) parameter estimations of FMOLS and DOLS, correspondingly. It is worth noting here that the "within-dimension" outcomes do not change from "between-dimension" outcomes. As seen in Table 4, both MTS and FBS estimated coefficients are statistically significant and positive at 1% and 5% levels in all models. The MTS coefficients range from 0.093 to 0.107, implying that the panel long-run elasticity for mobile telephone use is inelastic. In other words, the %1 increase in Mobile-cellular telephone subscriptions per 100 inhabitants increases by approximately 0.1% in GDP in the G7 countries. The positive MTS coefficient in our model is rational and in line with the findings of Waverman et al. (2005), Lee et al. (2012), and Ward and Xheng (2016).

The coefficient sign of FBS is positive on all models with p-value of 0.000, as expected. The coefficients of FBS range between 0.600 and 0.625, implying that %1 rising in Fixed-broadband subscriptions per 100 inhabitants is associated with around 0.6% increase in GDP. This finding is strong empirical support of the findings of Roller and Waverman (2001), Gillett et al. (2006), Van Gaasbeck et al. (2007), and Cleeve and Yiheyis (2014). It is rational to have positive MTS and FBS coefficients in all estimated models. This is because mobile telephone and broadband uses are the main driving factors of ICT and it is crystal clear that ICT minimizes communication costs by allowing individuals and companies to send and receive information faster and cheaper. As already discussed in-depth in the Introduction and Literature Review sections, ICT is likely to increase efficiency, productivity, and total output, as a result of effective knowledge distribution.

Table 4

Panel FMOLS and DOLS Estimations

	FMOLS		DOLS	
	Homogeneous Within Dimension	Heterogeneous Between Dimension	Homogeneous Within Dimension	Heterogeneous Between Dimension
INV	[0.862]* (0.000)	[0.862]* (0.000)	[0.680]* (0.000)	[0.680]* (0.001)
INF	[-0.049]* (0.001)	[-0.049]* (0.000)	[-0.037][a] (0.012)	[-0.037][b] (0.063)
GCG	[0.368] (0.176)	[0.368] (0.353)	[0.276] (0.384)	[0.276] (0.376)
FBS	[0.093]* (0.000)	[0.093]* (0.000)	[0.107]* (0.001)	[0.107]* (0.000)
MTS	[0.600]* (0.000)	[0.600]* (0.000)	[0.625]* (0.000)	[[0.625]* (0.000)
R^2	0.989	0.989	0.995	0.995
S.E.	0.081	0.081	0.067	0.067

Note: * and [a] indicate statistical significance at the 1% and 5% levels, correspondingly. ( ) and [ ] denote the p-values and the coefficients of the variables, correspondingly. Ind. Var. denotes independent variables of the models. Models are constructed based on equation (1). R^2 and S.E. indicate R-squared and S.E. of regression, correspondingly.

In the final part of this paper, the panel Granger causality test is implemented to investigate the causal effect of mobile telephone and broadband uses on economic growth. The findings from the test are reported in Table 5. The estimation of F-statistics from the panel Granger causality test mirrors that the null hypothesis of mobile telephone and broadband use do not Granger cause economic growth in the G7 countries can be rejected at the 5% level with F-statistics of 4.814 and 5.719, correspondingly. These findings mean that the vulnerability in mobile telephone and broadband uses significantly leads to vulnerability in economic growth in the G7 countries.

Table 5
Panel Granger Causality Test

Null Hypothesis:	F-Statistic	Prob.
INV → GDP	0.945	0.333
INF →GDP	0.001	0.996
GCG →GDP	2.482	0.118
FBS →GDP	5.719	0.018*
MTS →GDP	4.814	0.030[a]

Note: *, [a], and [b] denote statistical significance at the 1%, 5%, and 10% levels, respectively.

6. Conclusion

In this study, we sort to investigate the effect of mobile telephone and broadband uses on economic growth in the G7 countries, using macro-level data throughout 2000-2017. To the best of our knowledge, no previous study has been comprehensively conducted to investigate the effect of these two ICT indicators on economic growth using a single panel dataset. Therefore, this study fills the gap empirically using Pedroni and Kao cointegration, FMOLS, DOLS, and panel Granger causality tests. Our empirical findings reveal that mobile telephone use contributes to the economic growth in the G7 countries. %1 increase in mobile phone subscriptions per 100 inhabitants increases around 0.1% of GDP in the long-run. Moreover, changes in mobile phone use lead to changes in the GDP. This indicates how a mobile phone is an important driver for GDP. Our findings also show that broadband use is associated with increased economic growth in the long-run in G7 countries. The broadband expansion causes economic growth.

If policymakers in the G7 countries aim to accelerate economic growth in their countries, then their attention should also be directed towards ICT drivers such as mobile telephone and broadband uses in the long run. Thus, policymakers should first understand the importance of the ICT drivers and then they have to facilitate ICT investments via either subsidizing them or accelerating telecommunication-related reforms in their countries.

Further studies are necessary for this topic to detect the effects of mobile telephone and broadband uses on economic development in the different regions and developing countries, although Our findings provide strong empirical results. Furthermore, one of the main limitations of this study is that we had access to only 18 years of the dataset. Thus, further study might be conducted in the future with access to a longer dataset which will provide more robust results.

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