ARTICLE IN PRESS

Telecommunications Policy ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Telecommunications Policy

URL: www.elsevier.com/locate/telpol

Accounting for telecommunications contribution to economic growth: A study of Small Pacific Island States

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ARTICLE INFO

Keywords:
Telecommunications
Economic growth
ARDL bounds approach
Causality
Small Pacific Island States

ABSTRACT

Noting the developments in the telecommunications sector in Small Pacific Island States (SPIS), this paper explores the effect of telecommunications on per worker output over the periods 1979–2012. We use the ARDL bounds procedure within an augmented Solow framework to explore the effects. Additionally, we examine the causality effect using the Toda and Yamamoto procedure. The results show that telecommunications contribute 0.33% in the short-run and 0.43% in the long-run to output per worker; a bidirectional causality between capital per worker and output per worker, and unidirectional causality from telecommunications to output per worker, and capital per worker, respectively, are noted. Subsequently, we emphasize the need for greater innovation and competition in the telecommunications sector, and linking cutting-edge communication technologies to key sectors to boost efficiency and productivity in the long-run.

1. Introduction

Telecommunication services have paved the way for greater advancement in technologies and shifted the digital frontier in many parts of the world. However, in a number of small and developing countries, telecommunications remain a growing sector which is undergoing major reforms in its effort develop to a level that it can efficiently interlink industries and speed-up production processes. In this paper, we examine the role of telecommunications viz. economic growth in the developing Pacific Island Small States (SPIS).

SPIS consists of Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Palau, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu (World Bank, 2014).[2] In many respects, the growth and development progress of these countries are constrained by a number of factors including, being sea locked, isolation from major markets, geographic standing, high cost of doing business, low economies of scale and vulnerability to natural disasters and emerging adverse

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[1] Tel.:+692 625 3206; cell: +692 456 4151; fax: 692 625 7471.
[2] Papua New Guinea (PNG) is not in the definition of SPIS category given that PNG is large both in terms of geography and population size.

http://dx.doi.org/10.1016/j.telpol.2014.08.005
0308-5961/

Please cite this article as: Kumar, R. R., et al. Accounting for telecommunications contribution to economic growth: A study of Small Pacific Island States. *Telecommunications Policy* (2014), http://dx.doi.org/10.1016/j.telpol.2014.08.005

climatic conditions.[3] However, in recent years, with the development of electronic and digital technologies, some of the barriers hampering development have been reduced. Amid these developments, the role of telecommunications has been pivotal.

The telephone services in the Pacific are crucial in enhancing communication and building network for various economic activities. Due to the nature of telecommunication services, which requires good infrastructure and locations for telephone lines to be placed, the expansion and use of the services have remained largely confined to urban and industrial areas. To support and speed-up economic activities, a number of small states are now opening up the communication sectors to competition and investment at the unilateral and regional levels. Although the phenomenon is only recent, the small states are now developing their telecommunication services and undergoing major reforms in its effort to expand and exploit the sector.

To our knowledge, there is no study done to explore the dynamics of telecommunications and economic growth in SPIS. The reasons for the gap in the literature includes: inconsistent and/or unavailability of data on telecommunication indicators for many (developing) countries; communications technology was in embryonic stage and hence was given a lesser priority and interest in the development agenda in the past; and there was no clear-cut method available to examine the macro-level effects of telecommunications. However with the help of the World Bank (2013, 2014) database which has recently published data on telecommunication indicators in SPIS as a group, we attempt to overcome these limitations and examine the growth effects accordingly. At the outset, we posit telecommunications technology to be a critical driver of growth which is likely to yield dividends in terms of productivity and efficiency gains if developed, managed and utilized appropriately. When the telecommunication services are augmented with mobile and wireless technology and effectively implemented in the key sectors of the economy, we expect further reduction in the factors impeding the flow of communication and trade, consequently causing scaling-up effect of major economic activities.

In regards to method, we adopt the augmented Solow (1956) model as the underlying framework. For analysis, we use the ARDL cointegration (Pesaran, Shin, & Smith, 2001), and the Toda and Yamamoto (1995) Granger-causality procedures, respectively. The rest of the paper is set out as follows. In Section 2, we present a brief literature survey followed by a summary of telecommunications development in SPIS in Section 3. In Section 4, we discuss the modelling techniques and present the respective results. Finally, Section 5 concludes.

2. A brief literature survey

The literature on the role of technology in speeding-up growth and development process dates back (implicitly) to the neo-classical growth theory (Solow, 1956) and became relatively more pronounced, if not explicit, in the modified growth models and recent studies (Katz, 2009; Minghetti & Buhalis, 2010; Romer, 1990). Admittedly, in early studies the definition of technology (or technological progress) was (implicit) not precisely defined. The basic assumptions of the conventional models were constant returns to scale, diminishing marginal productivity of capital, exogenously determined technical progress, and substitutability between capital and labour thus emphasizing the role of savings or investment ratio as crucial driver of short-run economic growth. Technological progress is considered a long-run phenomenon and exogenously determined. However, in the modified Solow model (Lucas, 1988; Romer, 1986), technological progress under the assumption of increasing returns to scale is broadly defined as new knowledge (Romer, 1990; Grossman & Helpman, 1994), innovation (Aghion & Howitt, 1992), public infrastructure (Barro, 1990), among other things (Rao, 2010; Kumar & Kumar, 2012; Kumar, 2014), and are treated as endogenous in the growth model.

Notably, the effect of technology is magnified when the latter include technology that supports communication, enhances productivity and improves the wellbeing of the society (Cronin, Colleran, Herbet, & Lewitzky, 1993; Datta & Agarwal, 2004;Lam & Shiu, 2010; Kumar et al., 2014; Shahiduzzaman & Alam, 2014). In this regard, development in technology (broadly defined) is expected to lower the cost of production, streamline supply chain processes, provides access to information in decision making and support consumers in acquiring quality products at competitive prices (Buhalis & Law, 2008; Porter, 2001).

In regards to the empirical evidences, a number of studies have focused on the technology-led growth (Tech-LG) hypothesis using cross-country regression techniques. For instance, Hardy (1980) considers 60 countries over the 1968–1976 periods and finds strong evidence that telephones contribute to the economic development. Madden and Savage (1998) examine a sample of 27 Central and Eastern European (CEE) countries over the period 1990–1995 and find a positive relationship between investment in telecommunication infrastructure and economic growth. Similarly, Roller and Waverman (2001) consider 21 Organisation for Economic Co-operation and Development (OECD) countries over a 20-year period (1970–1990) and find a positive causal relationship between investment in telecommunication infrastructure and subsequent economic performance. Thompson and Garbacz (2007) consider a panel of 93 countries for the period 1995–2003 and find that penetration rates of telecommunication services improves the productive efficiency of the world as a whole and particularly in some subsets of low income countries. Seo, Lee, and Oh (2009) analyse a panel of 29 countries in the 1990s and conclude that ICT investment has a positive effect on GDP growth.

[3] Some Small Pacific Island Countries such as Tuvalu, Kiribati, and some parts of Fiji, are witnessing the sea-level rise.

Moreover, Koutroumpis (2009) uses the model introduced by Roller and Waverman (2001) for 22 OECD countries over the period 2002–2007 and find broadband penetration (a proxy for ICT) has a positive causal link with economic growth in the presence of critical mass and infrastructure. Tseng (2009) examines the developments in ICT among six Asian countries, namely South Korea, Taiwan, Singapore, Hong Kong, China and India, and finds, inter alia, an enormous contribution from the use of ICT in economic growth; that innovation configurations of ICT differ significantly among these countries due to the relative innovation strengths within the sub-fields of ICT; and a high degree of inter-relationships among the six countries in ICT.

In addition, Gruber and Koutroumpis (2010) use the data from 192 countries for the period 1990–2007 and find a significant effect of mobile telecommunications diffusion on GDP and productivity growth. Vu (2011) investigates the effect of ICT on growth for a sample of 102 countries for the period 1996–2005 and find inter alia: (1) a substantial improvement of growth in the sample period relative to previous years; (2) a statistically significant relationship between growth and ICT; and (3) that penetration of personal computers, mobile phones, and internet users have a significant causal effect on growth. Castellacci and Natera (2013) use a panel of 98 countries over the period 1980–2008 and present the idea that dynamics of national innovation system is driven by innovative capability which includes technological output, scientific output, and innovative output; and the absorptive capacity, which includes income per capita, infrastructures and international trade.

On the other side of the spectrum, there are a few studies which find inconclusive outcomes. Among these include Dewan and Kraemer (2000), which examine 36 countries over the 1985–1993 periods and find returns from capital investments in ICT, although positive and significant for developed countries, were not statistically significant for the developing countries. Pohjola (2002) examines a sample of 43 countries over the period 1985–1999 and finds no statistically significant correlation between ICT investment and economic growth.[4] At a country level, various studies support Tech-LG hypothesis. Among these include: Jorgenson and Stiroh (2000), Jorgenson (2001), and Oliner and Sichel (2000) for the United States of America (US); Oulton (2002) for the United Kingdom (UK); Jalava and Pohjola (2002, 2008) for Finland; Daveri (2002) for European Union (EU) economies; Jorgenson and Motohashi (2005) for Japan; Jorgenson (2003) for the G-7 economies; Jorgenson and Vu (2007) for 110 countries; Kuppusamy, Raman, and Lee (2009) for Malaysia; Venturini (2009) for the US and 15 EU countries; Kumar (2011) for Nepal, Kumar and Kumar (2012, 2013a) and Kumar and Singh (2013) for Fiji; Kumar (2012) for Sub-Saharan Africa (SSA), Kumar (2013, 2014) for the Philippines and Vietnam, respectively.

The Tech-LG hypothesis has also been examined at firm-industry level. For instance, at a firm level, Lehr and Lichtenberg (1999) examine firms in service industries in Canada and find personal computers made a positive contribution to productivity growth. Stiroh (2002) investigates 57 major US industries and finds a strong link between ICT and productivity. Similarly, Brynjolfsson and Hitt (2003) find that firms that invested in computer technology were able to realize greater productivity (output per unit of input). O'Mahony and Vecchi (2005) use a pooled data at the industry level for the US and the UK and find a positive effect of ICT on output growth and excess returns relative to the non-ICT assets.

Against the literature and background supporting the scaling effect of communications technology, and the fact that telecommunications industry has undergone significant reforms in SPIS, it is pertinent and timely to examine the role of telecommunications viz. economic growth.

3. Telecommunication services and multilateral commitments

3.1. Background

Historically, telecommunications sector in SPIS was heavily monopolized. However, with global demeanour to liberalize trade, most of the countries in SPIS group have statutorized, corporatized or privatized their telecommunications sector. Federated States of Micronesia (FSM) was among the first SPIS to restructure its telecommunications department into a statutory body. It formed the Federated States of Micronesia Telecom Corporation which is a fully state owned corporation responsible for the provision of all telecommunications services.

In Niue, through the Communications Act 1989, Telecom Niue was established to operate the domestic and international Post and Telecommunication services. Telecom Niue was also given the control and management of the frequency spectrum. Palau has statutorized all its telecommunication services in 1982 when it established the Palau National Communications Corporation by an Act of the Palauan Congress.

Tongan Telecommunications Commission (TTC) was established under the provision of the Tonga Telecommunications Commission Act 1984. It took over the operation of domestic telecommunication service from the Telegraph and Telephone Department of Tonga. Under the World Trade Organization (WTO) multilateral trade rules of the General Agreement on Trade in Services (GATS), Tonga has opened up some of its telecommunications sector. TCC is now fully a public enterprise and falls under the Ministry of Public enterprises of the Government of Tonga. It is a sole provider of fixed telephone lines, holds 70% market share of dial up and broadband internet, and more than 50% market share in GSM mobile services. The two GSP service providers are Digicel and U-call, the latter is owned by TCC.

[4] However, we argue that prior to 1993 many (developing) countries had poor accessibility and availability of communications technology and technology-based products. In light of this, post 1993 is a period of information age that has experienced a significant insurgence in technology as many countries slowly emulated the advanced production processes and adopted the superior communications technologies from the advanced and neighbouring developed countries.

Tuvalu Telecommunications Corporation was established in 1994 under the Tuvalu Telecommunication Corporation Act of 1993. The corporation is state-owned and a sole provider of telecommunication services and with the exclusive rights under the Act to install and provide all telecommunication services in Tuvalu. Tuvalu has also unilaterally opened up its mobile telephone sector with foreign entry of Digicel.[5]

Telecom Fiji Limited (TFL), initially a private limited liability company, was formed in 1989. The company provided telecommunications services in Fiji for 25 years under the exclusive license granted by the then government of Fiji. However, in 1999, the government of the Republic of Fiji Islands deregulated its telecommunications sector allowing for the entry of competitors in the mobile telephony sector. To date, in addition to TFL there are three major suppliers of mobile (cellular) communications services – Vodafone, Digicel and Inkk.

Kiribati telecommunications was liberalized with the formation of two companies, Telecom Kiribati Limited (TKL) and Telecom Services Kiribati Limited (TSKL) – the former is fully owned by the state while the latter (TSKL) is a privatized company. Both of these companies operate as semi-autonomous public entities. The TKL provides public access television, satellite television and internet services. The fixed lines and mobile services are operated by TKSL on Tarawa and Kirimati Island. The Telecom Authority in Kiribati (TAK) regulates the telecommunications, collects revenue from licensing and sells domain names. Digicel is also in Kiribati to provide mobile phone services in Tarawa.

Samoa's telecommunication sector is partially liberalized. SamoaTel, a fixed-line provider, was corporatized in 1999 and holds a 10-year exclusive license to provide the main telecommunication services. The first cellular network was launched by Telecom Samoa Cellular Ltd in 1997. There are now two new cellular providers in operation – Digicel Samoa Ltd. and SamoaTel. The entrance of Digicel which also provides value added services such as mobile telephony has boosted the competition level resulting in reduction of communication costs. The Samoan government explicitly stated in its economic strategic plan to liberalize its telecommunication services under partial private investor involvement.

Telecom Vanuatu Limited (TVL) has a monopoly in providing all telecommunication services including local, long-distance, international cellular, leased lines and telex services. The urban areas are serviced by modern digital exchanges through a fully underground network. However, the rural areas remain inadequately serviced. Vanuatu was the first country in the Pacific region to pass electronic transaction, e-business, and interactive gaming legislation. In 2002 the analogue cellular network was replaced with a digital GSM 900 system resulting in more than threefold growth in the number of mobile subscribers. In March 2008, Digicel launched a global system for mobile communications (GSM) network in Vanuatu.

Timor-Leste's telecommunication service known as Timor-Leste National Telecommunications Network or Timor Telecom (TT) in Timor-Leste was established in October 2002 by local and international shareholders (Portugal Telecom) in their effort to become internationally competitive while avoiding any financial burden on the state. Timor Telecom provides general access to fixed phone, mobile phone and Internet services. In 2012, the government of Timor-Leste has introduced a decree-law and completed an agreement with TT to end its monopoly. Following this, the government has issued licenses to Telekomunikasi Indonesia International (Telin) and Vietnam's Viettel Global Investment JSC (Viettel). New communication networks, such as web portal SAPL TL and 3G had been launched in the market. Projects to further expand the service coverage includes the constructions of Fibre Optic Ring in Dili, Government Network, Information Systems for SMS, exchange email platform, creation of a new call centre and new data centre, expansion of the national transmission backbone linked with Indonesia through the beam, and infrastructure storage facilities.

Papua New Guinea (PNG)[6] is one of the biggest developing economies in terms of geography and population in the Pacific with a population size of more than seven million. Telecommunications is inadvertently the major channel of communication for businesses, public sector, and the citizens. Telikom Limited (Telikom) is the public network operator and service provider which is fully owned by the government. PNG has three mobile service operators: Digicel PNG, bemobile (owned by the Independent Public Business Corporation) and Citifone (a product Telikom), and a fixed line operator (Telikom Limited). Telikom was established in 1997 and was given the exclusive rights to provide all telecommunication services including value-added services until 2002. PNG has also made commitments in the telecommunications sector under the GATS and hence is opened to foreign entrants into the domestic market

3.2. Multilateral commitments in the telecommunications sector by SPIS countries

Six countries (Fiji, PNG, Samoa, Solomon Islands, Tonga, and Vanuatu) are members of the WTO. Tonga, Samoa and Vanuatu have made commitments to liberalize their telecommunications sector under the four modes of supply – cross border, consumption abroad, commercial presence, and the movement of natural person's (MNP). The demeanour in which these two countries have liberalized their telecommunications sector can be characterized as partial entry with certain conditions within the sector to regulate the foreign entrants.

Moreover, the three countries have made commitments under the GATS framework of the WTO in basic and value-added services of the telecommunications sector. The services include commitments in voice telephone, packet-switched data transmission, circuit switched data transmission, telex, telegraph, facsimile and private leased circuit; commitments in

[5] Digicel is one of the leading mobile service providers in the Pacific region.

[6] PNG is not part of the small states. We briefly discuss the telecommunications development since PNG is a developing country in the Pacific region, and also a member of WTO.

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electronic mail, voice mail, on-line information and database retrieval, electronic data interchange, enhanced/value added facsimile services, including store and forward, store and retrieve (electronic data interchange), code and protocol conversion and on-line information and/or data processing; and full commitments under Modes 1–3 of the supply of services under the market access and national treatment commitments[7]; and partial commitment in mode 4 concerning the entry and temporary stay of nationals of another member country that fall into the categories of services salesperson, intra-corporate transferees, managers, executives and specialists. Unlike other countries, Samoa has not made any significant commitments under mode 4 except for those in its horizontal commitments pertaining to the immigration rules of entry into the market.

4. Econometric modelling and estimation techniques

4.1. Framework

For the purpose of modelling and analysis, we use the conventional Cobb–Douglas type production equation within the augmented Solow (1956) framework. The initial equation is defined as

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \tag{1}$$

where A_t is the aggregate stock of technology, K_t is the capital stock, and L_t is the labour stock at time, t; and α and β are the capital and labour shares, respectively. Using (1) with the Hicks-neutral technical progress, the output per worker (y_t) is defined as

$$y_t = A_t k_t^{\alpha}, \quad \alpha \in (0,1) \tag{2}$$

where k_t is the capital per worker. Eq. (2) is augmented with telephone lines (% total population), which is a proxy for telecommunications development (TEL_t) and is included as a shift variable to capture the effects on total factor productivity (TFP) (Rao, 2010). Subsequently,

$$A_t = f(TEL_t) \tag{3}$$

and

$$A_t = A_o e^{gt} TEL_t^{\theta} \tag{4}$$

where A_o is the initial stock of knowledge, g refers to the growth of technology over time, t, and, e^{gt} includes other *catch-all* factors.

Hence,

$$y_t = (A_o e^{gt} TEL_t^{\theta}) k_t^{\alpha} \tag{5}$$

Taking the log of (5), we obtain the log-linear equations for estimation.

4.2. ARDL specifications

Next, we specify the autoregressive distributed lag (ARDL) specifications (6)–(8). Note that each equation has a dummy (*dum*) variable associated that represents a single structural break period in the respective level series (Perron, 1997). We include the respective break dummy (dum_y, dum_k, and dum_{tel}) variable in the specifications in order to compute a robust bound statistics. To examine the cointegration relationship, there are two key steps involved: First, Eqs. (6)–(8) are estimated by ordinary least squares (OLS) technique. Second, for each equation, the existence of a long-run relationship is traced by imposing restrictions on all estimated coefficients of lagged level variables equating to zero. Hence, bounds test is based on the *F*-statistics (or Wald statistics) with the null hypothesis of no cointegration ($H_0: \beta_{i1} = \beta_{i2} = \beta_{i3} = 0$) against its alternative hypothesis of a long-run relationship ($H_1: \beta_{i1} \neq 0;\ \beta_{i2} \neq 0;\ \beta_{i3} \neq 0$).

$$\Delta Ly_t = \beta_{10} + \beta_{11} Ly_{t-1} + \beta_{12} Lk_{t-1} + \beta_{13} LTEL_{t-1} + \alpha_{10} dum_y + \sum_{i=1}^{p} \alpha_{11i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{12i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{13i} \Delta LTEL_{t-i} + \varepsilon_{1t} \tag{6}$$

$$\Delta Lk_t = \beta_{20} + \beta_{21} Ly_{t-1} + \beta_{22} Lk_{t-1} + \beta_{23} LTEL_{t-1} + \alpha_{20} dum_k + \sum_{i=1}^{p} \alpha_{21i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{22i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{23i} \Delta LTEL_{t-i} + \varepsilon_{2t} \tag{7}$$

[7] The General Agreement on Trade in Services (GATS) defines four modes through which international supply of service can occur. Mode 1 refers to *cross border supply* where only the service cross the border: examples include a law firm delivering legal advice via phone, a physician providing medical diagnosis to a patient via email, a financial service supplier supplying portfolio management or brokerage service across border. Mode 2 refers to *consumption abroad* where the consumer consumes the service outside his or her home country: examples include tourist activities, travelling abroad for medical treatment, language courses etc. Mode 3 refers to *commercial presence* includes services supplied by foreign-owned or subsidiary of a bank, medical services provided by a foreign-owned hospital, courses offered in host country by a foreign-owned school, etc. Mode 4 refers to *presence of natural persons* where an individual is temporarily present in an economy other than her own to provide commercial service: examples include computer services delivered to a consumer by an employee of a foreign computer company, computer programmer, plumber, fruit picker going abroad on a short-term contract.

$$\Delta LTEL_t = \beta_{30} + \beta_{31} Ly_{t-1} + \beta_{32} Lk_{t-1} + \beta_{33} LTEL_{t-1} + \alpha_{30} dum_{tel} + \sum_{i=1}^{p} \alpha_{31i} \Delta Ly_{t-i} + \sum_{i=0}^{p} \alpha_{32i} \Delta Lk_{t-i} + \sum_{i=0}^{p} \alpha_{33i} \Delta LTEL_{t-i} + \varepsilon_{3t} \quad (8)$$

4.3. Data

The sample data is grouped data and consists of all the countries in the recent classification of Small Pacific Island States (Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Palau, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu) by the World Bank (2014). The sample period is from 1979 to 2012. All the key indicators and variables, such as the gross domestic product (GDP) and gross fixed capital formation (at 2005 constant prices), population, employment ratio, and percent of population with access to telephone lines, are sourced from the *World Development Indicators and Global Development Finance* (World Bank, 2013). We use perpetual inventory method to build data for capital stock.[8] We assume depreciation rate (δ) of 4%, initial capital stock (K_0) to be 1.1 times the real GDP of 1979, and the gross fixed capital formation is used as a proxy for investment (I_t). Labour stock is estimated using average employment rate and the population data for respective years. The percent of population having access to telephone lines is used as a proxy for telecommunications development.[9] The data is duly transformed into log form before using them in the analysis. The descriptive statistics of the sample is provided in Table 1.

4.4. ARDL bounds results

The ARDL approach is used because it is relatively simple and recommended for small sample size (Ghatak & Siddiki, 2001; Pesaran et al., 2001). In this approach, one may not need to test for unit roots and it is possible to investigate cointegration irrespective of the order of integration. However, we emphasize the need to conduct the unit root tests for a couple of reasons. First, to ensure that the series are indeed $I(0)$ and/or $I(1)$; second, to justify using ARDL approach instead of other approaches such as the ordinary least squares (OLS) method which is not recommended for variables in the presence of unit root; and third, examining the unit root provides information on the maximum lags to use in applying the Toda and Yamamoto (1995) non-Granger causality procedure. In addition, although the traditional unit root tests such as ADF and PP tests are suitable for small samples and are widely used, they do not provide information on structural break in the series, the presence of which can influence the bounds F-statistics and hence the inference on cointegration. To overcome this problem, we use the Perron (1997) unit root test with single unknown structural break in the series. From the results, we find that except for capital per worker, all variables in the levels have unit root (Table 2), and the first difference $I(1)$ series are stationary. The structural breaks in the level series are noted in 2007 for output per worker and capital per worker, and in 1991 for telecommunications. Similarly, in the first difference series, one period structural break is noted in 1990 for output per worker, 1984 for capital per worker, and 1988 for telecommunications. Notably, these structural breaks broadly capture the developments and periods of reforms in the telecommunications sector in the SPIS countries. We factor these structural breaks by setting the respective dummy variables to one when carrying out the bounds procedure to examine the cointegration relationship. Moreover, to examine the cointegration based on bounds procedure, we use the Narayan (2005) critical bounds which are specifically computed for small sample size (i.e. sample size of at most 80).[10] Consequently, the bounds F-statistics ($F=9.0645$) show evidence of long-run cointegration at 5% level of significance when output per worker (Ly_t) is set as dependent variable (Table 3).[11]

4.5. Long-run results with short-run dynamics

After confirming the existence of a long-run relationship between y_t, k_t, and TEL_t, the diagnostic tests are reviewed from the ARDL lag estimates.[12] These include: Lagrange multiplier test of residual serial correlation (χ^2_{sc}); Ramsey's RESET test using the square of the fitted values for correct functional form (χ^2_{ff}); normality test based on a test of skewness and kurtosis of residuals (χ^2_n); and heteroscedasticity test based on the regression of squared residuals on squared fitted values (χ^2_{hc}). The results are reported in Table 4. In what follows, we find that the diagnostic test rejects the acceptance of the null hypothesis of the presence of serial correlation ($\chi^2_{sc}=0.3162$: $F(1, 26)=0.2515$), normality biasness ($\chi^2_n=0.7392$) and

[8] We assumed depreciation rate (δ) of 4%; initial capital stock (K_0) as 1.1 times the GDP (constant 2005 prices) of 1979; and gross fixed capital formation (constant 2005 prices) is used a proxy for investment (I_t). Hence, $K_t=(1-\delta)K_{t-1}+I_t$. Note the choice of δ and K_0 are arbitrarily determined as long as the output per worker and capital per worker exhibit concavity, that is, diminishing returns to scale, and hence the steady-state convergence.

[9] The percentage of population having access to telephone lines is used as a proxy for telecommunications development instead of the percentage of population having access to mobile cellular phone services because the latter did not have consistent data available, and the fact that telephone services are an important medium of communication in the formal sectors of the economy in SPIS.

[10] Note that the critical bounds created by Pesaran et al. (2001) are for sample size of at least 80.

[11] Note that sample size is 34; however, the critical bounds reported in Narayan (2005) are for the sample size 30 and 35. Therefore, we report a more conservative bounds at $N=30$, and not at $N=35$. However, in case of the latter, our computed F-statistics passes the 1% critical bound [7.643, 9.063] as well.

[12] The ARDL lag estimation results, which precedes the long-run and short-run estimation is not included here. We only provide the diagnostic tests in order to ascertain the robustness of the estimated results. Moreover, we also test for the statistical significance of the cumulative structural breaks in the sample with a dummy when estimating the short-run and long-run relationships. However, the structural dummy was not statistically significant and did not influence the results, so it was not included in the final estimation.

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Table 1
Descriptive statistics and correlation matrix.

	Ly	*Lk*	*LTEL*
Mean	8.2669	9.1481	1.6709
Median	8.3087	9.2031	1.7760
Maximum	8.3997	9.4926	2.4197
Minimum	7.8918	8.0455	0.8296
Std. dev.	0.1318	0.2951	0.5359
Skewness	−1.4376	−2.4431	−0.1504
Kurtosis	4.6801	8.8639	1.5596
Jarque-Bera	15.7101	82.5366	3.0674
Probability	0.0004	0.0000	0.2157
Ly	1.0000		
Lk	0.9099	1.0000	
LTEL	0.8700	0.7055	1.0000

Table 2
Unit root tests with single structural break.

Variables	Level		1st Diff.	
	t-Stat	Break	*t*-Stat	Break
Ly	−3.2158[0]	2007	−5.5708[4]^{A}	1990
Lk	−5.8292[1]^{B}	2007	−10.662 [0]^{A}	1984
LTEL	−2.1606[0]	1991	−5.2366[0]^{B}	1988

Notes: Maximum lag length is set at 2. Critical values are obtained from Perron (1997). The null hypothesis is that a series has a unit root with a structural break. A, B denotes rejection of null hypothesis of unit root at 1% and 5% level of significance.

Table 3
Results of bounds test with structural breaks.

Dependent variable	Structural break	Computed *F*-statistic
Ly	$dum_y=1$: 2007	9.0645^{B}
Lk	$dum_k=1$: 2007	0.2014^{NS}
LTEL	$dum_{tel}=1$: 1991	2.3948^{NS}
Critical value (%)	Lower bound value	Upper bound value
1	7.977	9.413
5	5.550	6.747
10	4.577	5.600

Notes: Critical values for the bounds are from Narayan (2005): case V: unrestricted intercept and unrestricted trend, *p*. 1990; $k=2$, and $N=34$, B indicates significance at 5%; NS=not statistically significant.

heterocedacity ($\chi^2_{hc}=0.5266$: $F(1, 31)=0.5207$) at 1% level of significance. From the results, except for the functional form bias, the results show the equation performed well as the disturbance terms are normally distributed and serially uncorrelated with homoscedasticity of residuals.[13] Moreover, the CUSUM and CUSUM of square plots show that the parameters of the model are stable over time (Figs. 1 and 2).

In the short-run (Table 5), capital per worker contribute 0.63% ($\Delta Lk_t=0.6341$) and telecommunications ($\Delta LTEL_t=0.3297$) contribute 0.33% to output, respectively. The error correction term ($ECT_{t-1}=-0.7677$), which measures the speed at which prior deviations from the equilibrium are corrected, has correct (negative) sign and is significant at 1% level of statistical significance thus indicating a relatively speedy convergence to long-run equilibrium. In other words, roughly 77% of the previous period deviations are corrected in the current period. The positive coefficients of telecommunications from the short-run results indicate that telecommunications development has a direct positive effect on the output per worker.

[13] Note that functional form can be improved by including lagged variables of dependent variable as explanatory variables or controlling for other policy variables.

Please cite this article as: Kumar, R. R., et al. Accounting for telecommunications contribution to economic growth: A study of Small Pacific Island States. *Telecommunications Policy* (2014), http://dx.doi.org/10.1016/j.telpol.2014.08.005

Table 4
Diagnostic tests – autoregressive distributed lag estimates ARDL(1,1,0) is selected.

Test types	LM version	*p*-Value	F version	*p*-Value
Serial correlation	$\chi^2(1)=0.3162^A$	0.574	$F(1,26)=0.2515$	0.620
Functional form	$\chi^2(1)=8.8228$	0.003	$F(1,26)=9.4879$	0.005
Normality	$\chi^2(2)=0.7392^A$	0.691	Not applicable	
Heteroscedasticity	$\chi^2(1)=0.5266^A$	0.468	$F(1, 31)=0.5027$	0.484

ADL lag estimates test statistics			
R-squared	0.9722	*R*-bar-squared	0.9670
S.E. of regression	0.0220	*F*-stat. *F*(5, 27)	188.6131
Mean of dependent variable	8.2765	S.D. of dependent variable	0.1211
Residual sum of squares	0.0131	Equation log-likelihood	82.4369
Akaike info. criterion	76.4369	Schwarz Bayesian criterion	71.9474
DW-statistic	1.8386	Durbin's *h*-statistic	0.66819

Notes: 'A' refers to acceptance of no serial correlation, normality, and heterocedacity biasness at 1% level of significance.

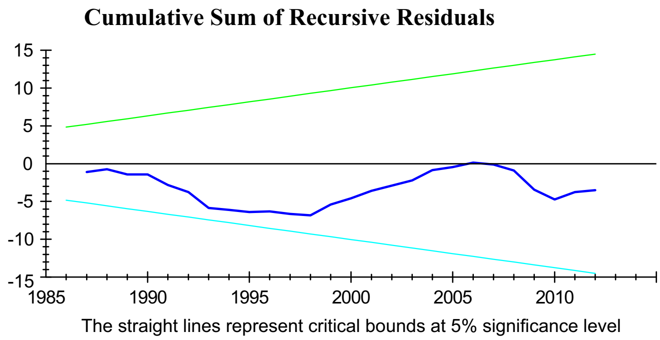

Fig. 1.

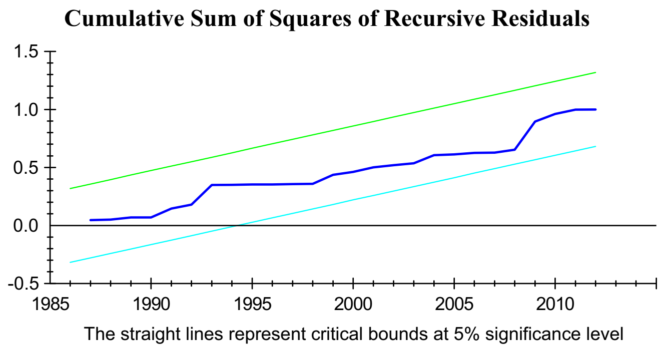

Fig. 2.

As noted, in the long-run (Table 5), telecommunications has a momentous effect on growth. The capital per worker ($Lk_t=0.5178$) share is 0.52 and the telecommunications ($LTEL_t=0.4295$) share is 0.43. In other words, a 1% increase in telecommunications, ceteris paribus, results in 0.43% growth in output per worker.[14] The capital share, however, is slightly higher than the stylized value of one-third (Ertur & Koch, 2007; Rao, 2007). This is plausible when: (a) the capital and labour inputs tend to grow at relatively similar rates; (b) an economy is predominantly developing and hence a large number of self-employed persons earn income from both capital and their own labour (Gollin, 2002) thus making it difficult to obtain meaningful measures of income shares; and (c) the quality of data and the sample size which also makes it difficult to

[14] At country level, in case of Fiji, previous studies find that the long-run elasticity of ICT worker (proxied by the number of Telecommunication lines) with respect to output per range from 0.32 to 1.07 (Kumar & Singh, 2013;). However, no other studies have examined this for other Pacific Island Countries, possibly due to data limitations.

Table 5
Estimated long run coefficients and error correction representation: *ARDL*(1, 1, 0) selected is based on Akaike information criterion.

Long-run: dependent variable Ly			*Short-run: dependent variable* ΔLy_t		
Regressor	Coefficient	*t*-Ratio	Regressor	Coefficient	*t*-Ratio
Lk	0.5178	7.6685[A]	ΔLk_t	0.6341	7.9583[A]
LTEL	0.4295	5.2939[A]	$\Delta LTEL_t$	0.3297	5.6502[A]
Constant	3.1507	4.8972[A]	*Constant*	2.4188	2.8763[A]
Trend	−0.0203	−4.1249[A]	*Trend*	−0.0156	−4.9841[A]
			ECT_{t-1}	−0.7677	−6.1247[A]
Short-run dynamics test statistics					
R-squared		0.8685	*R*-bar-squared		0.84409
S.E. of regression		0.0220	*F*-stat. *F*(4, 28)		44.5632
Mean of dependent variable		0.0136	S.D. of dependent variable		0.05572
Residual sum of squares		0.0130	Equation log-likelihood		82.4369
Akaike info. criterion		76.4369	Schwarz Bayesian criterion		71.9474
DW-statistic		1.8386	*N* (sample)		34

Notes: A=significant at 1% level, B=significant at 5% level.

compute capital stock (Bosworth & Collins, 2008) that can perfectly exhibit decreasing returns to scale and thus conform to a desirable steady-state convergence. We concur to all these reasons in case of this study.

Furthermore, the *Trend* variable indicates that SPIS countries have experienced a marginal 'pull-back' or negative effect over the sample period. Although, it is difficult to single out the factors that can explain these negative effects, the *Trend* coefficient at best captures the structural factors/changes (such as institutions, culture, mindset, political system, etc.) that may have had a 'growth retarding' effect thereby marginally offsetting the positive effects of capital productivity and telecommunications development in the model.

4.6. The Toda–Yamamoto approach to Granger non-causality

Next, we carry out the Granger causality test to examine the direction of causality among the indicators using the Toda and Yamamoto (1995) approach. This approach is suitable when the economic series are either integrated of different orders, not cointegrated, or both. In these cases, the error-correction model (ECM) cannot be applied for causality tests and the standard (pair-wise) causality test may not give robust results unless all the variables are $I(0)$ (stationary) through first and/or second order differentiation. Hence, Toda and Yamamoto (1995) provides a reliable method to test for the presence of non-causality, irrespective of whether the variables are $I(0)$, $I(1)$ or $I(2)$, not cointegrated or cointegrated of an arbitrary order. Moreover, using this procedure, one can also examine the 'combined' or the conjoint effects of the parameters (excluded variables) on the target variable (Kumar & Kumar, 2013b). In order to carry out the Granger non-causality test, the model is presented in the following vector autoregression (VAR) system:

$$Ly_t=\alpha_0+\sum_{i=1}^{k}\alpha_{1i}Ly_{t-i}+\sum_{j=k+1}^{d\,max}\alpha_{2j}Ly_{t-j}+\sum_{i=1}^{k}\eta_{1i}Lk_{t-i}+\sum_{j=k+1}^{d\,max}\eta_{2j}Lk_{t-j}+\sum_{i=1}^{k}\varphi_{1i}LTEL_{t-i}+\sum_{j=k+1}^{d\,max}\varphi_{2j}LTEL_{t-j}+\lambda_{1t} \tag{9}$$

$$Lk_t=\beta_0+\sum_{i=1}^{k}\beta_{1i}Lk_{t-i}+\sum_{j=k+1}^{d\,max}\beta_{2j}Lk_{t-j}+\sum_{i=1}^{k}\theta_{1i}Ly_{t-i}+\sum_{j=k+1}^{d\,max}\theta_{2j}Ly_{t-j}+\sum_{i=1}^{k}\vartheta_{1i}LTEL_{t-i}+\sum_{j=k+1}^{d\,max}\vartheta_{2j}LTEL_{t-j}+\lambda_{2t} \tag{10}$$

$$LTEL_t=\gamma_0+\sum_{i=1}^{k}\gamma_{1i}LTEL_{t-i}+\sum_{j=k+1}^{d\,max}\gamma_{2j}LTEL_{t-j}+\sum_{i=1}^{k}\phi_{1i}Ly_{t-i}+\sum_{j=k+1}^{d\,max}\phi_{2j}Ly_{t-j}+\sum_{i=1}^{k}\mu_{1i}Lk_{t-i}+\sum_{j=k+1}^{d\,max}\mu_{2j}Lk_{t-j}+\lambda_{3t} \tag{11}$$

where the series are defined in (9)–(11). The null hypothesis of non-causality is rejected when the p-values falls within the desired 1–10% of level of significance. Hence, in (9), Granger causality from Lk_t to Ly_t and $LTEL_t$ to Ly_t implies $\eta_{1i}\neq 0\forall i$ and $\varphi_{1i}\neq 0\forall i$, respectively. Similarly, in (10), Ly_t and $LTEL_t$ Granger causes Lk_t if $\theta_{1i}\neq 0\forall i$ and $\vartheta_{1i}\neq 0\forall i$, respectively; and from (11) Ly_t and Lk_t Granger causes $LTEL_t$ if $\phi_{1i}\neq 0\forall i$ and $\mu_{1i}\neq 0\forall i$. From the unit root results (Table 2), the maximum order of integration is 1 ($d_{max}=1$) and the optimal lag length chosen from ARDL VAR estimation using the Akaike information and Schwarz Bayesian criteria is 1 ($k=1$). Hence, the maximum lags that can be used to carry out the non-causality tests is 2 ($d_{max}+k\leq 2$). This implies that when examining the causality, appropriate lags that can be chosen should not exceed 2. Importantly, in conducting the causality tests, it is important to examine the properties of inverse roots of the AR (auto-regressive) characteristics polynomial diagram. It order to obtain a robust causality result (based on the chi-square and *p*-values), the inverse roots should lie within the positive and the negative unity. Where the inverse roots lie outside the unit boundaries, this can be corrected by including appropriate lags and/or trend variable as instruments (exogenous variable) in

Table 6
Granger non-causality test with reported χ^2.

	Excluded variable (X)	Dependent variable (Y)		
		Ly	*Lk*	*LTEL*
$X \to Y$	*Ly*	–	13.5760^{A} (0.0011)	0.43644^{NS} (0.8039)
	Lk	5.8803^{B} (0.0529)	–	2.65024^{NS} (0.2658)
	LTEL	16.5606^{A} (0.0003)	25.5791^{A} (0.0000)	–
	Combined	17.1802^{A} (0.0018)	26.5097^{A} (0.000)	10.2483^{B} (0.0364)

Notes: df=2; A and B refers to 1%, 5%, levels of significance, respectively; NS=not statistically significant; p-values are in the parenthesis. Significance within 1–10% level indicates presence of causality, from X to Y ($X \to Y$).

the VAR equation. We ensure the AR inverse roots are within the positive/negative unit boundary before proceeding to the causality assessment. For our purpose, we used the lag-length of 2 to examine the causality results.[15]

The results (Table 6) show a bidirectional causality between output per worker and capital per worker ($Ly \leftrightarrow Lk$) where the causality from Ly to Lk ($Ly \to Lk$) is significant at 1% ($\chi^2=13.5760$: p-value=0.0011), and the causality from Lk to Ly ($Ly \leftarrow Lk$) is significant at 5% level ($\chi^2=5.8803$: p-value=0.0529), thus confirming a *mutually reinforcing* effect of output and capital; and unidirectional causality from telecommunications to output per worker ($LTEL \to Ly$) at 1% level of significance ($\chi^2=16.5606$: p-value=0.0003), and from telecommunications to capital per worker ($LTEL \to Lk$) at 1% level of significance ($\chi^2=25.5791$: p-value=0.0000). Furthermore, we also note the *combined causation*, which is an indication of the interaction effect running from the excluded variables to the dependent variable. Interestingly, although we find evidence of no causality from output per worker and capital per worker to telecommunications separately, we do find the combined causality (interaction between output and capital) to cause telecommunications ($Ly \times Lk \to LTEL$) at 5% level of significance ($\chi^2=10.2483$). Similarly, the interaction between output and telecommunications ($Ly \times LTEL \to Lk$) cause capital accumulation at 1% level of significance ($\chi^2=26.5097$); and the interaction between capital and telecommunications ($Lk \times LTEL \to Ly$) cause output at 1% level of significance ($\chi^2=17.1802$).

5. Conclusion

In this paper, we provide a brief overview of the telecommunications sector in SPIS and present a new and original methodological set-up for analysing the role of telecommunications viz. economic growth. Moreover, the focus of the paper is on SPIS which is a fresh addition to the existing literature on growth and telecommunications. We have empirically shown that capital per worker and telecommunications have positive and significant short-run and long-run effects on per worker output. The causality nexus further emphasize telecommunications have the potential to influence output as well as capital per worker. In this regard, in order to fully realize the benefits of telecommunications, SPIS needs to consider a more liberal approach in terms of promoting greater competition whilst ensuring that telecommunications services are not compromised.

Undeniably, telecommunications and mobile technology are critical sources of improving productivity and efficiency in the key sectors in SPIS. Among the key sectors of interest includes banking, tourism, health, education, manufacturing and to some extent, agriculture, which can leverage from technological advance. Therefore, to propel economic growth, SPIS can consider at least in the short to medium run, adapting efficient business and communications models from successful neighbouring technology-based developed countries. Moreover, of equal importance will be the need for adequate investments in ICT and the ability of the key sectors in its current configuration to link-up and deliver the required volumes and quality of ICT investments to generate robust business growth. The challenge for the SPIS (and other small developing countries for that matter) remains the issue of scale and volume. Hence, unlike large economies, SPIS need to be focus more on developing the basic ICT infrastructure and be equally selective in embedding advanced technologies in reengineering business processes and prioritizing technology deployment in key sectors of the economy which will result in positive externalities.

Acknowledgement

The authors would like to sincerely thank the guest editors, Professors Dr. Sandro Mendonça, Dr. Dimitris Varoutas, Dr. Sofie Verbrugge, Dr. Erik Bohlin and the anonymous referees. The usual disclaimer applies.

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[15] Since the maximum lag-length required for causality assessment is 2, we examined lag=1 as well. We note that lag-length of 2 gives robust results and contain the AR inverse roots within the positive and negative unity.

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