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SPREAD OF ICT AND ECONOMIC GROWTH IN PACIFIC ISLAND COUNTRIES: A PANEL STUDY

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ABSTRACT

This paper investigates the impact of information and communications technology (ICT) on economic growth in Pacific Island countries by employing an augmented production function model and panel data analysis from 2002 to 2017. The empirical findings reveal that ICT-related indicators have a positive and significant impact on the economic growth process, along with the fundamental variable of capital stock. The effect of control variables such as foreign direct investment and exports have a positive effect on the real gross domestic product per capita, whereas inflation has a negative effect. The sensitivity evaluation of ICT indicators with different control variables produces consistent evidence of ICT's effect on economic growth. Policymakers as well as ICT stakeholders should enhance investments for improving ICT-related infrastructure and promoting technology to boost economic growth in Pacific Island countries.

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I. INTRODUCTION

Economic growth is a critical factor for a country's wellbeing. Various speeds of the economic growth process have had substantially different impacts on welfare, and different economies experience different living conditions due to growth divergence and patterns that vary over time. Since the early 18th century, several theories of economic growth have evolved (Solow, 1956; Romer, 1986; Lucas, 1990), and there is a large volume of literature on the different factors of economic growth. However, attention to factors related to information and communications technology (ICT) in economic growth have not received much attention, since ICT emerged as an influential factor only in recent years.[1] The role of ICT is now recognized as one of unifying communications, since it integrates telecommunications, computers, wireless signals, as well as software, not only enabling individuals' access to information but also promoting businesses and accelerating productive economic activities.

The development of ICT-related technology has been recognized as a primary conduit for more job creation and economic growth. Improved advancements in ICT have been determined as the main transformer of economic activities and international trade (World Bank, 2017). Given the improvement in the productivity rates of advanced and developed economies since the 1990s, use and development of ICT capital have been extraordinary (Venturini, 2006).

The greater utilization of ICT has reduced the cost of communications, which ultimately enhance the flow of information and the production of output. ICT is a symbol of technological change and a main factor in the economic growth of industrial countries (Farhadi et al., 2012). Since the last couple of decades, the development of mobile phones and the Internet has facilitated the spread of ICT-related technologies. This rise in ICT has connected countries worldwide. Today, economies are linked more than ever before, thanks to thriving ICT-supported economic activities.

For many researchers and policymakers, development and investment in ICT are important for generating entrepreneurship, employment, economic growth, and improvements in living conditions. ICT can play an important role in R&D, international trade, and financial inclusion. It also enhances the productivity and skills of the labor input, which indirectly influence economic growth. Similarly, ICT plays a critical role in other sectors of the economy, such as in the development of e-commerce, education, transportation, tourism, and travel (Xing, 2018). Technology has also become a cornerstone for the banking and financial systems, since it enables them to avoid black economic activities, reduce costs, reach unbanked segments of the population, and improve the stock value of firms in the market (Lin and Lin, 2007; Jayaraman and Makun, 2019).

Studies on the relation between ICT and economic growth are increasing within the broad area of growth economics. Researchers and the literature mostly focus on developed and Organisation for Economic Co-operation and Development (OECD) countries and use common indicators of ICT, such as the numbers of

[1] Although modern growth theories focus on technology such as research and development (R&D), knowledge, and innovation, the detail and specific level of analysis of this proposition are open to debate and have recently attracted the research attention.

broadband subscriptions, Internet users, and fixed telephone lines (Waverman et al., 2005; Zahra et al., 2008; Kaur and Malhotra, 2014; Aghaei and Rezagholizadeh, 2017), perhaps because these indicators are more prevalent in these countries. Nevertheless, these studies flout the spread of ICT pervasiveness in small developing countries and other important indicators of ICT, such as mobile phone subscriptions and the percentage of people with access to the Internet, which is prevalent and rising in small developing countries.

Studies on small, developing Pacific Island Countries (PICs) are inadequate. Although Kumar et al. (2015) have attempted to investigate the impact of ICT on economic growth for small island states, they only use two independent variables as ICT indicators: capital stock and access to telephone landlines. The authors do not take into account the impact of ICT as a mode of communication and Internet use, such as the number of mobile phone subscriptions (GSM Association, 2016).[2] Further, their study ignores other factors that give rise to suspected bias due to omitted variables (Ishida, 2015).

Given the paucity of studies on PICs, which are now experiencing the rapid spread of ICT, we seek to investigate the impact of ICT on economic growth, using a panel study of five major countries,[3] namely, Fiji, Samoa, the Solomon Islands, Tonga, and Vanuatu. These are the only small PICs with a reliable and consistent database on national income and ICT-related indicators. Further, our study differs from others because it departs from the usual bivariate approach—adopted by, for example, Datta and Agarwal (2004), Kumar et al. (2015), and Dewan and Kraemer (2000)—thereby avoiding any likely bias due to omitted variables. Unlike in earlier studies, which use a single ICT indicator, we use three different indicators (mobile phone subscriptions, access to the Internet, and fixed telephone subscriptions) to examine how they influence economic growth and to investigate whether the general impact of ICT variables on growth remains steady given individual effects. This paper also investigates whether the results are robust to different estimation techniques and control variables, which include export as a percentage of the Gross Domestic Product (GDP), Foreign Direct Investment (FDI) as percentage of the GDP, external debt, and a financial sector development indicator such as broad money as a percentage of the GDP.

With respect to economic growth, PICs have not performed very well. While some have done better than others, their growth generally remains modest and

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2 Fiji has the highest unique subscriber penetration rates for mobile phones (83%), followed by Palau (64%), Tonga (58%), Vanuatu (53%), the Solomon Islands (47%), and Samoa (43%). In most of the other countries, about one-half of the population has a mobile phone subscription. About 50% of Fiji's population also has access to the Internet through mobile phones.

3 The five PICs, which are permanent members of the World Trade Organization, have agreed to liberalize their telecommunications industry under four modes of service supply under the General Agreement on Trade in Services (GATS): mode 1 is cross-border supply; mode 2 is consumption abroad; mode 3 is a commercial presence, including services supplied by foreign-owned companies; and mode 4 is the presence of natural persons to provide commercial services. The manner in which some of these countries have opened up their telecommunications industry can be described as fractional entry with ensured conditions within the sector for regulating foreign entrants. Moreover, of the five PICs, three (Tonga, Samoa, and Vanuatu) have made commitments under the GATS framework of the World Trade Organization in terms of value-added services in the telecommunications industry.

they have not achieved their economic growth potential (AusAID, 2006; Chand, 2006). PICs face several challenges in their quest for economic development, including their geographical distance from major international markets, rising business costs, and the lack of opportunities for economies of scale. However, the use of ICT in recent years has reduced some of these barriers to development. Hence, analyzing the dynamic role of ICT in enhancing the growth potential of PICs is important.

The major implication of this research is that ICT has a positive effect on PICs' economic growth. We suggest policies that encourage greater investment, access, and use of ICT-related technologies, especially mobile phone subscriptions and access to the Internet, to enhance economic growth.

The paper is organized as follows. Section II reviews the literature on ICT and economic growth. Section III provides a theoretical framework and describes the data. Section IV presents the estimation methodology and the results. Finally, Section V provides the study's conclusions, with policy implications.

II. LITERATURE REVIEW

The literature on ICT and economic growth is mostly based on growth accounting and empirical analysis. The literature has generally focused on large developing and developed countries. Although ICT development has diverged between developed and emerging economies (Rath, 2016), many of these studies confirm ICT's positive role in the economic growth process, especially after the 1990s in developed economies. For instance, Jorgenson and Stiroh (2000) focus on the productivity implications of ICT in the United States and find ICT to have a positive effect on growth. Inklaar et al. (2005) compare the role of ICT between Europe and the United States from 1979 to 2000 and show that its contribution is greater in the United States. Similarly, Jalava and Pohjola (2008) examine the contribution of ICT and electricity on economic growth in Finland in a panel regression setting for the period 1990–2004. They show that ICT's contribution to the GDP is greater than Finland's electricity consumption.

The theoretical research also mostly envisages ICT having a positive impact on GDP in developed and developing countries. Quah (2002) contends that the evolution of ICT is enhancing education and labor skills overall. Greater use of ICT-related technology raises labor productivity and consequently increases economic growth. Levine (1997) contends that ICT helps provide access to information and induces investment and economic growth.

More recently, numerous researchers from the OECD and the European Union have also confirmed the productive influence of information- and communication-related technologies on economic growth (Edquist and Henrekson, 2004, 2017; Falk and Biag, 2015). Showing a positive impact of the Internet, mobile phones, and R&D on economic growth, these studies suggest that the diffusion of technology also improves the contribution of R&D and human capital, which indirectly leads to economic growth.

Saidi and Mongi (2018) use a panel data set to examine the causal link between ICT, education, R&D, and the GDP. They show evidence of significant effects of ICT and R&D on the GDP. The results also reveal bidirectional causality between

ICT and R&D in the short run, whereas education and ICT exhibit long-run causality. Majeed and Khan (2018) find evidence that ICT can help improve a population's health outcomes. Consequently, a healthy population contributes more to economic growth.

Some of the literature also examines how the beneficial effects of ICT-related innovation can be exploited to obtain faster and more sustainable levels of economic growth. Several studies have been undertaken in this area. For example, Roller and Waverman (2001) show that improvements in the telecommunications sector play an important role in economic growth through FDI and other positive spillovers. Vu (2004) suggests that greater benefits of ICT can be obtained by understanding language, reforms in education, and improving institutional quality.

Similarly, other studies look solely at the impact of communications technology. For instance, Roller and Waverman (2001) use a sample of 21 OECD economies to demonstrate that wireline telecommunications contribute positively to their economic growth. Czernich et al. (2011) find similar evidence in a panel of 20 OECD economies. They show that the development of Internet broadband caused an increase in the GDP per capita growth rate. Further, Bertschek et al. (2015) have reviewed various studies and confirm the favorable impact of Internet broadband on economic growth.

Furthermore, other studies have examined the role of landline and mobile phone use in furthering economic growth in less developed economies through the spread of telecommunications, lessening the digital divide, and investing in people through policy initiatives (Waverman et al., 2005). Kozma (2005) argues that confidence with respect to ICT-related technology prevails, in that it can play a crucial role in poverty reduction, institutional system reforms, productivity, and economic growth. Becchetti and Adrani (2005) suggest that ICT plays a key role in the conditional growth convergence of economies. More recently, Rath and Hermawan (2019) have used different indicators to find that ICT has had a positive effect on Indonesia's long-run economic growth, although the magnitude of the effect is very small.

In contrast, there is research that shows ICT to have a negative impact on economic growth. For instance, Stiroh (2002) uses an industrial data set from 1984 to 1999 for the United States to show evidence of the negative effect of ICT. Similarly, for the United Kingdom, O'Mahony and Vecchi (2005) find ICT to have a negative effect on industry output levels, which they suggest is due to low skill levels and a lack of ICT investment. Lee et al. (2005) argue that technology affects economic growth through various mechanisms, such as FDI spillover. Their results indicate that developing economies do not benefit from ICT due to low levels of productivity. According to Hofman et al. (2016), the contribution of ICT in Latin American countries is small.

Yet another group of studies presents inconclusive findings on the ICT–economic growth nexus, particularly with respect to emerging and developing economies. For example, Dewan and Kraemer (2000) examine more than 30 countries for the period 1985 to 1993. They show that, although investment in ICT-related facilities has a beneficial and statistical significant impact on more developed nations, it is not substantial for less developed economies. Pohjola (2002), using data on 43 countries from 1985 to 1999, finds a nonsignificant relation concerning ICT and economic output; however, the findings have been disputed by recent studies, where ICT has a significant effect on economic growth (Niebel, 2018; Stanley et al., 2018). Similarly, Jacobsen (2003) separately studies 84 countries from 1990 to 1999 and shows the growth effect of computer technology to be nonsignificant.

Steinmuller (2001) argues that ICT allows less developed nations to achieve higher growth rates. A leapfrogging approach allows these nations to skip a few of the steps associated with the capacity building of developed economies. The author states that every country can take advantage of such leapfrogging. For nations to conquer any problems hampering these opportunities, the World Bank (2017a) argues that successful restructuring needs to be instituted by policymakers. Well-established national ICT strategies are vital for boosting private and public investment in ICT-related technologies and to create more affordable access for low-income populations. King et al. (1994) argue that organizations are enormous influencers that can promote an excellent ICT investment environment. Governments can expand the stock of human capital by supporting advanced education, e.g., which will provide further ICT investments.

The literature review above shows few gaps in the literature on the ICT–economic growth nexus. First, the literature has mostly focused on large developing and developed economies, paying very little attention to small developing economies. Second, some studies also question the positive effect of ICT and show mixed outcomes for the ICT–economic growth nexus. Third, previous studies have mostly used similar ICT indicators, such as investment in ICT, Internet access, and the number of fixed telephone and broadband Internet subscribers. However, this study contributes to the current literature by analyzing the dynamic effects of ICT in five small developing PICs, using three different ICT indicators, as well as control variables. Moreover, this paper also examines whether the results are robust to different estimation techniques and control variables.

III. THEORETICAL FRAMEWORK AND DATA

A. Theoretical Framework

Our econometric modeling procedure stems from the standard Cobb–Douglas production function utilized by Solow (1956), which was also employed by Rao (2007), Rao et al. (2008), and Kumar et al. (2015), with Hicks-neutral technological development. In Solow's (1956) framework, the long-run growth rate is explained by the rate of growth of technical progress (total factor productivity), which is exogenously determined. Hence, it is reasonable for us to extend and capture the growth effects of ICT and other growth-enhancing variables.

Following Solow framework, we can express the output per capita as:

$$y_t = A_t k_t^{\alpha}, \quad 0 < \alpha < 1 \tag{1}$$

where, y_t is output per capita; A_t is the stock of technology, also known as total factor productivity; k_t is the stock of capital, and a is the share of capital.

The model assumes that the evolution of technology is given by

$$A_t = A_o e^{gt} \tag{2}$$

where, A_0 is the initial stock of technical expertise, also known as total factor productivity, and g represents the trend of technology growth over time t. The effects of ICT indicators on A_t (total factor productivity) are realized when the right-hand side variables enter into the functional form as shift variables.

Hence, it is plausible to write

$$A_t = f(ICT_t) = ICT_t^{\beta} \tag{3}$$

Here, A_t is part of the technology component in Equation (1) and can therefore be redefined and expressed as:

$$A_t = A_o e^{gt} ICT_t^{\beta} \tag{4}$$

Thus, the augmented Solow growth model is further modified as:

$$y_t = A_o e^{gt} ICT_t^{\beta} k_t^{\alpha} \tag{5}$$

For the purpose of estimation, the above model is transformed into logarithmic form[4] and rearranged as:

$$lny_t = \alpha_0 + \alpha_1 lnk_t + \beta_1 lnICT_t + \varepsilon_t \tag{6}$$

Similarly, Equation (6) is further augmented by including several other control variables to explain economic output, such as FDI, export, and inflation:

$$lny_t = \alpha_0 + \alpha_1 lnk_t + \beta_1 lnICT_t + \beta_2 lnFDI_t + \beta_3 lnEXP_t + \beta_4 lnINF_t + \varepsilon_t \tag{7}$$

where, *ICT* represents three indicators, that is, (i) the number of mobile subscriptions per 100 inhabitants, (ii) the percentage of individuals with access to the Internet, and (iii) the number of fixed telephone line subscriptions per 100 inhabitants; *EXP* is exports of goods and services as a percentage of the GDP; *FDI* is FDI as a percentage of the GDP; and *INF* is the annual inflation rate. The hypotheses which are to be tested are that the variable *ICT* is positively associated with the dependent variable, namely, the GDP per capita, and hence the signs of all the ICT indicators are expected to be positive and significant.

[4] The variables were appropriately converted into logarithmic form before they were used in the regression analysis. Utilization of the variables in logarithmic form not only reduces errors but also enables us to obtain the elasticity estimates of the variables.

B. Data

The 16-year (2002–2017) data series for the panel of five PICs (The Fiji Islands, Samoa, the Solomon Islands, Tonga, and Vanuatu) in the study are drawn from three sources. The data for the real GDP per capita in US dollar constant prices (2010), *FDI* as a percentage of the GDP, exports as a percentage of the GDP, and inflation as a percentage are sourced from the World Bank's (2019) World Development Indicators. The data on capital stock per capita in constant US dollars (2010) are obtained from the Penn World Table (Feenstra et al., 2015). The ICT indicators are obtained from the International Telecommunication Union database.

The summary statistics of the variables and correlation matrix are reported in Panels A and B of Table 1, respectively. The sample observations are grouped and consist of all five PICs, including their maxima, means, skewness, kurtosis, Jarque–Bera test statistics, p-values and variations of ICT indicators, real GDP, and other control variables. With respect to correlation, the ICT indicators are positively associated with the per capita GDP; capital stock has a positive correlation, about 0.83; and exports and FDI have correlations of about 0.04 and 0.15, respectively. Inflation has a negative correlation with the real GDP per capita.

Table 1.
Summary Statistics of Variables and the Correlation Matrix

In Panel A of this table, we provide the summary statistics of all the variables employed in the regression. All variables are examined in level form. In Panel B, we provide correlation matrix of the variables. *y* is real GDP per capita in US$, *k* is real capital stock per capita in US$, *EXP* is export as percent of GDP, *FDI* is foreign direct investment percent of GDP, *INF* is inflation in percentage, *MOB* is the internet subscription per 100 inhabitants, *INT* is internet access (percent of users per 100 inhabitants) and *FT* is fixed telephone subscription per 100 inhabitants.

Panel A: Summary Statistics								
Stats/variable	***y***	***k***	***EXP***	***FDI***	***INF***	***MOB***	***INT***	***FT***
Mean	2961.392	12135.800	36.794	4.915	4.342	46.375	14.535	8.565
Median	3412.028	13675.390	38.168	3.341	2.955	52.363	9.000	5.918
Maximum	4322.986	16587.810	62.841	24.359	17.320	119.749	49.966	30.461
Minimum	1062.325	5804.161	12.154	0.043	-2.342	0.230	0.502	1.164
Std. Dev.	944.454	3472.649	14.189	4.506	4.064	33.725	13.088	7.916
Skewness	-0.877	-0.879	-0.043	1.551	1.301	0.204	1.046	1.288
Kurtosis	2.410	2.373	1.867	6.431	4.733	2.074	2.899	4.071
Jarque-Bera	10.700	10.894	4.036	66.879	30.541	3.198	13.706	24.332
Probability	0.005	0.004	0.133	0.000	0.000	0.202	0.001	0.000
Observations	80	80	80	80	80	80	80	80

Panel B: Correlation Matrix								
	y	***k***	***EXP***	***FDI***	***INF***	***MOB***	***INT***	***FT***
k	0.827	1.000						
EXP	0.042	0.001	1.000					
FDI	0.153	0.126	0.371	1.000				
INF	-0.235	-0.239	-0.099	0.092	1.000			
MOB	0.461	0.321	0.192	0.026	-0.383	1.000		
INT	0.591	0.458	-0.003	-0.076	-0.326	0.839	1.000	
FT	0.582	0.538	-0.391	-0.156	-0.010	0.150	0.259	1.000

IV. ESTIMATION METHODOLOGY AND RESULTS

A. Estimation Methodology

To examine the impact of ICT on economic growth, this study employs panel estimation procedures for the group of countries under study. Panel data are two dimensional, with cross-sectional and time series data. Hsiao (2007) lists the two main advantages of panel data analysis that have led to its popularity: (i) data accessibility and (ii) the ability to model a wide range of human behaviors. Hurlin (2010) identifies other reasons to favor panel data analysis: it allows for (i) large data sets, raising the number of degrees of freedom, (ii) greater scope for economic analysis relative to time series, and (iii) the ability to control for bias arising from omitted variables. However, Hurlin cautions about unobserved heterogeneity in panel analysis, since large data sets do not necessarily provide more information.

We begin by applying four different panel unit root tests (Maddala and Wu, 1999 - Fisher-ADF; Maddala and Wu, 1999 - Fisher-PP; Levin, Lin, and Chu, 2002; Im, Pesaran, and Shin, 2003) to examine the integration order of the variables. The results of the four different panel unit root tests are reported in Table 2. They show that the null hypothesis of non-stationarity cannot be rejected in terms of levels; however, it is rejected for the first-difference form. Thus, we reach the overall conclusion that the variables in the model are integrated of order I(1).

Table 2.
Panel Unit Root Test Results

This table reports results from panel unit root tests. In Panel A, variables are considered in level form while in Panel B variables are in first difference form. LLC and IPS indicate, respectively, the Levin et al. (2002) and Im et al. (2003) panel unit root tests. MW (ADF) and MW (PP) represent Maddala and Wu (1999) and Fisher-ADF and Fisher-PP panel unit root tests. The LLC, IPS, MW (ADF) and MW (PP) all test the null hypothesis of non-stationarity. The values in brackets are the probabilities for the test of the null hypothesis. The lag length is chosen based on Schwartz Information Criterion with a maximum of 4 lags. All variables are in log form. Finally, *, ** and *** indicate significance level at 1%. 5% and 10 % respectively.

Variables	**Test statistics (probability values)**				
Panel A: In Level	**LLC**	**IPS**	**MW(ADF)**	**MW(PP)**	**Conclusion**
y	0.6718(0.250)	0.9722(0.8345)	5.9727(0.8175)	6.2992(0.789)	-
k	2.8548(0.322)	0.8068(0.2089)	13.430(0.2006)	16.197(0.094)	-
FDI	2.3075(0.210)	0.3390(0.3673)	10.231(0.4204)	14.827(0.138)	
EXP	0.9352(0.174)	0.5732(0.2833)	11.028(0.3553)	13.669(0.188)	-
INF	1.1089(0.133)	0.7683(0.7789)	9.5854(0.4549)	17.7613(0.059)	
MOB	1.9162(0.427)	0.7177(0.7636)	5.6669(0.8424)	7.7835(0.650)	-
INT	1.2340(0.891)	1.6132(0.9467)	2.9382(0.9828)	2.0427(0.996)	
FT	3.1671*(0.000)	0.0967(0.4615)	10.332(0.4118)	2.0525(0.995)	
Panel B: First Difference					
y	3.3075*(0.000)	2.4030*(0.008)	23.235*(0.009)	31.605*(0.000)	I (1)
k	6.1825*(0.000)	1.9369**(0.026)	24.071*(0.007)	6.0151*(0.000)	I (1)
FDI	1.9207**(0.027)	2.5427*(0.005)	23.691*(0.008)	86.313*(0.000)	I(1)
EXP	5.6599*(0.000)	4.0625*(0.000)	35.573*(0.000)	53.437*(0.000)	I (1)
INF	1.7917**(0.036)	2.7314*(0.0032)	25.512*(0.004)	86.350*(0.000)	I (1)
MOB	2.8945*(0.001)	2.3198**(0.010)	21.940**(0.015)	40.616*(0.000)	I (1)
INT	1.7247**(0.042)	1.6203**(0.052)	24.907*(0.005)	26.724*(0.002)	I (1)
FT	2.3201**(0.010)	1.4096***(0.079)	24.018*(0.002)	25.208*(0.001)	I (1)

B. Panel Regression Results and Discussion

B.I. Pooled Ordinary Least Squares (OLS) Results

After examining the stationarity properties of the variables, we estimate the long-run impact of ICT indicators and other control variables on real economic output. Panel data allow for large numbers of degrees of freedom, great sample variability, and the capability to account for complex human behaviors relative to cross-sectional data. Panel analysis provides rather accurate predictions of outcomes by pooling the data sets (Hsiao, 2007). Accordingly, for validity and accuracy, our estimation uses three models: a pooled panel OLS model, a fixed effects model, and a random effects model. Table 3 presents the results of the pooled OLS regression analysis for the five PICs from 2002 to 2017.

Table 3.
Pooled OLS Results for ICT and Economic Growth

This table provides the long run results between economic growth (*y*) and three *ICT* indicators along with other independent variables based on the pooled OLS estimator. We estimate three different proxies of *ICT* with fixed control variables in each regression and report results in columns (1), (2) and (3). All three regressions are estimated with White-Period coefficient covariance to avoid heteroscedasticity. The *t*-statistics are in parentheses. Finally, ***, ** and * indicate levels of significance at the 1%, 5% and 10%, respectively.

	(1)	**(2)**	**(3)**
Variables	*y*	*y*	*y*
Capital stock	0.9175***	0.8954***	0.6954***
	(15.002)	(12.681)	(9.3456)
FDI	0.0239***	0.0198	0.0046
	(3.7543)	(1.1165)	(0.3198)
Export	0.0028	-0.0316	0.1085**
	(0.5902)	(-0.6131)	(2.2335)
Inflation	0.0110	0.0121	-0.00514***
	(0.5697)	(0.5743)	(-2.9575)
Mobile Cell-Subs	0.0832***		
	(5.3947)		
Internet access		0.00991***	
		(4.0413)	
Fixed Tele-Subs			0.1755***
			(6.3245)
Constant	-0.3448	-0.2315	0.3471
	(-1.3216)	(-0.7847)	(1.2263)
R-squared	0.8481	0.8259	0.8815
Observations	77	77	72

Column (1) of Table 3 provides clear evidence of a positive, statistically significant relation between ICT and economic growth. The estimated coefficient of the number of mobile cellular subscriptions (*Mobile Cell-Subs*) shows that a 1% increase in mobile cellular subscriptions leads to a 0.08% increase in the real GDP per capita. This is because mobile subscriptions enhance access to information, including products and services, reduces communication costs, and improves productivity, thereby boosting economic growth. This finding is in line with theoretical expectations and observations that mobile phones are widely used and accessible relative to other substitutes for overcoming the hurdles imposed by geographical distances and transactional costs. The findings are consistent with Majeed and Ayub (2018).

Column (2) of Table 3 shows a significant and positive association between Internet access and economic growth. The elasticity coefficient of the Internet access variable indicates that a 1% increase in Internet access causes a 0.009% increase in economic growth. Internet access provides information, including economic and employment opportunities, boosts the efficiency of businesses, and moderates transactional frictions in the economy. This result is consistent with the study of Jin and Cho (2015).

Column (3) of Table 3 depicts a positive and statistically significant relation between fixed telephone line subscriptions (*Fixed Tele-Subs*) and economic growth, indicating that a 1% increase in fixed telephone subscriptions causes a 0.17% increase in the real GDP per capita. The results confirm the beneficial effects of ICT-related technologies on economic growth, with ICT improvements opening up greater opportunities and bringing benefits to different sectors of the economy. ICT plays a critical role in bringing about inclusivity among the population, including access to information and economic opportunities, thereby helping economies in their growth process (Jin and Cho, 2015; Saidi and Mongi, 2018).

The effects of the control variables are found to be in line with the theoretical expectations and findings of previous research. In all three regressions, capital stock has a positive and empirically significant effect on the real GDP per capita, with coefficients ranging from 0.69 to 0.91. The higher share of capital stock could be due to the pooling of data sets without controlling for heterogeneity among the countries.

Exports of goods and services also have a positive effect on economic growth. The coefficients of exports indicate that a 1% increase in exports raises the real GDP per capita by 0.002% and 0.1% (column 1 and 3). Exports remain an important source of foreign exchange and employment in PICs and are fundamental for economic growth. This finding is consistent with the works of Romer (1990) and Dollar and Kraay (2002).

We find that controlling for FDI has a positive effect on economic growth for all three models. However, in some cases, FDI lacks statistical significance. Perhaps not all countries attract the same levels of foreign investment. For instance, some of the smaller PICs, such as Samoa and Tonga, receive comparatively low levels of FDI. On average, their FDI inflows account for less than 2% of their GDP. The effect of inflation on economic growth is negative.

B.II. Fixed Effects Results

Pooled OLS pools all the data sets ($N*T$) and runs a regression ignoring the cross section and time series effects. Therefore, the technique does not distinguish between countries, since they all have the same coefficients. However, this assumption might not be realistic (Gujarati and Porter, 2009). Although the countries in our sample are similar in terms of characteristics, since they are from the same Pacific region and of similar size, each is unique in terms of their ICT industry. Grouping all the countries together neglects their potential heterogeneity. Further, ignoring individual country characteristics is likely to instigate endogeneity bias. One way in which endogeneity propagates is through omitted variable bias. The fixed effects model is more reasonable for modeling unobserved individual heterogeneity across economies and to control for omitted variable bias (Williams, 2017).

Table 4 presents the results based on the fixed effects model for ICT indicators and economic growth. These fixed effects model results are consistent with the initial pooled OLS findings. In column (1), mobile cellular subscriptions exert a strong positive effect on economic growth. A 1% increase in mobile subscriptions leads to an increase of about 0.08% in the real GDP per capita.

The results in column (2) of Table 4 reveal a positive relation between Internet access and economic growth, while column (3) shows that fixed telephone line subscriptions and economic growth are positively related, indicating a 1% increase in fixed telephone line subscriptions causes a 0.06% increase in the real GDP per capita. The effects of the control variables are also consistent with the pooled OLS results. The share of capital stock is positive and statistically significant in all three regressions, with coefficients of 0.18, 0.20, and 0.27 respectively. This finding is consistent with the work of Rao et al. (2008).

Table 4.
Fixed Effect Results for ICT and Economic Growth

This table provides long run results of ICT and economic growth based on fixed effect model. Three important *ICT* indicators (mobile cellular subscription, internet access and fixed telephone) whose data is available were estimated with same control variables and results are in column (1), (2) and (3). **y** is per capita output and is the dependent variable in the regression. Heteroscedasticity is controlled by applying Whites period coefficient covariance in estimation. T-ratios are in parentheses. ***, ** and * indicates level of significance at 1%, 5% and 10%.

	(1)	**(2)**	**(3)**
Variables	*y*	*y*	*y*
Capital stock	0.1807** (2.439)	0.2037** (2.2892)	0.2740*** (3.2697)
FDI	0.0186* (2.1102)	0.0041 (0.8768)	0.0011 (0.2094)
Export	0.0304*** (4.7481)	0.0582* (1.9960)	0.0278 (0.7911)
Inflation	0.0031 (0.6684)	-0.0084* (-1.5543)	-0.0766*** (-3.5257)
Mobile Cell-Subs	0.0880*** (6.4921)		
Internet access		0.0560*** (7.0527)	
Fixed Tele-Subs			0.0674*** (3.1444)
Constant	4.1047*** (13.486)	3.9915*** (10.062)	3.0102*** (6.7217)
R-squared	0.8698	0.9204	0.9883
Observations	77	77	75

B.III. Random Effects Results

Further, although the fixed effects model addresses likely heterogeneity between the five countries, since each country has a different intercept, the intercepts do not vary over time and tend to be time invariant. For the fixed effects to perform efficiently there should be variability within the subject of the variables. Williams (2017) argues that, if there is no variability within the subject, fixed effects estimation results could produce very high standard errors. Similarly, Nwakuya and Ijomah (2017) argue that the fixed effects model cannot examine the time-invariant cause of the variables. On the other hand, a random effects model enables random variability across countries, without correlations between explanatory variables. Hence, it will utilize the entire data set, produce unbiased coefficients, and yield lower standard errors in the estimates (William, 2017).

Table 5 presents the findings from a random effects model. Interestingly, they remain consistent. The results show evidence of a positive and statistically significant relation between ICT indicators and economic growth in PICs. The effects of the control variables (*FDI* and *Export*) are positive, whereas inflation has a negative effect. Overall, the results of empirical analysis of the panel data suggest that ICT-related technology is beneficial for the economic growth process. The number of mobile cellular subscriptions, Internet access, and the number of fixed telephone subscriptions are all statistically significant and essential to economic growth. The estimated coefficient indicates that a 1% increase in these ICT-related indicators, on average, increases output by 0.07–0.17%. Although the magnitude of this coefficient is small, it points to the significance of ICT use and access in the economic growth process of PICs. For small developing island economies, as in PICs, where ICT development is costly and low relative to developed economies and even regional neighbors such as Australia and New Zealand, the positive contribution of ICT to economic output is remarkable.

Table 5.
Random Effect Results for ICT and Economic Growth

This table provides the long run estimated coefficient for ICT and economic growth model based on random effect model. *y* denotes economic growth and is the dependent variable. The independent variable of *ICT* is proxied by mobile cellular subscription, internet access and fixed telephone along with some fixed control variables. We report results of each of the regressions in columns (1) to (3). Panel Corrected Standard error (PCSE) is used in random effect estimation. T-ratios are in parentheses. ***, ** and * indicates level of significance at 1%, 5% and 10%.

	(1)	(2)	(3)
Variables	*y*	*y*	*y*
Capital stock	0.3377*** (5.8695)	0.3116** (2.3346)	0.3593*** (2.7309)
FDI	0.0223*** (6.0358)	0.0264*** (3.2590)	0.0564** (1.9174)
Export	0.0308** (2.8248)	0.0540 (0.4053)	0.0894 (1.8895)**
Inflation	-0.0181** (2.3006)	-0.0163** (-1.9355)	-0.0213** (-2.4534)
Mobile Cell-Subs	0.0784*** (2.3638)		
Internet access		0.0916*** (6.1007)	

Table 5.
Random Effect Results for ICT and Economic Growth (Continued)

	(1)	(2)	(3)
Variables	*y*	*y*	*y*
Fixed Tele-Subs			0.1750*** (3.4635
Constant	3.0257* (5.7851)	3.5073* (6.3727)	4.2065** (2.6634)
R-squared	0.7859	0.8229	0.8813
Observations	80	80	80

To verify the appropriateness of the fixed effects and random effects models, we conduct redundant fixed effects and correlated random effects Hausman tests. The results of these two tests are presented in Table 6. The null proposition for the redundant fixed effects test is that the fixed effects are redundant. In Panel A, for the fixed period test, the null hypothesis is easily rejected, indicating that fixed period effects are not redundant. However, the p-values for the cross-sectional fixed tests are nonsignificant, indicating that the null hypothesis cannot be rejected and the effects are redundant. This finding implies that the omitted variable bias effect is not fixed for countries in the panel across time and that the random effects model would be appropriate.

However, in a random effects model, omitted variables are uncorrelated with the explanatory variables.[5] We therefore conduct a correlated random effects Hausman (1978) test (Gounder and Sharma, 2012). The results are reported in Panel B of Table 6. The results reveal that the null hypothesis of the random effects model cannot be rejected, implying that the random effects model is appropriate.

Table 6.
Fixed and Random Effects Test

This table has results on fixed and random effects test. In Panel A, we provide the result of the redundant fixed effect test. The null hypothesis is that the 'fixed effect is redundant'. In Panel B, we provide the result for correlated random effects model – the Hausman test. The null hypothesis is that the 'omitted variables are uncorrelated with explanatory variables'. Finally, * denotes significance at 1% level.

Panel A: Redundant fixed effect test		
Tests	**Statistic**	***p-value***
Period fixed	306.45*	0.0000
Period Chi-square	229.01*	0.0000
Cross section fixed	1.3673	0.1966
Cross section Chi-square	24.404	0.5850
Panel B: Correlated random effect - Huasman Test		
Test summary	***Chi-square* stats**	***p-value***
Period random	8.9346	0.2574

5 Angrist and Pischke (2008) suggest that, under the assumption of random effects, the errors of a given country could be correlated across periods. To this end, panel corrected standard errors are used in the random effects estimation.

C. Sensitivity Evaluation

We evaluate sensitivity as part of the robustness check for the ICT and economic growth findings presented in Section IV. In doing so, we use additional control variables, such as broad money, external debt, the labor force, and the fertility rate, to ensure that the positive effect of ICT on the real GDP per capita is robust.

Table 7 presents the estimated results for the ICT-related indicators after the introduction of four additional control variables. The effect of ICT indicators on the real GDP per capita is positive and steady for all four sensitivity test variables. The number of mobile phone subscriptions, Internet access, and the number of fixed telephone line subscriptions remain positive and statistically significant. Hence, the empirical results of the sensitivity evaluation indicate that the ICT effects on economic growth are robust and not susceptible to other variables in the empirical analysis.

Table 7.
Sensitivity Evaluation with Different Control Variables

In this table we provide the sensitivity evaluation of the long-run estimated coefficient. We applied the same procedure as noted in Table 5; however, here we have used different control variables in our regression. The *t*-statistics are provided in parentheses. Finally, *** indicates statistical significance at the 1% level.

ICT indicators	Broad Money	External Debt	Labour Force	Fertility Rate
Dependent variable: (y) Real GDP per capita				
Mobile Cell-Subs	0.0856***	0.0782***	0.0776***	0.0720***
R-squared	(6.3065)	(5.3389)	(5.3896)	(4.9680)
	0.865	0.845	0.846	0.852
Internet access	0.1110***	0.0941***	0.0943***	0.0828***
	(5.2315)	(4.2393)	(4.1736)	(3.5014)
R-squared	0.8495	0.827	0.826	0.831
Fixed Tele-Subs	0.1642***	0.1255***	0.1277***	0.1028***
	(5.0656)	(4.6217)	(4.9099)	(3.6547)
R-squared	0.859	0.853	0.858	0.862

V. CONCLUSION

This paper explores the effects of ICT on economic growth in PICs. While previous work on the subject has mostly examined large developing and developed countries, our focus on PICs adds another aspect to the literature. To empirically accomplish our objective, we use a neoclassical growth framework and panel data analysis for five PICs from 2002 to 2017. The results are based on pooled OLS, fixed effects, and random effects estimation techniques. Our main findings can be summarized as follows. First, all the ICT indicators have a positive and statistically significant effect on economic growth. This result indicates that ICT-related technological development is beneficial for the long-term economic growth process of PICs, even though the magnitudes of some of the indicators are modest. Second, in addition to the ICT indicators, we use control variables and determine their impact on economic growth. Exports and FDI have positive effects on the real GDP per capita, whereas inflation has a negative effect. Third, we subject the effects of the ICT indicators to different sets of control variables to evaluate the sensitivity of the findings. The results remain robust in sensitivity tests. Our findings invite governments and policymakers as well as ICT stakeholders to re-examine their policies to attract investment to improve the ICT infrastructure and increase access and use of these technologies to boost economic growth.

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