Broadband Connectivity in Pacific Island Countries

Asia-Pacific Information Superhighway (AP-IS) Working Paper Series

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Cover Design: Jonas Flake
Cover Photo: Shutterstock / BlueOrange Studio, Winui (View of tropical islands and the Pacific Ocean in Palau).

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Abbreviations and Acronyms

AAL	Average Annual Loss
AIT	Asian Institute of Technology
AP-IS	Asia-Pacific Information Superhighway
APT	Asia-Pacific Telecommunity
BMKG	Indonesian Agency for Meteorology, Climatology and Geophysics
CROP	Council of Regional Organizations of the Pacific
ESCAP	Economic and Social Commission for Asia and the Pacific
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GNI	Gross National Income
ICT	Information and Communications Technology
ITU	International Telecommunication Union
LDC	Least Developed Countries
LLDC	Landlocked Developing Countries
PITA	Pacific Islands Telecommunications Association
PDNA	Post-Disaster Needs Assessment
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
UNISDR	United Nations International Strategy for Disaster Reduction

Executive Summary

Despite being separated by the vastness of the Pacific Ocean, small island developing states in the Pacific have gained a stronger sense as a subregional community to act on mutual development concerns with the advent of broadband Internet. Broadband[1] as a form of Internet access provides high call-up speeds, and is offered via digital subscriber line, fibre optic cable and satellite. Broadband connectivity has enabled technological innovations and smart applications that can help address policy challenges in a wide range of development sectors.[2]

However, broadband access in the Pacific Island countries has been unequal. According to a study by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP),[3] there were 19 ESCAP members with 2 per cent or lower fixed-broadband penetration in 2016—of which eight were Pacific Island countries. At the same time, New Caledonia and French Polynesia had more than 19 per cent fixed-broadband penetration,[4] while Fiji, Nauru and Tonga had mobile-broadband penetration of more than 30 per cent.

While improvement in broadband connectivity in the Pacific has been attributed to regulatory policy reforms and other measures, the broadband divide[5] continues to widen within the Pacific subregion and between the Pacific and other ESCAP subregions despite best-intentioned policy interventions. For instance, it would cost PGK 230 (about USD 70) for a mobile prepaid 6 GB data monthly package in Papua New Guinea, while a similar package (6.5 GB) in Fiji would cost only FJD 24.99 (about USD 12).[6]

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[1] Unless stated otherwise in this working paper, broadband connectivity refers to both fixed-broadband and mobile-broadband connections with high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s, as defined by: ITU, "Definitions of World Telecommunication/ICT Indicators", March 2010. Available from https://www.itu.int/ITU-D/ict/material/TelecomICT_Indicators_Definition_March2010_for_web.pdf.

[2] Including health, food security, disaster risk reduction, natural resource management, education, trade, energy, transport, public governance and taxation.

[3] ESCAP, *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific* (Bangkok, 2017). Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

[4] Broadband penetration is the percentage of population that has subscribed to fixed-broadband or mobile-broadband services. The use of ITU indicators such as fixed-broadband subscriptions per 100 inhabitants, mobile-broadband subscriptions per 100 inhabitants and proportion of population covered by a mobile network, as measures of a country's access to broadband connectivity has limitations. However, these are the indicators that have been set by the 2030 Agenda for Sustainable Development to measure the role of ICT. Moreover, these indicators have been used by ITU to collect ICT data from national governments, which allow for country comparison over time.

[5] The broadband divide is the differences in the ratio in penetration rates (of fixed broadband or mobile broadband) between different groups of economies, between women and men, young and elderly, and different regions, etc. See: ITU, "Chapter 2: Bridging the digital divide", in *World Information Society Report 2007* (Geneva, 2007). Available from https://www.itu.int/osg/spu/publications/worldinformationsociety/2007/WISR07-chapter2.pdf.

[6] Digicel Papua New Guinea, "Prepaid Plans". Available from

This working paper examines evidence that helps identify the key factors that influence broadband connectivity growth, including: (1) the economic development levels of countries; (2) access to e-government services; (3) access to affordable energy sources for powering the broadband infrastructure and devices; (4) access to affordable information and communications technology (ICT) devices (mobile and fixed telephony devices); (5) advent of emerging technologies;[7] (6) access to education for acquiring relevant skills; and (7) investment in resilient ICT infrastructure.

Based on the findings, three concrete actions for Pacific Island countries are recommended as a way forward:

1. Establish a subregional governance structure for effective coordination and cooperation in the development of ICT connectivity in the Pacific;
2. Improve the resilience of the ICT infrastructure in the face of frequent and major natural disasters; and
3. Conduct technical studies on specific issues identified in this working paper, including broadband affordability, skills and development of online content, and productive use of broadband connectivity.

To strengthen the Pacific subregion's capacity to meet its development goals, ESCAP has been supporting a key initiative to improve regional broadband connectivity by promoting a dense web of open access infrastructure. The Asia-Pacific Information Superhighway (AP-IS) initiative helps countries in their efforts to develop resilient, affordable and inclusive broadband connectivity in line with the tenets of the 2030 Agenda for Sustainable Development. ESCAP member countries recently endorsed the AP-IS Master Plan,[8] which outlines the principles, deliverables, timeline and financing mechanisms towards creating a regional broadband infrastructure that narrows the digital divide and helps countries accelerate the achievement of all Sustainable Development Goals. Initiatives of the endorsed AP-IS Master Plan are to be implemented between 2016 and 2018.

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https://www.digicelgroup.com/fj/en/mobile/plans-services/prepaid-plans.html. The two prices are from the same mobile network operator, Digicel.

[7] Emerging technologies include: (1) the Internet of Things (IoT); (2) fixed broadband and mobile broadband; (3) cloud computing; and (4) big data. For more details on these technologies, see: ESCAP, *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific* (Bangkok, 2017). Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

[8] United Nations Economic and Social Council, *Master Plan for the Asia-Pacific Information Superhighway*, 5 September 2016 (E/ESCAP/CICTSTI(1)/2). Available from http://www.unescap.org/sites/default/files/pre-ods/CICTSTI1_2E_rev1.pdf.

1. Background

1.1 An Overview of ICT in Asia and the Pacific

The Asia-Pacific region as a whole has experienced strong growth in broadband connectivity over the past decade. Over 50 per cent of the global fixed-broadband subscriptions come from the member countries of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). This is followed by Europe (20.3 per cent) and North America (13.1 per cent).[9] Some of the region's advanced economies are among the world's highest performers in information and communications technology (ICT) adoption. For instance, the *United Nations E-government Survey 2016*[10] ranked Australia (2nd), Republic of Korea (3rd) and Singapore (4th) as top four countries in global ranking on e-government services. According to the International Telecommunication Union (ITU), Macao, China has the world's highest mobile-broadband penetration rates, as well as the world's most affordable mobile-broadband services.[11] Singapore, Japan and Australia have been ranked sixth to eighth in the world, respectively, for mobile-broadband penetration.[12] The World Economic Forum ranked Singapore first for network readiness in 2016, and Japan, Hong Kong, Republic of Korea and New Zealand were within the world's top 17 countries.[13]

The wider usage of ICTs in the region has significant potential for sustainable development by increasing the flow of information and access to education, finance, health and other services. Indeed, a positive relationship between ICT and economic growth has been found by various studies.[14] For instance, a study found that a 10 per cent increase in high-speed Internet connections augmented annual economic growth by 1.3 per cent in developing

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[9] ESCAP, *State of ICT in Asia and the Pacific 2016: Uncovering the Widening Broadband Divide* (Bangkok, 2016). Available from http://www.unescap.org/resources/state-ict-asia-and-pacific-2016-uncovering-widening-broadband-divide.

[10] United Nations, *E-Government Survey 2016: E-Government in Support of Sustainable Development* (New York, 2016). Available from http://workspace.unpan.org/sites/Internet/Documents/UNPAN96407.pdf.

[11] Latest year with available data was 2014. ITU, "World Telecommunication/ICT Indicators Database 2017 (21th Edition/June 2017)", 3 July 2017. Available fromhttp://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.

[12] Ibid.

[13] The Network Readiness Index assesses the factors, policies and institutions that enable a country to fully leverage ICTs for increased competitiveness and well-being. World Economic Forum, "The Networked Readiness Index Historical Dataset 2012-2016", 2017. Available from https://www.google.co.th/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiyxMeskMvSAhUEWrwKHd7cCesQFggaMAA&url=http%3A%2F%2Fwww3.weforum.org%2Fdocs%2FGITR2016%2FWEF_NRI_2012-2016_Historical_Dataset.xlsx&usg=AFQjCNFGcIWB3S6092Y8PcUYEYSsaBcG3A&sig2=nvkcVSJGs8c1lEWeFa1lLg.

[14] The finding only applies to middle-income countries under certain conditions. For a detailed literature review, see: Christine Zhen-Wei Qiang and Carlo M. Rossotto, "Economic impacts of broadband", in *Information and Communications for Development 2009: Extending Reach and Increasing Impact*, World Bank (Washington, D.C., 2009). Available from http://siteresources.worldbank.org/EXTIC4D/Resources/IC4D_Broadband_35_50.pdf.

countries between 1980 and 2006.[15]

In the case of Pacific Island developing countries,[16] a recent World Bank report[17] projected that ICT-enabled opportunities[18] will potentially increase the annual growth rate of Fiji by 1.2 percentage point between 2015 and 2040. However, the report projected modest growth (between 0.3 to 0.6 percentage points) in Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu, and negligible growth (less than 0.1 percentage points) in Kiribati, Marshall Islands, Federated States of Micronesia and Tuvalu. The negligible growth projection in the latter countries is due to their lack of investment in ICT infrastructure, insufficient human resources and skills in ICT, and unfavourable business environment. On the other hand, Fiji's higher growth projection is based on the country's efforts to address these same factors.

Further, the World Bank report[19] found that enhanced connectivity for smaller Pacific Island countries would likely improve government's ability to provide e-government services. ICT-enabled opportunities could also generate a significant number of jobs and more income. In the case of Fiji, global outsourcing services (such as IT outsourcing, business process outsourcing and knowledge process outsourcing) could create up to 6,000 direct job, and almost 2.5 times more direct jobs in the telecommunication industry alone.

Until a decade ago, telecommunication services—mobile phones and Internet access—in Pacific Island countries were typically provided through government-owned telecommunication monopolies. These telecommunication services were generally expensive and serviced mostly urban areas. However, in the late 2000s, several Pacific Island governments[20] introduced competition in their mobile telecommunication markets, which kick-started improvement in access and affordability[21] with encouraging positive socioeconomic impacts. As a result, enhanced connectivity from telecommunication services has contributed to bridging the tyranny of distance that has frustrated sustainable development efforts in the Pacific islands.

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[15] Ibid.

[16] Unless stated otherwise, this paper focuses on Pacific Island developing countries, excluding Australia and New Zealand.

[17] World Bank, "Pacific possible: Long-term economic opportunities and challenges for Pacific Island countries", Discussion draft, 20 March 2017. Available from http://pubdocs.worldbank.org/en/901551487050695687/Pacific-Possible-consult.pdf.

[18] According to the World Bank report, ICT-enabled opportunities include business processing outsourcing, IT outsourcing and knowledge process outsourcing.

[19] World Bank, "Pacific possible: Long-term economic opportunities and challenges for Pacific Island countries", discussion draft, 20 March 2017. Available from http://pubdocs.worldbank.org/en/901551487050695687/Pacific-Possible-consult.pdf.

[20] Fiji, Papua New Guinea, Samoa, Tonga and Vanuatu started and followed later by other Pacific islands.

[21] Increase in teledensity (fixed-line, mobile) and Internet subscriptions per 100 people.

1.2 Partnerships in the ICT Sector

The expansion of mobile-broadband access in the Pacific islands culminated from effective partnerships between governments of Pacific Island countries, regional and international organizations such as the Asia-Pacific Telecommunity, ITU and the World Bank, and private telecommunication operators. The World Bank's Pacific Regional Connectivity Program funded several projects in the Pacific, including fibre-optic deployment, regulatory reforms and policy advice.[22] ITU and the Asia-Pacific Telecommunity contributed to capacity development of government officials in the Pacific, in the areas of technical standards, spectrum and Internet management, and emergency communications.[23] In terms of private sector participation, the foreign-owned Digicel was instrumental in the quick expansion of mobile-broadband networks in Fiji, Papua New Guinea, Samoa, Tonga and Vanuatu in the early 2000s. It later entered other Pacific markets including Nauru and Solomon Islands (see Annex 3). The respective incumbent telecommunication operators also contributed to the recent expansion of mobile broadband in these markets due to pressure from competition.

The Council of Regional Organisations of the Pacific (CROP)[24] has a sectoral working group on ICT with the objective to enhance sectoral coordination, and strengthen ICT integration and collaboration for sustainable development. The working group provides a common platform through which CROP agencies and other relevant stakeholders from government, the private sector and civil society can address priority issues in the ICT sector. The ICT Working Group is chaired by the University of the South Pacific.

According to the terms of reference of the CROP ICT Working Group in July 2016, the key tasks include:

- Developing strategies for ICT growth in the Pacific;
- Coordinating and monitoring ICT-related activities;
- Providing technical and policy advice to CROP heads, Pacific Islands Forum leaders, member countries, and Pacific Islands Forum Secretariat intergovernmental working groups participating in United Nations and other international negotiations and processes involving ICTs; and
- Planning and organizing Pacific Islands Forum ICT Ministerial Meeting, and participating in other Forum Ministerial meetings such as Forum Economic Ministers Meeting.

There is no regular intergovernmental meeting on ICT hosted by the University of the

[22] World Bank, "Pacific Regional Connectivity Program". Available from http://projects.worldbank.org/P113184/pacific-islands-regional-connectivity?lang=en.
[23] More details on ITU and Asia-Pacific Telecommunity programmes in the Pacific, see: http://www.itu.int/en/ITU-D/Regional-Presence/asiapacific/Pages/default.aspx and http://www.aptsec.org.
[24] CROP: ICT Working Group. Available from https://cropict.usp.ac.fj/index.php.

South Pacific, although ministerial meetings on ICT have been held in the past by the Pacific Islands Forum or the Secretariat of the Pacific Community. A key challenge is the limited human resource and capacity of the ICT ministries/agencies in Pacific Island countries, thus hindering their full participation in such regional forums. Other important partners in the Pacific on ICT development are the Pacific Islands Telecommunications Association (PITA) and the Pacific ICT Regulatory Resource Centre.

1.3 Socioeconomic Factors Affecting ICT in the Pacific

Pacific Island developing countries are home to 10.9 million people.[25] Papua New Guinea has the largest population size with 8.1 million people, while the remaining 2.8 million people are scattered among the smaller Pacific Island countries. Although there has been significant development in the telecommunication sector in some Pacific Island countries, access to broadband connectivity is generally still lacking. According to ITU data,[26] only 1.5 million Pacific islanders were connected to mobile broadband[27] in 2016, and about 0.2 million people were connected to fixed-broadband services (i.e., 1.5 per cent of 10.9 million people). French Polynesia, New Caledonia and Papua New Guinea have 74 per cent of all fixed-broadband subscriptions in the Pacific Island countries (see Figure 1). As for mobile broadband, the majority of the Pacific Island countries' subscriptions are in Papua New Guinea (46 per cent), Fiji (31 per cent) and French Polynesia (5 per cent).

Most of the Pacific Island countries have large rural populations (more than 40 per cent of total population), and the majority are young, highly literate but unemployed,[28] indicating a significant opportunity for future labour needs.[29] However, high rural population coupled with high unemployment rates of largely youthful population limit effective contribution to the formal economic sector. The gross domestic product (GDP) per capita of most Pacific Island countries are quite low compared to other SIDS in the Caribbean region.[30] Kiribati and Solomon Islands have GDP per capita of less than USD 1,700 (see Table 1). Pacific Island countries (except for Fiji and Papua New Guinea) have very limited economic production base, relying mainly on the agricultural, fisheries and tourism sectors. Most goods

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[25] Excluding Australia and New Zealand.

[26] ITU, "World Telecommunication/ICT Indicators Database 2017 (21th Edition/June 2017)", 3 July 2017. Available fromhttp://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.

[27] 11 per cent share of the total population, including Papua New Guinea; 23 per cent share of total population, excluding Papua New Guinea.

[28] This is due to limited employment opportunities offered by a limited industry-based economy in most Pacific Island countries. As a result, more young populations complete secondary schools without employment opportunities.

[29] Accurate unemployment figures for Pacific Island countries are lacking, but it has been reported that some Pacific Island countries' unemployment rate could be as high as 60 per cent. ESCAP, "Addressing High Unemployment Focus of UN Meeting on the Pacific Islands", press release, no date. Available from http://www.unescap.org/news/addressing-high-unemployment-focus-un-meeting-pacific-islands.

[30] The Caribbean region outperformed the Pacific region in both fixed-broadband and mobile-broadband subscriptions per 100 inhabitants between 2007 and 2015. Specific figures and trends available on request.

are imported and therefore costly. In addition, the development of the agricultural and fisheries sectors are highly vulnerable to climatic and natural disasters.

Table 1: ICT and socioeconomic statistics of selected Pacific Island countries

Country (year: 2015)	Mobile-broadband subscriptions per 100 inhabitants	Fixed-broadband subscriptions per 100 inhabitants	International Internet bandwidth per Internet user (unit)	Fixed-broadband sub-basket as % of GNI per capita	Mobile-cellular sub-basket as % of GNI per capita	GDP per capita (USD constant)	Population (million)	Rural population (% of total)	Population (% of total) aged 15-64 years old
Australia	130.2	30.4	88,304	1.1	0.3	55,671	24.1	10.4	65.8
Fiji	54.3	1.4	23,726	3.9	4.3	4,402	0.9	45.9	65.4
French Polynesia	29.3	19.4	40,347				0.3	44.2	68.9
Kiribati	0.9	0.1	4,426	65.8	5.5	1,637	0.1	55.6	61.4
Marshall Islands	0.0	1.9	34,571	12.6	5.6	3,437	0.1	27.1	
Federated States of Micronesia	0.0	3.0	23,192	11.1	9.4	2,833	0.1	77.5	61.9
New Caledonia	11.1	21.0					0.3	29.3	67.5
New Zealand	101.3	32.4	109,601	1.8	0.2	36,842	4.7	13.7	65.2
Palau						10,313	0.02	12.4	
Papua New Guinea	9.2	0.2	20,112	4.2	8.8		8.1	87.0	60.0
Samoa	26.6	1.2	13,159	11.8	5.0	3,762	0.2	81.0	57.7
Solomon Islands	12.9	0.2	11,971	237.4	8.9	1,479	0.6	77.2	57.3
Tonga	56.0	2.8	33,947	1.9	2.7	3,796	0.1	76.2	57.9
Tuvalu	0.0	10.1	155,655			3,403	0.01	39.4	
Vanuatu	22.3	1.6	21,921	3.2	9.8	2,874	0.3	73.6	59.6

Source: Produced by ESCAP, based on data from World Bank, "World Development Indicators". Available from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed 13 December 2017).
Note: The data for mobile-broadband and fixed-broadband subscriptions per 100 inhabitants in New Caledonia is from 2017.

The gap in access to reliable broadband service and the Internet within the Pacific subregion and between the Pacific and the rest of the Asia-Pacific region continues to widen and is unlikely to close without interventions.

Given the widening broadband divide affecting the Pacific subregion, member countries took concrete steps enabling ESCAP to take action via the Asia-Pacific Information Superhighway (AP-IS) initiative. The AP-IS is designed to advance connectivity for sustainable development and disaster risk management[31] and is underpinned by Resolution 73/6 adopted

[31] ESCAP, "Asia-Pacific Information Superhighway". Available from http://www.unescap.org/our-work/ict-disaster-risk-reduction/asia-pacific-information-superhighway/about.

by the 73rd ESCAP Commission Session in 2017.[32]

This working paper aims to support the analysis on the state of ICT connectivity in the Pacific and examine drivers of broadband access in Pacific Island countries. Section 2 discusses broadband trends and affordability, while Section 3 outlines drivers of broadband connectivity. Section 4 includes an econometric analysis of the broadband drivers, and Section 5 concludes with policy recommendations. This working paper is targeted at policy-makers in the ICT and other socioeconomic sectors in the Pacific for informed decision-making. It will also contribute to the implementation of the AP-IS and connecting Asia and the Pacific for enhanced and benefits and inclusive sustainable development.

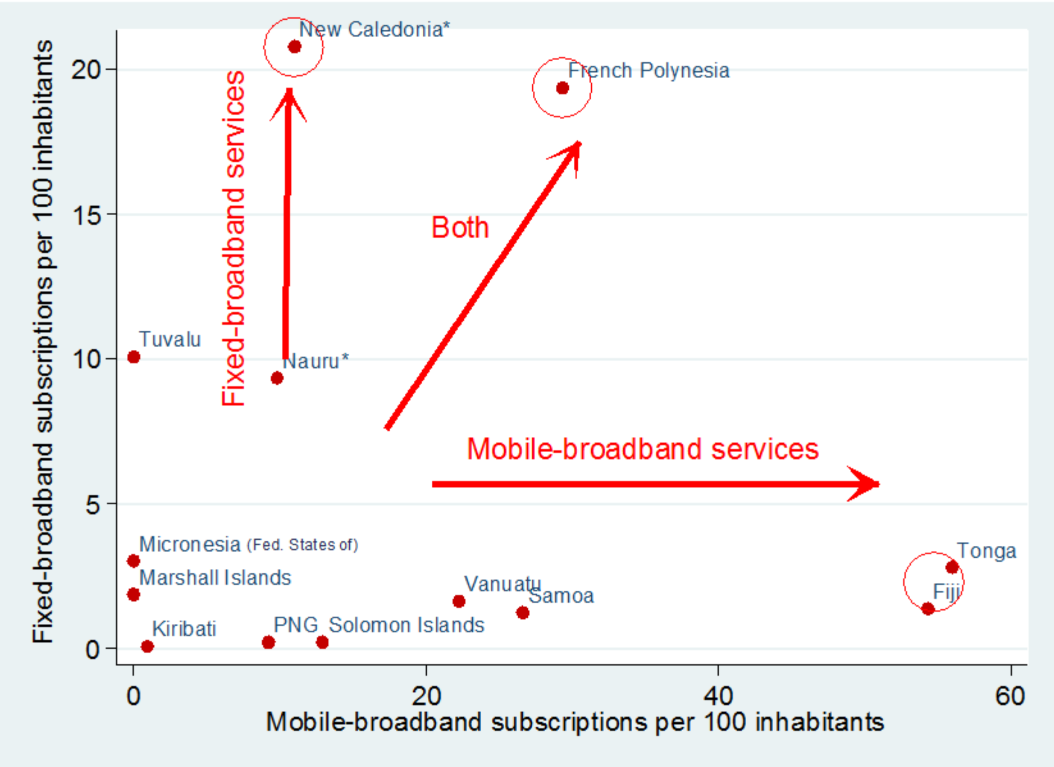
[32] For more information on the AP-IS, see: ESCAP, "Asia-Pacific Information Superhighway". Available from http://www.unescap.org/our-work/ict-disaster-risk-reduction/asia-pacific-information-superhighway.

2. State of Broadband Connectivity

2.1 Broadband Trends

While both fixed-broadband and mobile-broadband subscriptions per 100 inhabitants have increased over time in the Pacific Island countries, the pace has been uneven (see Figure 1). One group of countries (New Caledonia, Tuvalu, Federated States of Micronesia and Marshall Islands) has improved access to fixed-broadband connectivity. The second group (Fiji and Tonga) has improved access to mobile-broadband connectivity, but lack of access to fixed broadband. The third group, which includes French Polynesia (and to a lesser extent, Nauru), has managed to improve access to both fixed broadband and mobile broadband. The distinction between groups of countries is useful for understanding the type of regulations and best practices of top performers—New Caledonia in fixed-broadband, Fiji and Tonga in mobile-broadband, and French Polynesia in both.

Figure 1: Snapshot of mobile- and fixed-broadband penetration in Pacific Island countries, 2016

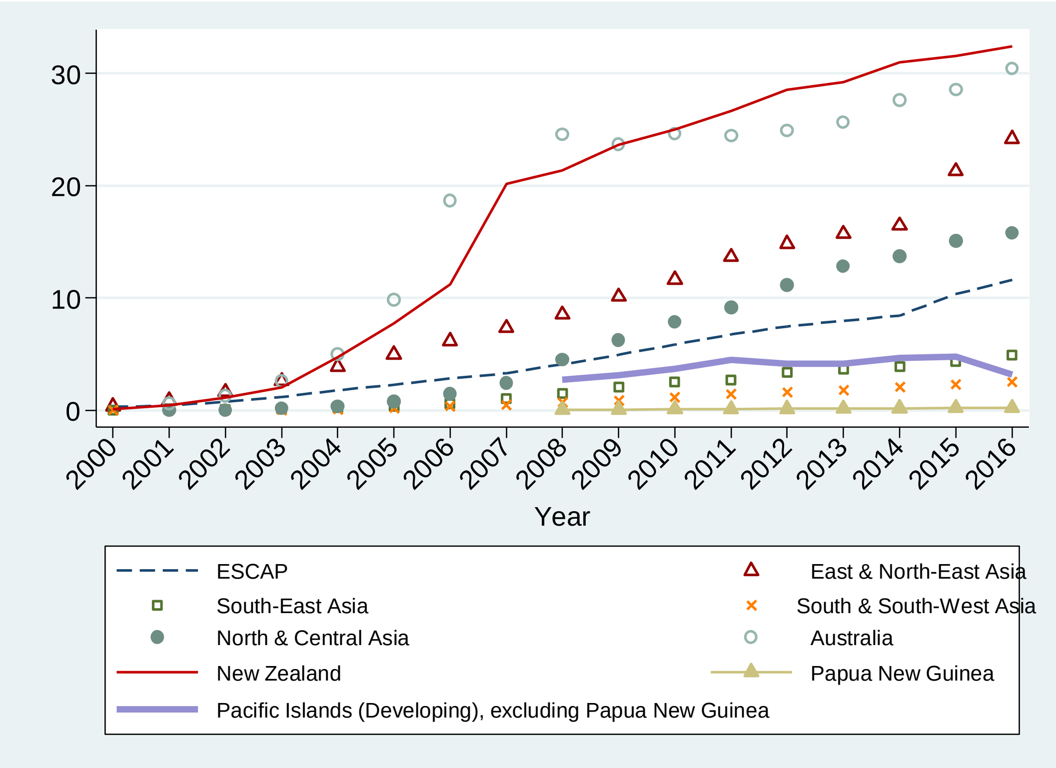


Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).
Notes: * = Countries with the latest data available; PNG = Papua New Guinea

2.2 Fixed Broadband

When compared with other subregions, the Pacific is lagging behind most ESCAP subregions[33] (see Figure 2). However, when Papua New Guinea[34] is excluded, the level of fixed-broadband connectivity in the remaining smaller Pacific Island countries is on par with South-East Asia and slightly higher than South and South-West Asia. Hence, targeted intervention towards improving fixed-broadband connectivity in Papua New Guinea would improve the Pacific's overall connectivity performance significantly.

Figure 2: Fixed-broadband subscriptions per 100 inhabitants by subregion, 2000-2016



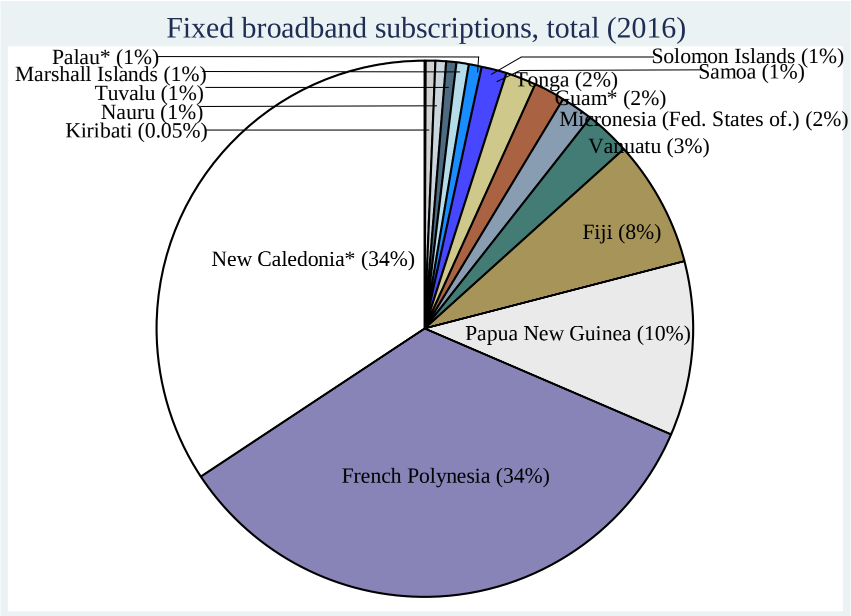
Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).

Figure 3 portrays the sizes of the market (total subscriptions) for fixed-broadband subscriptions in the Pacific. For larger markets like New Caledonia, French Polynesia and Papua

[33] For the list of countries in each ESCAP subregion, see page 57 of: ESCAP, *State of ICT in Asia and the Pacific 2016: Uncovering the Widening Broadband Divide* (Bangkok, 2016). Available from http://www.unescap.org/resources/state-ict-asia-and-pacific-2016-uncovering-widening-broadband-divide.
[34] One of the most populous countries in the Pacific region with a total population of 8.1 million.

New Guinea, there is significant potential for foreign direct investments in fixed-broadband services.

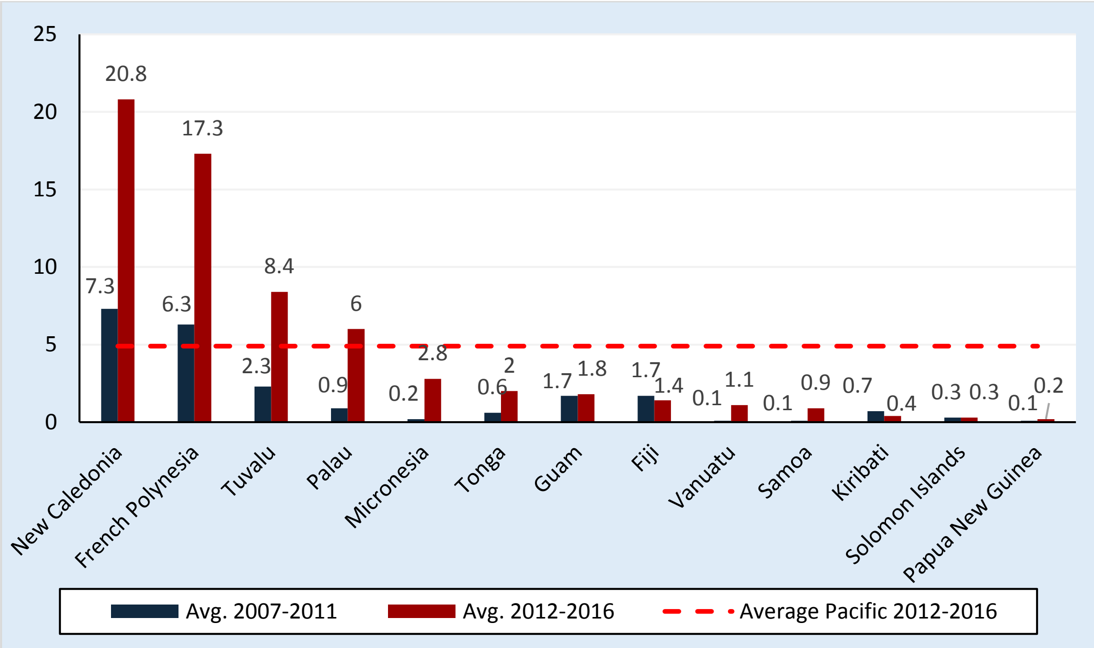
Figure 3: Fixed-broadband subscriptions in Pacific Island countries, 2016



Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).

In the case of fixed-broadband subscriptions, New Caledonia, French Polynesia, Tuvalu and Palau have shown improved access over time, above the Pacific subregion's average (see Figure 4).

Figure 4: Fixed-broadband subscriptions, averages over two periods – 2007-2011 and 2012-2016

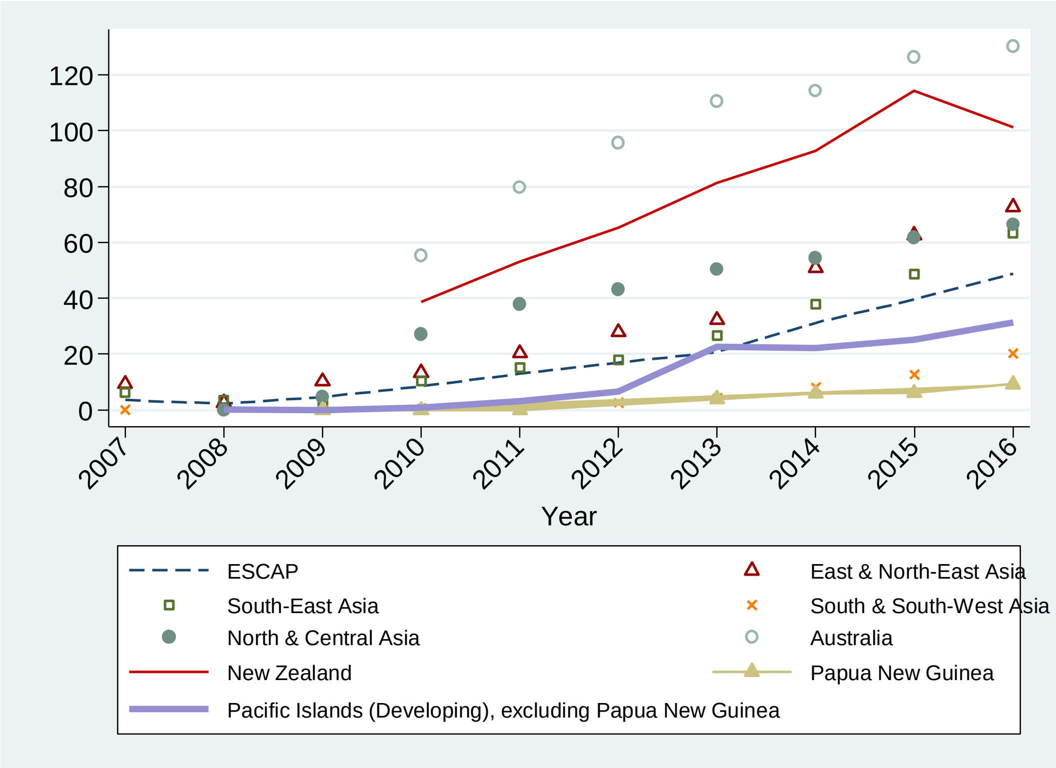


Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).
Note: Due to missing data, the first period is 2007-2010 and the second period is 2011-2014 for Guam; and the first period is 2008-2011 and the second period is 2012-2015 for Papua New Guinea.

2.3 Mobile Broadband

In terms of access to mobile broadband, the Pacific is lagging behind most ESCAP subregions except for South and South-West Asia (see Figure 5). However, improvement on access to mobile broadband has been experienced (on average) since 2008.

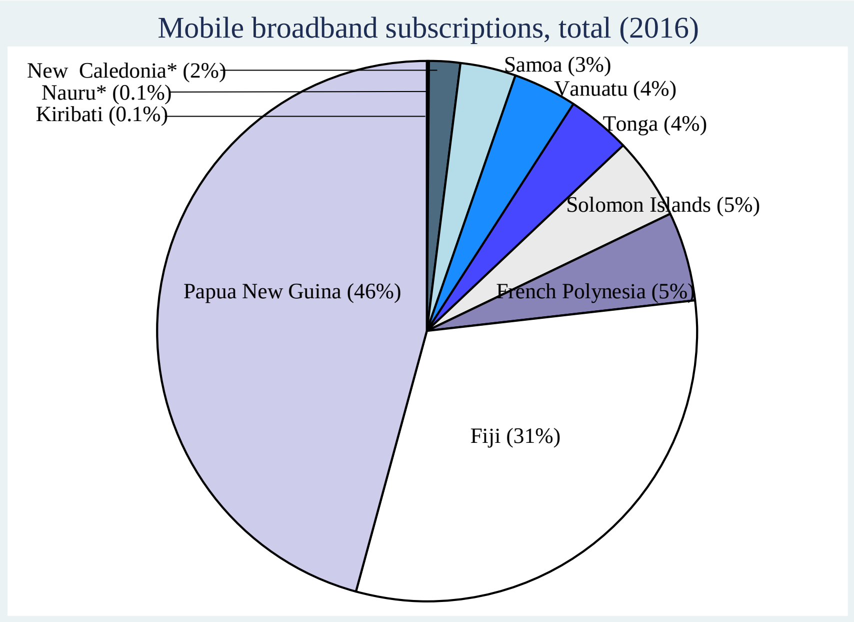
Figure 5: Mobile-broadband subscriptions per 100 inhabitants by subregion, 2007-2016



Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).

Figure 6 shows the larger markets for mobile-broadband services like Papua New Guinea, Fiji, French Polynesia and Solomon Islands provide significant opportunities for foreign direct investments.

Figure 6: Mobile-broadband subscriptions in Pacific Island countries, 2016



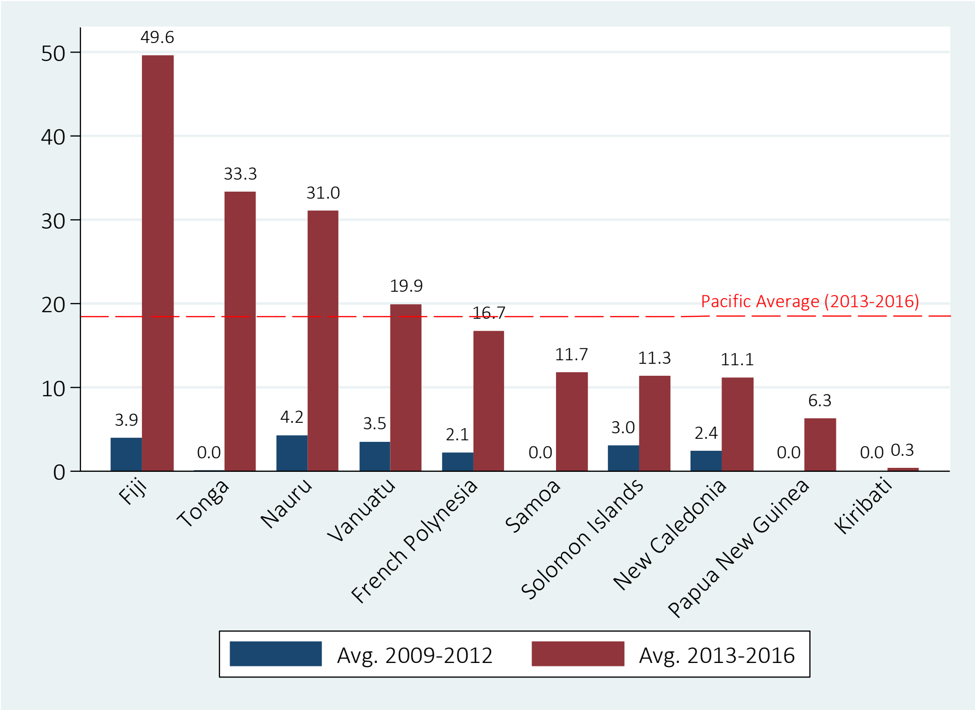
Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).

The significant increase in mobile-broadband subscriptions in Fiji, Tonga[35] and other Pacific Island countries (see Figure 7) is attributed to the introduction of competition and entrance of the private telecommunication operator, Digicel, with investment in the mobile network infrastructure, which improved the access and affordability of mobile-broadband services. In the case of French Polynesia, a new submarine cable deployed in 2010 drastically improved mobile-broadband adoption. In fact, the Pacific Island countries with available data on mobile broadband (shown in Figure 7), with the exception of Kiribati, has demonstrated strong growth in mobile-broadband adoption over time, reflecting the important role of regulatory reform.[36]

[35] While broadband access has increased in Tonga, its affordability continues to be a challenge.

[36] For information on telecommunications regulatory reform in Pacific Island countries, see: Siope Vakataki 'Ofa, *Telecommunications Regulatory Reform in Small Island Developing States: The Impact of the WTO's Telecommunications Commitment* (Newcastle upon Tyne, Cambridge Scholars Publishing, 2012).

Figure 7: Mobile-broadband subscriptions, averages over two periods – 2009-2012 and 2013-2016



Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017).

2.4 Submarine Fibre-optic Cables and Satellites

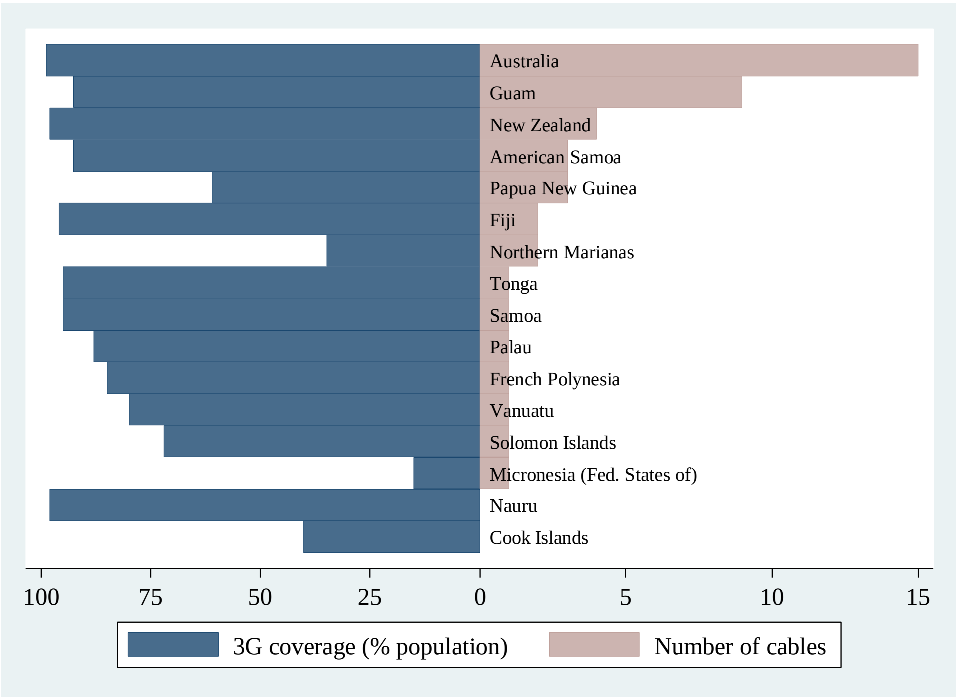
The state of domestic network development (measured by percentage of total population covered by 3G/LTE/WiMax networks) within Pacific Island countries is promising. The 3G network coverage (Figure 8) is, however, more prominent in most Pacific Island countries, compared to LTE/WiMax network coverage (Figure 9). This is due to limited roll-outs of LTE/WiMax technologies by mobile operators in most Pacific Island countries. While this may indicate that the mobile-broadband infrastructure is well developed, the resilience (in terms of number of international communication redundancies)[37] of the established 3G networks may be low because of their high vulnerability to natural disasters (for a detailed

[37] Redundancy in telecommunications is a system design in which means of communications between two points (domestic or international) are duplicated so if one means of communication fails, there will be a backup to ensure continuous communication. For example, a country's means of communication to the outside world can be in the form of satellite dish provided by a telecommunication operator. In addition, this country could be connected via one or more submarine fibre-optic cables, which could serve as a backup if satellite communication fails. Increasing communication redundancy is extremely important in Pacific Island countries because they are extremely vulnerable to natural disasters such as earthquakes, tsunamis and tropical cyclones.

discussion on e-resilience, see Section 3.5).

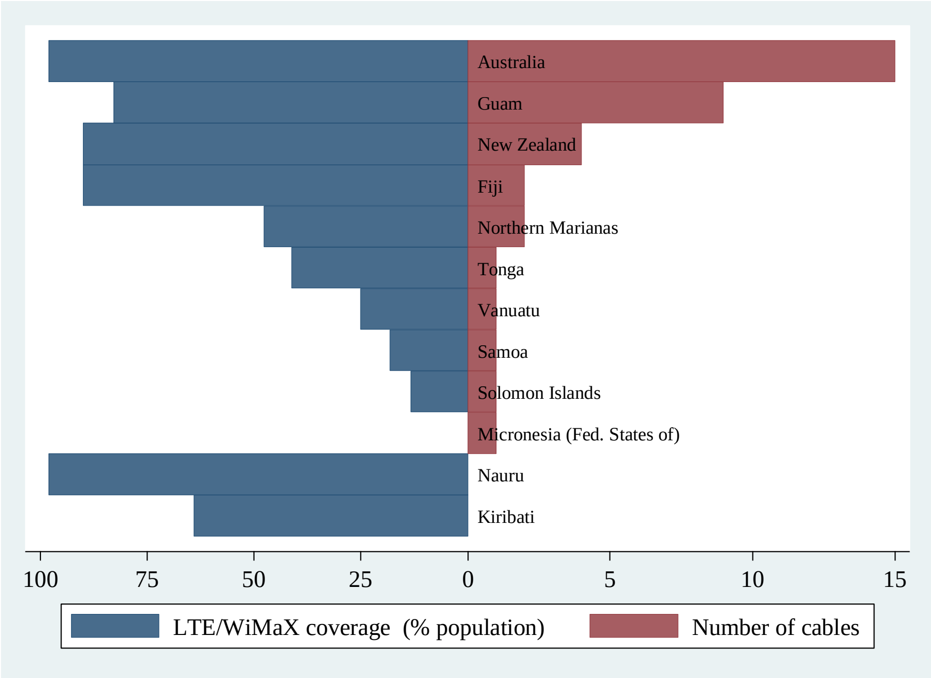
When comparing the 3G network coverage of Pacific Island countries in Figure 8, two main groups of countries emerge. The first group includes Australia, Guam, New Zealand and American Samoa with high 3G network coverage and better international communication redundancies (i.e., higher number of cables deployed). Guam and American Samoa have historically had multiple submarine fibre-optic cables deployed due to their close cooperation with the United States of America. The second group includes the remaining Pacific Island countries with high 3G network coverage but limited redundancy (i.e., connected to one fibre-optic cable and to satellite communication, which is not reported in the figure).

Figure 8: Number of submarine fibre-optic cables and 3G coverage, 2016



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017). Number of cables from http://www.submarinecablemap.com.

Figure 9: Number of submarine fibre-optic cables and LTE/WiMaX coverage, 2016



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017). Number of cables from http://www.submarinecablemap.com.
Note: Kiribati and Nauru have satellite communications. See: https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2017/Submarine%20Cable/submarine-cables-for-Pacific-Islands-Countries/ITU%20PITA%20Suva%20Workshop%20Maui%20Sanford%2002%20Aug%202017.pdf.

Tonga deployed its first international submarine cable from Fiji in 2013, and now work is underway to extend this submarine cable to two other major island groups (Ha'apai and Vava'u), which will cover more than 90 per cent of the total population in Tonga.[38] In the case of New Caledonia[39] and French Polynesia,[40] telecommunication services are predominantly provided by the French-supported and state-funded operator, *Office des Postes et Télécommunications*. A submarine cable was deployed in 2010, which has enhanced international bandwidth capacity, with additional submarine cables and satellite connections currently planned to further increase the availability of bandwidth.[41] Furthermore, *Office des Postes et Télécommunications* in New Caledonia awarded Alcatel-Lucent a three-year contract in November 2015 to extend its dense wavelength division multiplexing[42] solution across all

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[38] Tonga Cable Limited. Available from http://www.tongacable.net/.
[39] Office des Postes et Télécommunications, "About OPT New Caledonia: Organisation". Available from http://www.opt.nc/about-opt-new-caledonia/organisation.
[40] Fandom, "French Polynesia". Available from http://prepaid-data-sim-card.wikia.com/wiki/French_Polynesia.
[41] BuddeComm, "French Polynesia - Telecoms, Mobile and Broadband – Statistics and Analyses: Executive Summary", 20 October 2016. Available from https://www.budde.com.au/Research/French-Polynesia-Telecoms-Mobile-and-Broadband-Statistics-and-Analyses.
[42] ADVA Optical Networking, "DWDM". Available from http://www.advaoptical.com/en/products/technology/dwdm.aspx.

inhabited New Caledonian islands in order to increase bandwidth over existing fibre-optic networks.

2.5 Broadband Divide

As illustrated, the state of broadband connectivity in the Pacific subregion is multi-faceted. While French Polynesia, New Caledonia, Fiji and Tonga are found to have experienced strong growth on access to broadband connectivity, other Pacific Island countries are lagging behind. For instance, eight Pacific Island countries had less than 2 per cent of average fixed-broadband penetration in 2012-2016[43] (see Figure 4 for countries included).

As a result, the broadband divide in the Pacific subregion has intensified over time. Using standard deviation (measure of the sample distribution) to examine patterns of broadband connectivity, the trends are pointing towards wider distribution. This means that the difference between countries with high broadband access and low broadband access is increasing over time. In the case of fixed-broadband subscriptions (see Table 2), the standard deviation values increased by 30 times between 2010 and 2016. During this period, the minimum value remained at zero indicating that some countries did not experience any improvement in broadband access. However, the mean increased from 0.4 in 2010 to 19.2 in 2016, pointing towards improved broadband access in a majority of the Pacific Island countries.

[43] The latest data available for Guam is 2014.

Table 2: Fixed-broadband subscriptions per 100 inhabitants

Year	Obs.	Min. value	Median	Max. value	Mean	Coefficient of variance	Mean deviation	Relative mean deviation	Deviation of logs	Interq. range	Standard deviation
2010	11	0	0	1.7	0.4	1.8	0.5	1.5	0.4	0.8	0.7
2011	11	0	0	6.4	1.6	1.5	2	1.3	1.7	3.9	2.3
2012	8	0	1.7	10.8	3.5	1.2	3.6	1	0.5	7	4.3
2013	11	0	4.4	53.5	8.6	1.8	8.8	1	0.9	8	15.4
2014	11	0	6	42.3	10.9	1.2	10.4	1	1.9	19.3	13.5
2015	11	0	9.6	50	15.5	1.2	14.8	1	1.6	26.1	18.6
2016	11	0	12.9	56	19.2	1.1	16.8	0.9	1.3	29.3	20.8

Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016.
Notes: Countries included: Fiji; French Polynesia; Kiribati; Marshall Islands; Federated States of Micronesia; Papua New Guinea; Samoa; Solomon Islands; Tonga; Tuvalu; and Vanuatu. Observations missing for Papua New Guinea (2012), Samoa (2012) and Tonga (2012).

In the case of mobile-broadband subscriptions (see Table 3), the overall picture is less gloomy with standard deviation values declining during the period 2014-2016. Nevertheless, the standard deviation value in 2016 (6.1) was still higher than the 2010 value (5.1). In addition, the minimum value remained at 0.1 during the period. Access improved over time for the majority of the Pacific Island countries with an increase in mean value between 2010 and 2015 (2016 experienced a drop).

Table 3: Mobile-broadband subscriptions per 100 inhabitants

Year	Obs.	Min. value	Median	Max. value	Mean	Coefficient of variance	Mean deviation	Relative mean deviation	Deviation of logs	Interq. Range	Standard deviation
2010	12	0.1	1	15.5	3.1	1.6	3.5	1.1	1.6	2.2	5.1
2011	10	0.1	1.9	17.1	4.3	1.4	4.4	1.0	1.7	4.1	6
2012	11	0.1	1.4	18.9	4.4	1.5	4.7	1.1	1.7	5.2	6.4
2013	12	0.1	1.4	20.9	5	1.4	5.5	1.1	1.7	7.4	7
2014	12	0.2	1.7	22.4	5.4	1.4	5.5	1.0	1.6	6.4	7.4
2015	12	0.1	2	21	5.4	1.3	5.6	1.0	1.7	7.3	7.3
2016	10	0.1	1.5	19.4	4	1.5	4.3	1.1	1.7	2.8	6.1

Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016.
Notes: Countries included: Fiji; French Polynesia; Kiribati; Federated States of Micronesia; New Caledonia; Palau; Papua New Guinea; Samoa; Solomon Islands; Tonga; Tuvalu; and Vanuatu. Observations missing for Federated States of Micronesia (2011 and 2012), New Caledonia (2016), Palau (2016) and Samoa (2011).

In addition, the interquartile range values (broadband access of a majority of the country sample, excluding low and high outliers) increased over time for both mobile and fixed-broadband access, indicating that the majority of the countries in the sample were converging at the mean.

2.6 Affordability

An important indicator that explains the broadband divide is affordability. According to a Broadband Commission report,[44] broadband is considered affordable in a country when the share of total gross national income (GNI) per capita spent on broadband services (mobile or fixed) is less than 5 per cent.

Based on the latest data available from ITU[45] for 182 countries in 2015, half of these countries spent 3 per cent or less of GNI per capita on fixed-broadband services, and 2 per cent or less on mobile-broadband services. Out of the 182 countries, 137 countries spent 5 per cent or less of GNI per capita (109 countries for fixed-broadband services). While the majority of countries have affordable broadband access, according to the Broadband Commission's threshold, there are still many countries with less affordable broadband access. See Annex 6 for the full list of countries ranked by affordability. Based on their ranking, the countries have been grouped into four quantiles: Q1 – most affordable; Q2 – slightly affordable; Q3 – less affordable; and Q4 – least affordable.

In the Pacific subregion, broadband access is still considered unaffordable (see Table 4 and Annex 6). In terms of mobile-broadband services ranking, Tonga is considered "slightly affordable" (2nd quantile), while mobile-broadband access in Fiji, Samoa, Marshall Islands, Vanuatu, Kiribati, Federated States of Micronesia and Solomon Islands are "less affordable" (3rd quantile). Papua New Guinea is considered "least affordable" (4th quantile).

For fixed-broadband services, Fiji is considered "less affordable" (3rd quantile) and the remaining Pacific Island countries are considered "least affordable" (4th quantile). No Pacific Island country was ranked in the first quantile (most affordable).[46]

It is worthy to note that affordability as per cent of GNI per capita was sourced by ITU based on the prices of the dominant operator in each country. It does not, however, consider lower-priced operators that are probably pricing much closer to its cost, and thus providing a more accurate perspective of the affordability of broadband in a country.

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[44] Broadband Commission, "Broadband Targets for 2015". Available from http://www.broadbandcommission.org/Documents/Broadband_Targets.pdf.
[45] ITU, "World Telecommunication/ICT Indicators Database 2017 (21th Edition/June 2017)", 3 July 2017. Available fromhttp://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.

[46] Thanks to Marc Lipton for raising this point.

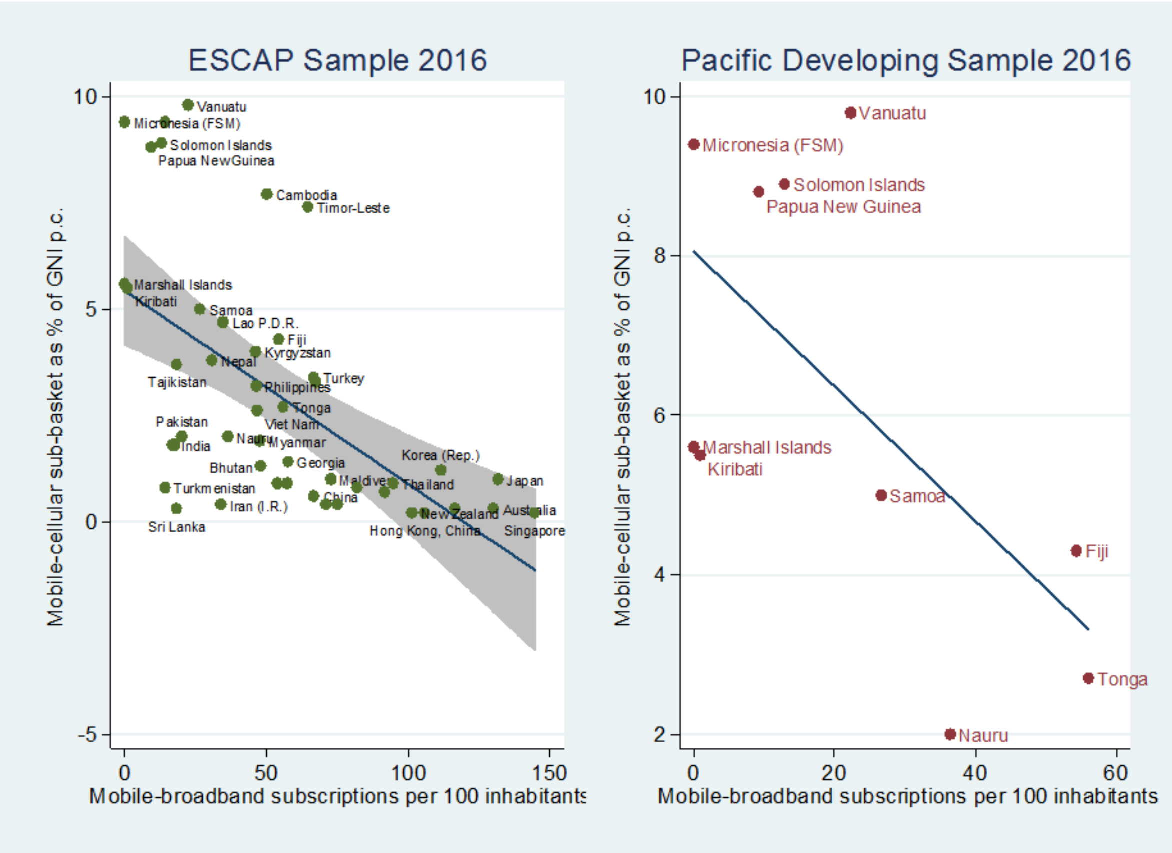
Table 4: Broadband affordability, 2016

Country	Mobile broadband		Fixed broadband		Capacity	
	Access	*Affordability*	*Access*	*Affordability*	*Broadband*	*Economic*
	Mobile-broadband subscriptions per 100 inhabitants	Mobile-cellular prices as % of GNI per capita	Fixed-broadband subscriptions per 100 inhabitants	Fixed-broadband prices as % of GNI per capita	International Internet bandwidth per Internet user	GNI per capita PPP (current international $)
Tonga	56.0	2	2.8	2	33,947	5,760
Fiji	54.3	4	1.4	4	23,726	9,140
Samoa	26.6	5	1.2	12	13,159	6,200
Marshall Islands	0.0	6	1.9	13	34,571	5,280
Vanuatu	22.6	10	1.6	24	21,921	3,050*
Kiribati	0.9	5	0.1	66	4,426	3,240
Federated States of Micronesia	0.0	9	3.0	11	23,192	4,330
Solomon Islands	12.9	9	0.2	237	11,971	2,150
Papua New Guinea	9.2	9	0.2	4	20,112	2,700*
Pacific average (simple)	**20.3**	**6.7**	**1.4**	**41.5**	**20,780**	**4,650**

Source: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016.
Note: * = latest available data is from 2014.

Less affordable broadband services are associated with lower access to broadband connectivity. Figure 10 shows an inverse relationship between the cost of mobile services and broadband access in Pacific Island countries, which means the higher its cost, the lower the level of access. Tonga and Fiji with the most affordable mobile services (least percentage share of GNI per capita spent) have the highest access to mobile broadband, while Vanuatu with the least affordable mobile service has lower level of access. This inverse relationship is also found in ESCAP countries.

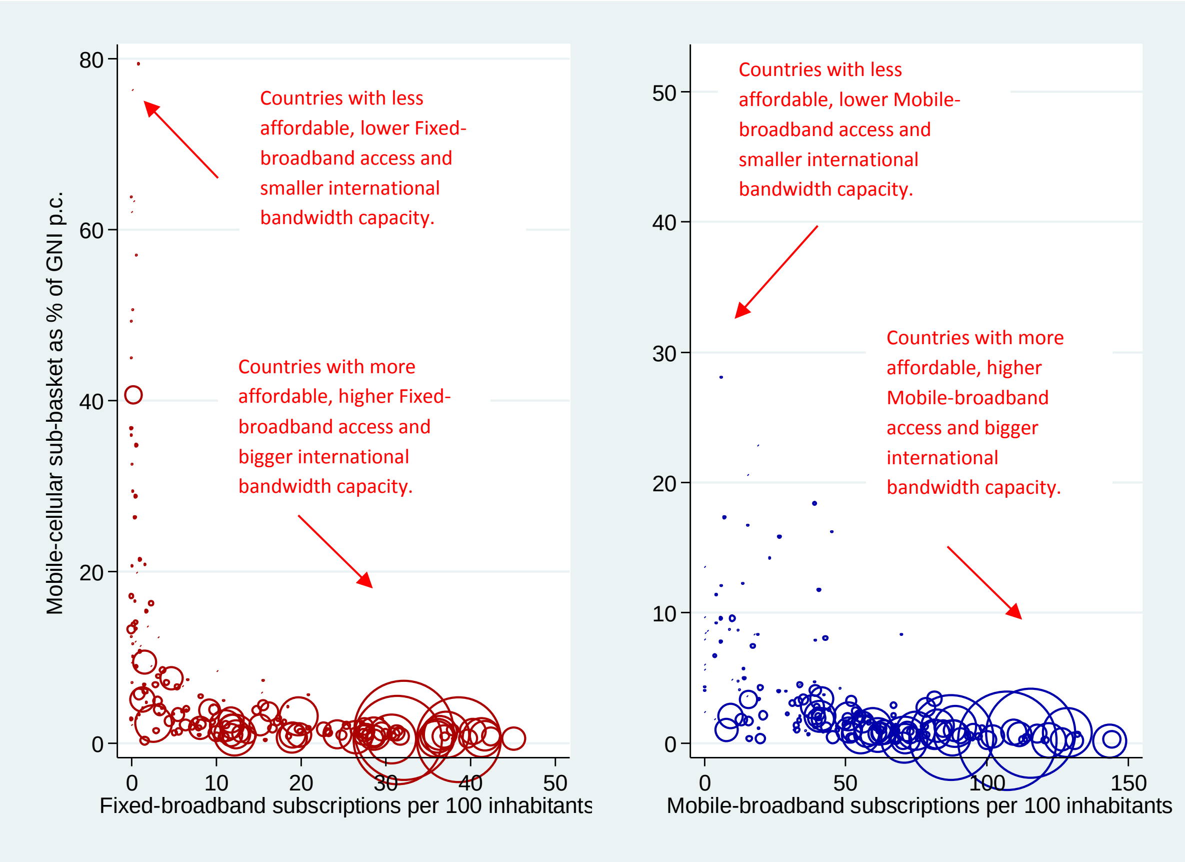
Figure 10: Affordability and access to mobile broadband, 2016



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017); and ITU, *Measuring the Information Society Report 2017* (Geneva, 2017).

Affordability and access are also linked to international broadband capacity. The capacity of broadband connectivity (measured by international Internet bandwidth per user) among countries is negatively correlated with the percentage share of GNI per capita and positively correlated with subscriptions to fixed and mobile broadband (see Figure 11). In other words, countries with less affordable broadband tend to have lower broadband access and smaller international bandwidth capacity, and countries with more affordable broadband tend to have greater broadband access and larger international bandwidth capacity. These trends are found for both fixed-broadband and mobile-broadband access, highlighting the important role of conducive regulatory policies for fair pricing and affordability of access.

Figure 11: Affordability, access and capacity of international broadband connectivity, world sample, 2016



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017); and ITU, *Measuring the Information Society Report 2017* (Geneva, 2017).
Note: Area of symbol proportional to a country's international Internet bandwidth per user.

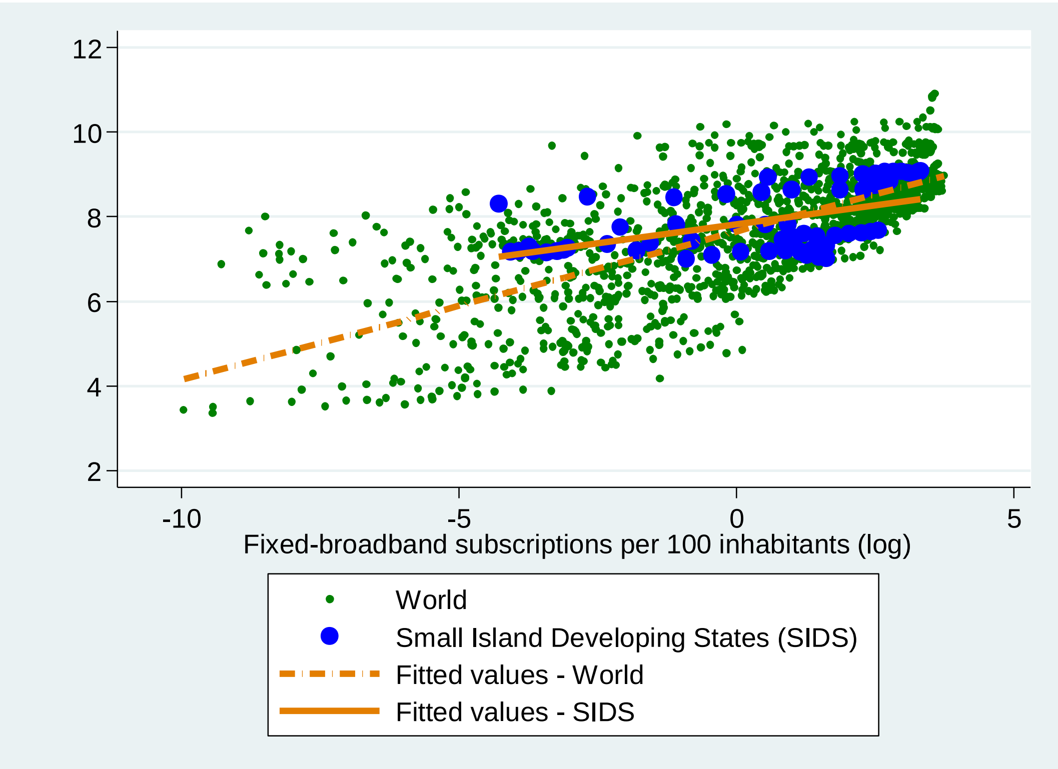
3. Drivers of Broadband Connectivity

This section discusses relevant drivers of broadband connectivity in Pacific Island countries. While not exhaustive, these drivers are found to enhance (or deter) demand for broadband access, thereby creating a virtuous circle of demand and supply.

3.1 Energy Source (Electricity)

Improvement in broadband access is affected by the availability of affordable, resilient and sustainable energy sources in Pacific Island countries. A positive and statistically significant relationship[47] is found between access to electricity (measured by electricity consumption) and fixed-broadband access (see Figure 12). The policy implication for the development of broadband connectivity is that other supporting infrastructure, in particular the electricity grid, needs to have the appropriate power generating capacity to supply the increasing power needs of expanding broadband networks.

Figure 12: Broadband access and electricity generation capacity of SIDS and the world, 2000-2015



[47] Correlation coefficient = 0.69.

Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016; and World Bank's World Development Indicators 2016.

Notes: Scatter plot for countries with available data between 2007 and 2015, with electricity consumption and broadband penetration less than 45 per cent. Due to missing data in many Pacific Island countries, SIDS data are used instead.

Electricity consumption has steadily increased for all Pacific Island countries over time (see Annex 7), but it is still considerably lower when compared with the world's or the region's average. Between 2000 and 2013, the world's mean per capita electricity consumption was 4,063 kWh, and for ESCAP countries, 3,025 kWh per capita. However per capita electricity consumption in small island developing states (SIDS)[48] was lower at 2,837 kWh. The low electricity consumption in SIDS could mean a lower access to affordable electricity and a major deterrent to the adoption of broadband connectivity. In Pacific Island countries, monthly electricity bills are costly. The average total bill of a consumer in the Pacific (based on 300 kWh on a 15A connection) is approximately USD 113 per month.[49]

Although electricity in Fiji, Federated States of Micronesia and Nauru is considered affordable (about USD 44/month) compared to the Pacific average, other countries show significantly higher monthly electricity bills. For example, electricity costs in Solomon Islands (about USD 217/month), Vanuatu (about USD172/month) and Cook Islands (about USD159/month) are higher than the subregion's average. Therefore, the limitation to generate the appropriate electricity capacity for a growing broadband network, coupled with high prices driven by high dependence on non-renewal diesel fuel can deter expansion of broadband connectivity. Most Pacific Island countries generate electricity from diesel fuel (see Annex 1), which is often subject to international market price fluctuations.

3.2 Opportunities of Enhanced Broadband Demand for Emerging Technologies

With increased broadband connectivity in some Pacific Island countries, some industry sectors are beginning (although to a limited extent) to leverage broadband for enabling solutions based on the Internet of Things (IoT) and big data. This subsection discusses four selected cases from Pacific Island countries on leveraging enhanced broadband connectivity for innovative and emerging technologies.

Tonga recently announced a project[50] to install smart meters for remote reading of

[48] Proxy for Pacific Island countries due to missing data.
[49] Utilities Regulatory Authority of Vanuatu, "Comparative Report: Pacific Region Electricity Bills," June 2016. Available from http://www.ura.gov.vu/attachments/article/106/Comparative%20Report%20-%20Pacific%20Region%20Electricity%20Bills%20June%202016%20(2).pdf.
[50] Pacific Islands Report, "Tonga to Install Smart Electric, Water Meters", 18 May 2017. Available from

households’ electricity and water consumption. Limited resources in the islands call for accurate measurement, timely monitoring of consumption, and efficient management of energy and water resources. Tonga Power will roll out 15,000 smart electricity meters to around 10 per cent of the population on the main island of Tongatapu from 2018, and another 20,000 smart meters in the next five years. The Tonga Water Board will undertake a similar exercise to monitor water usage by installing 8,000 smart water meters.

Through a collaboration between the World Wildlife Fund and the Secretariat of the Pacific Community to deal with illegal, unreported and unregulated fishing, fisheries officials in key landing ports around the Pacific are equipped with “ruggedized” tablet computers and trained to use the applications to track and trace Pacific tuna catches in real time.[51] This initiative has improved the safety and transparency of the fisheries sector.

To tackle fuel theft across the globe, an Australian company has developed a radio frequency identification and IoT-enabled solution for fuel tank management. The IoT sensor allows for the use of a card from an authorized user to purchase fuel, which helps prevent theft and enhances timely monitoring of fuel consumption for proper planning and procurement processes. According to the company, 700 systems have been deployed to date throughout the world, including in New Caledonia and Papua New Guinea.[52]

East View Geospatial, a private company, is currently conducting a pilot project in Papua New Guinea on leveraging artificial intelligence applications and big data to enhance the accuracy of automated feature identification (such as transportation, infrastructure and land use) in satellite imagery and streaming videos from aircraft, unmanned aerial systems and terrestrial sensors.[53]

While more examples of these emerging technologies can be found in the Pacific islands, the overall utilization of emerging technologies has been very limited due to low broadband access, lack of investment in research and development, narrow economic-based industry sectors, and low-income levels, among other factors. Some of these technologies (which were reported in the last 12 months) have been available in other technology-advanced countries for several years. Nevertheless, these recent cases highlight the importance of improved access to affordable and resilient broadband connectivity for leveraging future opportunities from emerging technologies.

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http://www.pireport.org/articles/2017/05/18/tonga-install-smart-electric-water-meters.

[51] World Wildlife Fund, "Big Technological Step for Tracing Tuna Catches", *Scoop*, 22 May 2017. Available from http://www.scoop.co.nz/stories/WO1705/S00060/big-technological-step-for-tracing-tuna-catches.htm.

[52] Nathaniel Prince, "RFID-enabled Fuel-Monitoring System Connects to the Internet of Things", *RFID Journal*, 27 February 2017. Available from http://www.rfidjournal.com/articles/view?15709; and Caleb Radford, "Internet of Things Puts Brakes on Fuel Theft", *Ferret.com.au*, 22 January 2017. Available from http://www.ferret.com.au/articles/news/internet-of-things-puts-brakes-on-fuel-theft-n2526829.

[53] Point of Beginning, "Machine Learning a Key Focus of East View Geospatial", 4 June 2017. Available from http://www.pobonline.com/articles/100958-machine-learning-a-key-focus-of-east-view-geospatial.

3.3 Skills and Broadband Adoption

The ability to read and write (literacy level) is strongly correlated[54] with broadband adoption. Several global studies[55] have reached similar conclusions—that the widening digital divide is due to digital illiteracy (i.e., the unfamiliarity with using digital technologies to access and use information, and the inability to read and write). The root cause of digital illiteracy is often an under-resourced education system.[56] In the Pacific, lack of funding (or high reliance on external funding from development partners, which creates uncertainty) for quality education was highlighted by a report of the United Nations Educational, Scientific and Cultural Organization as a critical challenge.[57] Quality education is also linked with nurturing sufficient ICT graduates from Pacific universities to supply appropriate expertise for the subregion's domestic industries. However, Pacific Island countries are still lagging behind in this area with very limited local capacity to develop software and applications with local content.

Access to secondary education has a positive correlation with mobile-broadband adoption (see Figure 13), and a similar trend is found for fixed-broadband adoption. In the Pacific, the gross enrolment ratios are lower than the world's average of 85 per cent, due to lower enrolment levels in larger Pacific Island countries such as Papua New Guinea and the Solomon Islands. Nevertheless, secondary education enrolments in Pacific Island countries are generally quite high with 82 per cent for male and 72 per cent for female students.[58]

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[54] Correlation coefficient of 0.46 for 154 countries with available data between 2000 and 2016 (539 observations included).

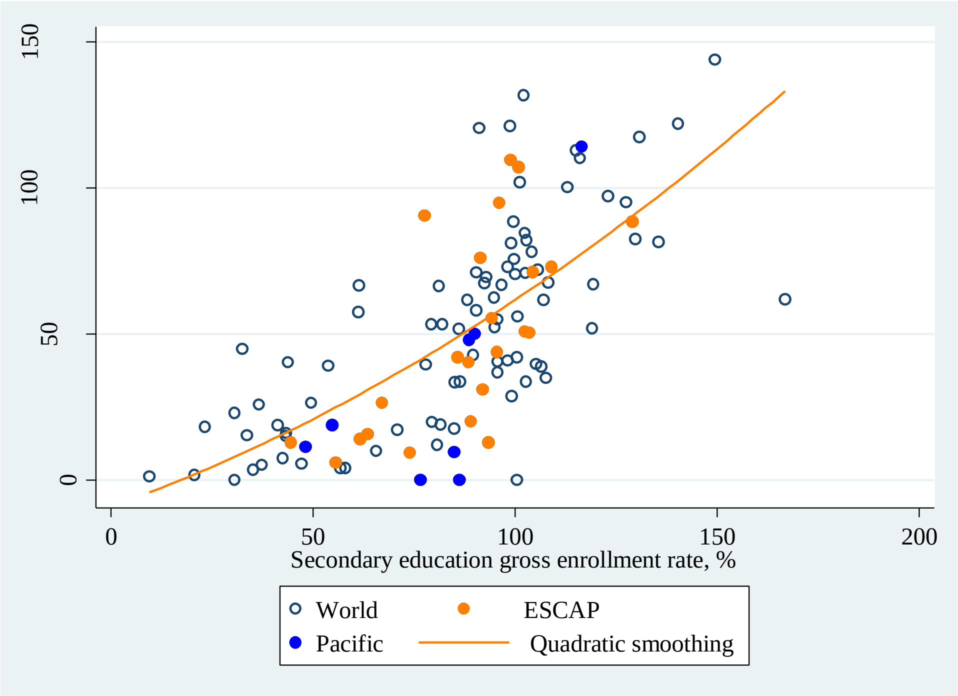
[55] Halit Ünver, "Explaining education level and Internet penetration by economic reasoning: Worldwide analysis from 2000 through 2010", *International Journal for Infonomics*, vol. 7, no. 1 (March/June 2014), pp. 898-912; McKinsey & Company, "Offline and falling behind: Barriers to Internet adoption", October 2014. Available from http://www.mckinsey.com/industries/high-tech/our-insights/offline-and-falling-behind-barriers-to-internet-adoption; and World Economic Forum, "The digital media readiness framework", June 2016. Available from http://www3.weforum.org/docs/WEF_WhitePaper_GAC_Digital_Media_Readiness_Framework.pdf.

[56] McKinsey & Company, "Offline and falling behind: Barriers to Internet adoption", October 2014. Available from http://www.mckinsey.com/industries/high-tech/our-insights/offline-and-falling-behind-barriers-to-internet-adoption.

[57] United Nations Educational, Scientific and Cultural Organization, *Pacific Education for All 2015 Review* (Paris, 2015). Available from http://uis.unesco.org/sites/default/files/documents/pacific-education-for-all-2015-review-en_1.pdf.

[58] Ibid.

Figure 13: Secondary education enrolments and mobile-broadband adoption, 2015 or latest available year



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017); and World Bank, "World Development Indicators". Available from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed 13 December 2017).

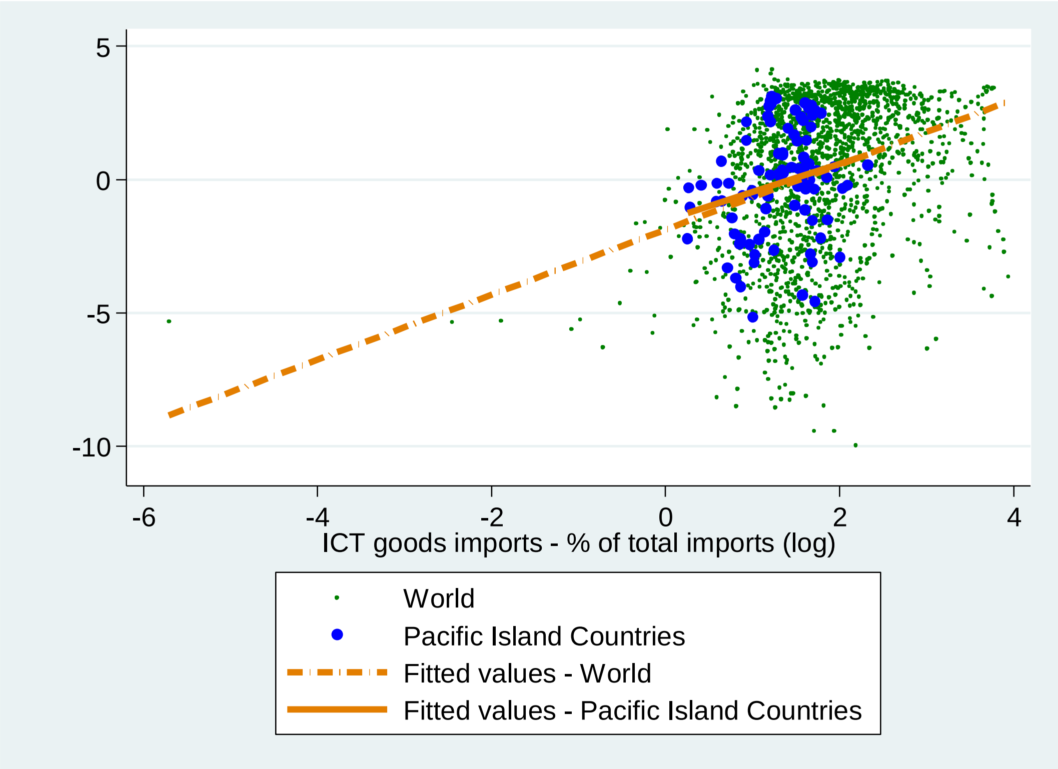
Note: Latest data available – Fiji (2012), Marshall Islands (2009), Solomon Islands (2012) and Tonga (2014).

3.4 Availability of ICT Goods Import and Trade Policy

Another relevant driver of demand for broadband connectivity in Pacific Island countries is the availability of ICT goods (mobile devices among others). This positive relationship[59] between the importation of ICT goods (measured as percentage of total imports) and fixed-broadband connectivity is found in both the world sample and in Pacific Island countries (see Figure 14). In the Pacific, most of the consumer ICT goods (such as smartphones, computers and consumer electronics) are imported from overseas. Between 2000 and 2015, 4 per cent of total imports were ICT goods in Pacific Island countries, on average. In the same period, only 0.6 per cent of total exports were ICT goods (see Table 5).

[59] Correlation coefficient = 0.19, N=2194.

Figure 14: Broadband access and ICT goods imports, 2000-2015



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016; and World Bank's World Development Indicators 2016.

This trend indicates a weak manufacturing base for producing electronic goods domestically in Pacific Island countries. Trade policy (taxation and other non-tariff policies) therefore has an important role in influencing the availability and affordability of ICT goods within Pacific Island countries. In fact, Pacific Island countries have higher tariff rates compared to ESCAP and world averages (see Table 5). While this may be a prudent fiscal measure, it could have an adverse effect on accessing affordable ICT goods (including mobile phone devices).

Table 5: Trade and tariff profiles by country groups, 2000-2015

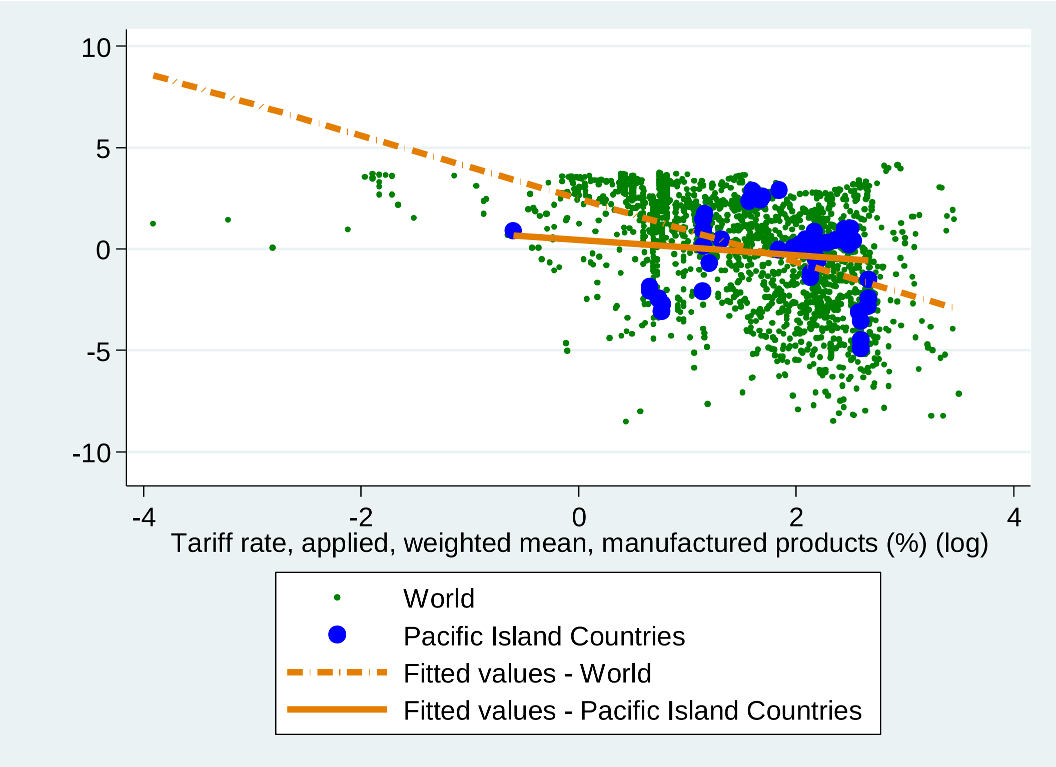
Averages	ICT goods imports (% of total)	ICT goods exports (% of total)	Tariff rate, most favoured nation, weighted mean, manufactured products (%)	Fixed-broadband subscriptions per 100 inhabitants
World	7.2	4.6	7.7	6.7
ESCAP region	9.8	8.5	7.1	4.8
Pacific Island countries	4.0	0.6	8.0	2.1
LDCs	3.8	0.6	11.5	0.2
LLDCs	4.9	0.6	9.7	1.1

Sources: ESCAP estimates, based on data sourced from ITU's World Telecommunication/ICT Indicators Database 2016; and World Bank's World Development Indicators 2016.
Note: ESCAP region average includes Pacific Island countries.

The relationship between tariff policy and fixed-broadband penetration is found to be negative and statistically significant[60] (see Figure 15). Higher tariffs increase domestic prices of ICT devices, thereby discouraging low-income households from accessing broadband connectivity. In addition, as discussed in earlier sections of this paper, access to broadband connectivity is sensitive to the socioeconomic conditions of Pacific Island countries.

[60] Correlation coefficient = -0.49, N=1850.

Figure 15: Broadband access and tariff on ICT goods imports, 2000-2015



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016; and World Bank's World Development Indicators 2016.

3.5 The Resilience ICT Infrastructure to Natural Disasters: E-resilience

Future demands (and access) of broadband connectivity are often disrupted by natural disasters. As a result, a functioning ICT infrastructure in times of disaster is critical for rescue and recovery efforts. The challenge for Pacific Island governments, therefore, is how best to develop and implement specific policies, regulations and initiatives to enhance e-resilience.

Resilience is, "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management".[61] When applied specifically to ICT (e-resilience), the concept implies two dimensions: (1) ICT for disaster response and recovery, including the rapid restoration of ICT infrastructure and services; and (2) ICT for disaster risk prevention, risk reduction and preparedness.[62] This subsection highlights the impact of natural disasters on Pacific Island countries, particularly their impact

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[61] UNISDR, "Terminology", 2 February 2017. Available from https://www.unisdr.org/we/inform/terminology.
[62] United Nations Economic and Social Council, *Space applications as a critical tool for enhanced e-resilience*, 15 August 2016 (E/ESCAP/CICTSTI(1)/5). Available from http://www.unescap.org/sites/default/files/pre-ods/CICTSTI1_5E.pdf.

on ICT infrastructures, and examines how ICT has contributed to early warning and disaster relief.

Pacific island countries are particularly prone to natural disasters. Between 2000 and 2016, the Pacific subregion experienced 225 natural disasters,[63] causing 1,752 fatalities, affecting 4.7 million people, and generating nearly USD 50 billion (in 2005 USD) worth of damages.[64] The *Global Assessment Report on Disaster Risk Reduction 2015* by the United Nations International Strategy for Disaster Reduction (UNISDR)[65] discussed the long-term risks. One indicator that highlights the risks is the multi-hazard average annual loss (AAL), which is the long-term expected loss per year, averaged over many years. While in each year over a short period of time there may be no losses, the AAL accounts for infrequent disasters and gives an estimate of savings a country needs to set aside each year to cover the cost of long-term losses from that hazard.[66] Figure 16 summarizes the hazard types and AAL among Pacific Island countries.

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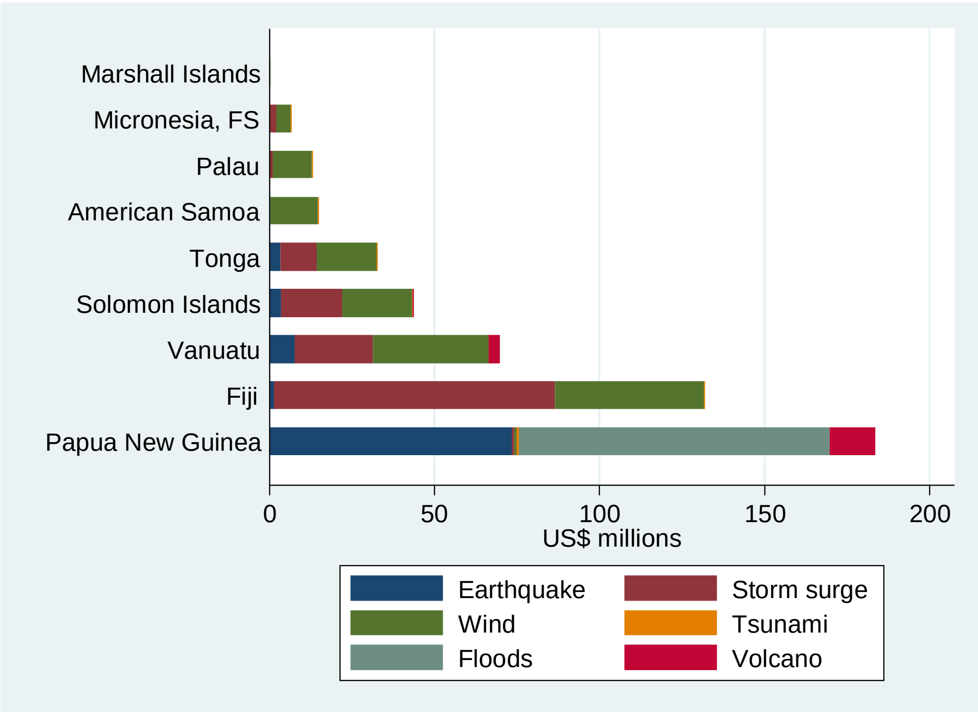
[63] Disaster categories included are drought, earthquake, extreme temperature, flood, landslide, mass movement (dry), storm, volcanic activity and wildfire.

[64] Centre for Research on the Epidemiology of Disasters, “EM-DAT: The International Disaster Database”, 2017. Available from http://emdat.be (accessed March 2017).

[65] UNISDR, *Global Assessment Report on Disaster Risk Reduction 2015* (Geneva, 2015). Available from http://www.preventionweb.net/english/hyogo/gar/2015/en/home/.

[66] Humanitarian Data Exchange, “Multi-hazard Average Annual Loss”, 2015. Available from https://data.humdata.org/dataset/multi-hazard-average-annual-loss.

Figure 16: Average annual loss in Pacific Island countries by hazard type[67]



Source: Produced by ESCAP, based on data from EMDAT. Available from http://emdat.be/ (accessed March 2017).

Wind (which includes cyclones and tropical storms) is a primary hazard that impacts the Pacific islands, with tropical cyclones frequently causing material damage and loss of lives. A related hazard, storm surge (caused by excessive rain), also significantly adds to the AAL estimates. In Papua New Guinea, which is more densely populated and located on the "Ring of Fire", earthquakes are a greater risk, as are floods.

In fact, Vanuatu and Tonga were ranked the first and second, respectively, with the highest exposure[68] to, and risk from, natural disasters such as cyclones, tsunamis and earthquakes in the world.[69] Nine of the top 15 countries with highest natural disaster exposures in 2016 were Asia-Pacific countries, of which four were Pacific Island countries (see Table 6).

[67] The high-income economies of Australia, New Zealand and New Caledonia were excluded to highlight the issues of low-income countries with special needs.
[68] Exposure refers to entities exposed and prone to be affected by a hazard event. These entities include persons, resources, infrastructure, production, goods, services or ecosystems and coupled social-ecological systems. Within the World Risk Index, exposure is related to the potential average number of individuals who are exposed each year to earthquakes, storms, droughts, floods and sea level rise.
[69] Bündnis Entwicklung Hilft and UNU-EHS, *World Risk Report 2016* (2016). Available from http://collections.unu.edu/view/UNU:5763.

Table 6: Asia-Pacific countries with high exposure to natural disasters

Global Ranking	Exposure to Natural Disasters
1	**Vanuatu**
2	**Tonga**
3	**Philippines**
4	**Japan**
5	Costa Rica
6	**Brunei Darussalam**
7	Mauritius
8	Guatemala
9	El Salvador
10	**Bangladesh**
11	Chile
12	Netherlands
13	**Solomon Islands**
14	**Fiji**
15	**Cambodia**

Source: Produced by ESCAP, based on data from Bündnis Entwicklung Hilft and UNU-EHS, *World Risk Report 2016* (2016). Available from http://collections.unu.edu/view/UNU:5763.

Specific country experiences from post-disaster needs assessment (PDNA) reports[70] reveal destructive impacts of natural disasters on ICT infrastructures. A few country experiences are discussed below.

Impact of Cyclone Winston on Fiji in 2016[71]

On 20 February 2016, Category 5[72] Tropical Cyclone Winston struck Fiji. The cyclone

[70] These reports are prepared by the respective country governments with the assistance of the Global Facility for Disaster Reduction and Recovery (GFDRR) and the international community at large. They are increasingly being used by governments and the international development community to base the recovery and reconstruction plans. While the PDNA reports do not provide a comprehensive coverage of all the damages that natural disasters cause, they are able to provide valuable lessons on the extent to which natural disasters have caused damage to the ICT infrastructure and how ICT has contributed to disaster risk reduction.

[71] Government of Fiji, "Fiji: Post-Disaster Needs Assessment – Tropical Cyclone Winston, February 20, 2016", May 2016. Available from https://www.gfdrr.org/sites/default/files/publication/Post%20Disaster%20Needs%20Assessments%20CYCLONE%20WINSTON%20Fiji%202016%20%28Online%20Version%29.pdf.

[72] Tropical cyclones are categorized by intensity scales according to their maximum sustained winds. In Fiji, cyclones are categorized on a scale of one to five, with five having the highest sustained wind speed. Tropical Cyclone Winston was the first Category 5 cyclone to directly impact Fiji and the most intense cyclone on record

affected 540,400 people, or approximately 62 per cent of the country's total population. The estimated cost of the damages caused by the cyclone in Fiji was USD 0.6 billion-0.9 billion, approximately one fifth of the country's GDP. The immediate damage in communication and electricity infrastructure caused the loss of cellular, fixed-line, radio and television services. While mobile network services were partially restored after only a few days, up to 50 per cent of all sites were still operating on generators due to the disruptions of electricity networks. In places where fixed-line services were disrupted, the service provider was offering free wireless devices as substitute, though except for business customers, the uptake was found to be minimal.

The contribution of the communication sector towards GDP averaged 6.4 per cent from 2007 to 2014, underscoring the value of access to information. The cyclone disabled power and communication networks linking the islands, with 80 per cent of the population losing electricity. The lack of communication inhibited timely access to critical information on the disaster impact that could have contributed to more effective response and recovery. Businesses were significantly affected by the lack of connectivity, particularly hotels and tourist attractions that relied on ICT for bookings and management.

The total damage to the communication sector[73] was estimated to be approximately USD 24 million. The cyclone damaged cellular transmission towers and equipment. As a result, new cellular transmission towers and equipment were recommended to be rebuilt to Category 3 and 4 specifications, especially in rural and remote sites. For increasing the resilience of fixed-line communication, the establishment of fibre rings was recommended to build redundant links that will enhance resiliency and backhaul to the islands. The PDNA report noted that in rural areas, communication infrastructure construction was not to Category 3 or 4 standards due to low returns on investment. This highlights the need to ensure that telecommunication operators adhere to stringent standards. The government expressed its willingness to assist the private sector in building more disaster-resilient infrastructure through public-private partnerships and infrastructure-sharing arrangements. In addition, other mechanisms such as early warning systems are critical for preparedness (see Box 1).

to affect the country.

[73] Including loss of income due to interruption of service.

Box 1: The establishment of a regional multi-hazard early warning system is a pressing need in the Pacific

In the aftermath of Tropical Cyclone Winston that devastated Fiji in early 2016, the Fijian Minister of Agriculture, Maritime and Rural Development and National Disaster Management stated that there is a pressing need to establish a regional multi-hazard early warning system for Pacific Island countries.

While responding to the impact of the cyclone, disaster management authorities realized that people in the Island States had limited experience with intense tropical cyclones like the Category 5 Tropical Cyclone Winston. This implies that the communities' understanding of the characteristics of a Category 5 cyclone and its associated risks was inadequate. People understood the threat of strong winds in the early warning that was disseminated prior to the disastrous event but their lack of recent experience with intense cyclones meant that they were not prepared for the occurrence of storm surges. Coastal communities found it difficult to make appropriate and timely decisions to evacuate to higher grounds.

This situation is not unique to Fiji and given the increasing trends of hydrometeorological hazards in the Pacific, regional multi-hazard early warning should be a priority. Through the Regional Specialized Meteorological Centres that was established in Nadi, Fiji by the World Weather Watch Programme of the World Meteorological Organization since 1995, Fiji has been forecasting tropical cyclones south of the equator, and issuing public and marine weather bulletins to seven neighbouring countries in the Pacific subregion. During a regional advocacy event in ESCAP, the Minister indicated that this regional weather advisory provides the solid foundation to develop the proposed regional multi-hazard early warning system in the Pacific.

Since then, ESCAP has provided regional advisory services to the Ministry of Agriculture, Maritime and Rural Development and National Disaster Management that included assistance in the conduct of an interagency and multisectoral PDNA, development of the Post Tropical Cyclone Winston Recovery Framework, as well as advocacy for the regional multi-hazard early warning system at regional and global levels.

Source: Produced by ESCAP, based on information by Mr. Puji Pujiono, Regional Advisor on Disaster Risk Reduction, ESCAP, (December 2016).

Impact of Cyclone Pam on Vanuatu in 2015[74]

The Category 5 Cyclone Pam struck Vanuatu between 12 and 14 March 2015, causing an estimated USD 449.4 million worth of damage and loss, equivalent to 64.1 per cent of Vanuatu's GDP.

The storm brought down communication systems linking the islands, which hampered initial efforts to obtain a comprehensive understanding of the full scale of the disaster's impact. Another report[75] noted that Internet traffic levels stayed extremely low for more than 36 hours after the onset of the cyclone before slowly beginning to recover, and it took about 10 days for traffic to gradually climb back up to normal levels.

It was reported that the use of SMS for early warning was effective in alerting citizens

[74] Government of Vanuatu, "Vanuatu: Post-Disaster Needs Assessment – Tropical Cyclone Pam", March 2015. Available from https://www.gfdrr.org/sites/default/files/publication/pda-2015-vanuatu.pdf.
[75] Akamai, "State of the Internet Q1 2015 report", 2015. Available from https://www.akamai.com/uk/en/multimedia/documents/state-of-the-internet/akamai-state-of-the-internet-report-q1-2015.pdf.

of the approaching cyclone, which resulted in the cyclone causing fewer than 20 causalities. Further, it was highlighted that the private sector and the government showed excellent immediate disaster coordination and rapid response. However, the national multi-hazard early warning system was severely impaired, with observation and communication equipment damaged. The Vanuatu Meteorology and Go-hazards Department estimated that it will require USD 2.1 million to rebuild the system.

The PDNA report noted that the communication distribution networks sustained the most substantial damage. Microwave towers, transmission towers and equipment were either destroyed or damaged, causing disruptions to mobile voice and data services, as well as to radio and television broadcasting. Communication with the capital was cut off for one day after the cyclone had passed. Outer islands did not have telecommunication services until a week later, and some experienced no connectivity for up to three weeks or longer. Businesses suffered from poor quality coverage (and higher costs due to calls requiring multiple attempts), with some resorts and bungalows being without services for a prolonged time.

Communication services were restored with the assistance of the Emergency Telecommunications Cluster.[76] Emergency satellite communications were established to many islands within five days, and approximately 80 per cent of the networks were functioning (with some loss in service quality) after ten days. Repairs required significant investment in towers and equipment by all communication networks. However, there were hindrances to repairs related to logistics and lack of electricity.

Impact of Earthquakes on New Zealand in 2011 and 2016

New Zealand is located on the Pacific Ring of Fire—a highly seismically active region. As such, it frequently experiences earthquakes and tsunamis. Notable disasters include the devastating earthquake that struck Christchurch on 22 February 2011, resulting in 185 deaths and causing more than USD 13.5 billion (in 2005 USD) worth of damage.[77] More recently, the Kaikoura Earthquake in November 2016 resulted in USD 3.2 billion worth of damage and two fatalities.

The impact of the Kaikoura Earthquake on the ICT infrastructure in the vicinity of the epicentre was severe. The terrestrial backbone fibre-optic cable supporting fixed and mobile networks was damaged in six places. It was laid alongside the South Island’s main highway

[76] The Emergency Telecommunications Cluster is a global network of organizations that work together to provide shared communication services in humanitarian emergencies. See https://www.etcluster.org.
[77] New Zealand Ministry for Culture and Heritage, “Christchurch earthquake kills 185”, 12 April 2017. Available from https://nzhistory.govt.nz/page/christchurch-earthquake-kills-185; and Centre for Research on the Epidemiology of Disasters, “EM-DAT: The International Disaster Database”, 2017. Available from http://emdat.be (accessed 31 January 2017).

that was blocked by a high number of slips, meaning that repair works on the cable took months. An interim planned solution was to connect to a submarine fibre-optic cable, 50 metres offshore. This example highlights the need for redundancy, as with one backbone terrestrial cable so severely damaged, the connectivity to the rest of the South Island was reliant on just one other terrestrial cable. If it was also damaged, much of the South Island would have remained offline. To minimize the chance of that happening, the telecommunication provider cancelled permits for any earth works or maintenance along the length of the cable, and asked residents living alongside the cable to ensure they protect against any risk of damage.[78]

Impact of Typhoon Chan-hom on the Northern Mariana Islands in 2015

On 7 July 2015, following the passing of Typhoon Chan-hom, the single submarine fibre-optic cable connecting the Northern Mariana Islands broke, severely disrupting all voice and data transmissions to the islands, including Internet communications, phone calls, text messages and banking transactions. Low Internet traffic persisted for six days at roughly 5 to 10 per cent of usual levels, before a slight recovery. Cable repair took two weeks, during which time the telecommunication provider could restore partial connectivity using an old microwave link.[79]

Disruptions to ICT Infrastructure in the Marshall Islands in 2017

In January 2017, a single submarine fibre-optic cable to the Marshall Islands was severed, putting the whole island chain offline. Subsequent use of satellite Internet was only able to provide 3 per cent of normal bandwidth used. Multiple users attempting to use the Internet were faced with loading errors and exceedingly low speeds. As a solution, Internet use was rotated on a two-to-three-hour basis to provide an acceptable level of service to all customers.[80]

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[78] Vodafone, "Vodafone, Spark and Chorus working together to restore services to Kaikoura", 16 November 2016. Available https://news.vodafone.co.nz/article/vodafone-spark-and-chorus-working-together-restore-services-kaikoura.

[79] Akamai, "State of the Internet Q3 2015 report", 2015. Available from https://www.akamai.com/uk/en/multimedia/documents/state-of-the-internet/akamai-state-of-the-internet-report-q3-2015.pdf.

[80] Feliz Solomon, "Tired of Waiting for the Internet Repairman? Just Be Glad You're Not in the Marshall Islands", *Time*, 10 January 2017. Available from http://time.com/4629911/internet-blackout-marshall-islands-micronesia.

Improving E-resilience: Investment in Submarine Fibre-optic Cable Redundancy

Many of the examples above (the Marshall Islands, the Northern Mariana Islands and New Zealand) illustrate the consequences of cable faults on Internet connectivity. Fibre-optic cables are an important component of broadband connectivity between countries as it carries a majority of the Internet traffic. It has been estimated that submarine cables carry 99 per cent of international data.[81] Submarine cables are more reliable and cost-effective compared to the satellite options. In addition, submarine cables' carrying capacity is much higher (measured in terabits per seconds), while satellites typically offer only 1,000 megabits per second and display higher latency[82] than submarine options.[83] Therefore, the resilience of submarine cables is extremely important to ensure broadband connectivity. However, disruptions to submarine cables causing Internet outages have been frequently recorded in the Pacific. Table 7 summarizes the effects of all recent significant cable faults in the Pacific subregion for which information is available.

Table 7: Fibre-optic cable disruptions in the Pacific, recent examples

Country/ Territory	Year	Event	Event description	Consequences
Australia	2016	Cause not specified	Pipe Pacific Cable 1 (PPC-1) between Australia and Guam broke.	The cable was expected to be out of service for one month at least. The consequences on Internet services were limited as traffic was re-routed via alternative cables such as the Australia-Japan (AJC) link.[84]
Australia	2013	Cyclone Oswald	Floods caused by cyclone Oswald damaged coastal cable near Gladstone, Queensland.	The damaged cable caused disruptions to 2G, 3G and 4G networks in Northern and Central Queensland. Landline and broadband services were cut in a number of locations in South-East Queensland.[85]
French Polynesia	2014	Landslide	A landslide occurred near the landing point of Honotua cable	As a result of the repair work, the cable had not operated for two days. A satellite backup

[81] Douglas Main, "Undersea Cables Transport 99 Percent of International Data", *Newsweek*, 2 April 2015. Available from http://www.newsweek.com/undersea-cables-transport-99-percent-international-communications-319072.
[82] Latency is the delay before a transfer of data begins following an instruction for its transfer.
[83] Thanks to David Butcher for raising this point.
[84] Richard Chirgwin, "Submarine cable cut lops Terabits off Australia's data bridge", *The Register*, 7 February 2016. Available from http://www.theregister.co.uk/2016/02/07/cable_cut_lops_terabits_off_australias_net_connectivity/.
[85] Ry Crozier, "Telstra flies in crew to repair flood-damaged fibre", *IT News*, 28 January 2013. Available from https://www.itnews.com.au/news/telstra-flies-in-crew-to-repair-flood-damaged-fibre-330319.

			linking French Polynesia to the rest of the world.	system was used to provide connectivity. International traffic could only reach 10 per cent of its normal capacity. Peer-to-peer and video services were unavailable [86]
Marshall Islands	2016-2017	Cause not specified	The undersea cable (HANTRU-1) linking the Marshall Islands with Guam was damaged between December 2016 and January 2017.	The damaged cable led to major Internet disruption in the country for three weeks. Banking, educational, government and business services were significantly affected. In Ebeye Islands, the Internet was completely cut off. A satellite backup system was used during the time of outage, but it could only provide 3 per cent of the normal bandwidth the population had access to via the cable in normal times. After one week, a rotating Internet system was implemented to provide services for two to three hours every day.[87]
New Zealand	2016	Earthquake	In November 2016, a 7.5 magnitude earthquake cut the terrestrial fibre-optic link between the city and the rest of the world.	Phone and broadband services in Kaikoura, South Island was cut off for a week. Telecommunication operators and infrastructure providers restored services by extending an existing undersea cable connecting Wellington and Christchurch.[88]
Northern Mariana Islands	2015	Typhoon Chan-hom	Following Typhoon Chan-hom, the undersea cable linking the Northern Mariana Islands with the rest of the world (Mariana-Guam Cable) experienced a break in July 2015.	At the time of the fault, the Northern Mariana Islands was linked to the rest of the world via this single fibre-optic cable. As a consequence, all Internet, banking and phone services stopped operating in the insular area. A second undersea cable is expected to be operational by the end of 2017.[89] This will ensure redundancy and reduce the risks of Internet outage.

[86] Cédric Valax, "Honotua: la Polynésie privée de câble pendant deux jours", *Radio 1*, 29 April 2014. Available from https://www.radio1.pf/honotua-la-polynesie-privee-de-cable-pendant-deux-jours/.
[87] Wendy Everett, "Internet blackout forces Marshall Islanders to give up social media contact 'cold turkey' at Christmas", *ABC News*, 9 January 2017. Available from http://www.abc.net.au/news/2017-01-09/internet-cable-repair-forces-marshall-islands-offline/8169484.
[88] Spark, Chorus and Vodafone, "Telecommunications services restored in Kaikoura", *Scoop*, 17 November 2016. Available from http://www.scoop.co.nz/stories/BU1611/S00654/update-telecommunicationss-services-restored-in-kaikoura.htm; and Tom Pullar-Strecker, "Kaikoura could get phone, internet back in days after quake cuts cable", *Stuff*, 15 November 2016. Available from http://www.stuff.co.nz/business/industries/86463492/Kaikoura-could-get-phone-internet-back-in-days-after-quake-cuts-cable.
[89] Telegeography, "Cable Compendium: a guide to the week’s submarine and terrestrial developments", 4 September 2015. Available from https://www.telegeography.com/products/commsupdate/articles/2015/09/04/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-developments/; and Gaynor Dumat-ol Dalen, "CNMI Disconnected: Cut Cable Shuts Down Phones, Banking", *Submarine Telecoms Forum*, 10 July 2015. Available from http://subtelforum.com/90cnmi-disconnected-cut-cable-shuts-down-phones-banking/.

Papua New Guinea	2017	Earthquake	A 5.5 magnitude earthquake cut the Pipe Pacific Cable 1 (PPC-1) near Madang, Papua New Guinea. PPC-1 links Papua New Guinea with Australia and Guam.	The APNG2 cable was used to re-route communication traffic. However, Telikom PNG expected potential congestion until the cable was fixed.[90]

Sources: Consolidated by ESCAP, based on information from http://www.submarinecablemap.com/ and other online sources.

The examples in Table 7 demonstrate the Pacific subregion's vulnerability to Internet disruptions. Countries with several undersea cables generally experience limited consequences on Internet connectivity if one of these links is damaged as they can re-route traffic. However, the vast majority of countries/territories in the subregion rely on a limited number of undersea cables to ensure Internet connectivity (see Table 8). For example, French Polynesia, Federated States of Micronesia, New Caledonia, Tonga and Vanuatu are all connected to the rest of the world via a single cable. Similarly, Palau, the Solomon Islands and Tonga will rely on a single fibre-optic link in the near future once current infrastructure projects are completed. These countries/territories are therefore at high risk of Internet disconnection if their sole link experiences a fault. This demonstrates the urgent need for redundancy in connectivity in the Pacific subregion. Another dimension that will likely affect reliable resilient submarine cables is their lifespan. Since the deployment of submarine cable is costly in Pacific Island countries, there should be appropriate planning to ensure replacement of older cables.

One of the submarine cables—Southern Cross Cable Networks—connecting the United States of America and the Asia-Pacific region is planning a third submarine cable between the United State of America, Australia and New Zealand, with Fiji, Samoa, Tokelau and Kiribati showing interest. This submarine cable is estimated to cost USD 350 million, and is projected to provide an additional 60 Tbps capacity to the existing 20 Tpbs capacity of the two cables. The new cable is expected to be operational by 2019.[91]

[90] https://twitter.com/pngtelikom/status/871627150704558080?lang=en
[91] Corinne Reichert, "NEXT subsea cable will be fastest between US and APAC: Southern Cross", *ZDNet*, 14 August 2017. Available from https://www-zdnet-com.cdn.ampproject.org/c/www.zdnet.com/google-amp/article/next-subsea-cable-will-be-fastest-between-us-and-apac-southern-cross/

Table 8: Number of cables linking the country with the rest of the world (including projects near completion), as of June 2017

0	1	2	3	4	9	10+
Cook Islands **Kiribati** **Nauru** **Niue** **Tokelau** **Tuvalu**	**French Polynesia** -Honotua (2010) **Micronesia (Fed. States of)** -HANTRU1 (2010) **New Caledonia** -Gondwana-1 (2008) **Palau** -SEA-US (Q3 2017) **Samoa** -Tui-Samoa (Q4 2017) **Solomon Islands** -SISC (Q4 2018) **Tonga** -Tonga cable (2013) **Vanuatu** -ICN-1 (2014)	**Northern Mariana Islands** -Atisa (June 2017) -Mariana-Guam Cable (1997)	**American Samoa** -SAS (2009) -Hawaiki (June 2018) -ASH (2009) **Papua New Guinea** -PNG National Submarine Fibre Cable Network -APNG-2 -PPC-1	**New Zealand** -SCCN (2000)[92] -Hawaiki (June 2018) -TGA (2017)	**Guam**[93] -PPC-1 (2009) -SEA-US (Q3 2017) -AAG (2009) -GOKI (2013) -Tata TGN-Pacific (2002) -HK-G (Q4 2019) -HANTRU1 (2010)	**Australia**[94] -Trident Subsea (Q2 2018) -AWE (Q4 2018) -SeaMeWe-3 (1999) -ASC (Q3 2018) -INDIGO-West (Q1 2019) -APNG-2 (2006) -PPC-1 (2009) -SISC (Q4 2018) - AJC (2001) -TGA (2017) -SCCN (2000) -Hawaiki (June 2018) -Telstra

[92] SSCN connects New Zealand to the rest of the world in two different locations, it is therefore counted twice.
[93] SEA-US and AAG are counted twice as they will each link Guam via two landing stations. However, Atisa and the Mariana-Guam cables are not counted as they only link Guam with the Northern Mariana Islands where they are the sole connection links with the rest of the world.
[94] Gondwana-1 and SISC are not counted for Australia as they are the sole cables linking New Caledonia and the Solomon Islands, respectively, to the rest of the world.

			Endeavour (2008) -PPC-1 (2009) -APNG-2 (2006)

Source: Consolidated by ESCAP based on information from http://www.submarinecablemap.com.

As a government measure towards protecting submarine cables, Australia created three “protection zones”,[95] restricting marine activities that could potentially damage the cables linking Australia to the rest of the world. The government also regulates closely all projects on deployment of new submarine cables.

At the subregional level, ESCAP has been strengthening the capacity of Pacific SIDS in operating multi-hazard early warning systems for extreme weather-related disasters through a project that runs from May 2016 to April 2018 (see Box 2). In particular, the project focuses on strengthening the access to and use of space-based and geospatial data to create, deliver and manage early warning signals in the Pacific subregion by assisting with the operation of national geoinformation platforms as a key part of the early warning system.

The project produced: gaps and needs analysis reports in collaboration with the Asian Institute of Technology (AIT) and the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG); enhanced capacity of Pacific developing countries in using geospatial data for early warning systems through intensive training programmes; strengthened national early warning systems of selected Pacific countries through the implementation of tailored country pilot projects; and drafted the Pacific strategy paper for early warning systems in the subregion through analysis and discussions at expert group meetings. A subregional workshop will be held in the Pacific on 4-5 April 2018 to share key findings and outputs, and discuss future collaborative actions.

[95] Australian Communications and Media Authority, "Declaring a submarine cable protection zone", 1 May 2017. Available from http://www.acma.gov.au/Industry/Telco/Infrastructure/Submarine-cabling-and-protection-zones/declaring-a-submarine-cable-protection-zone.

Box 2: ESCAP project on strengthening multi-hazard risk assessment and early warning systems in Pacific Island countries

1. **Project Objectives**
   - Strengthen the capacity of Pacific Island countries in multi-hazard assessment and early warning systems, including the use of space technology and geospatial information systems;
   - Assist Pacific regional cooperative platforms on data sharing for multi-hazard early warning systems; and
   - Contribute to global development agendas such as the Sustainable Development Goals (SDGs), Sendai Framework for Disaster Risk Reduction and Paris Agreement on Climate Change.

2. **Key Activities and Outputs**

   a. Organized the first subregional workshop in Nadi, Fiji on 13-15 September 2016, which led to:
   - Enhanced awareness on multi-hazard risk assessment and early warning systems;
   - Shared applicable practices and knowledge on early warning systems that use space technology applications in the Pacific context; and
   - Planned collective actions among Pacific Island countries for global events such as SDG-related meetings, United Nations Global Geospatial Information Management events and the tentative Ministerial Conference on Space in 2018.

   b. Produced the following two analysis reports (January-December 2017):
   - Gaps and needs analysis on multi-hazard early warning systems in the Pacific (by BMKG in collaboration with the Secretariat of the Pacific Regional Environment Programme or SPREP); and
   - Gaps and needs analysis on geoportal and geospatial data for early warning systems in the Pacific (by AIT in collaboration with SPREP).

   c. Conducted the following two intensive training workshops on:
   - Building and operating geoportals, geodatabase and geospatial data management for early warning systems. The training was held at AIT, Thailand on 6 February - 3 March 2017, and participated by representatives from eight Pacific Island countries; and
   - Multi-hazard risk assessment and early warning systems. The training was held at BMKG, Indonesia on 10 July - 2 August 2017, and participated by representatives from six Pacific Island countries.

   d. Conducted the following pilot projects in the Pacific (August-December 2017):
   - AIT conducted five pilot projects focusing on operating national geoportals and geospatial database with training in Fiji, Federated States of Micronesia, Solomon Islands and Tonga; and
   - BMKG conduct three pilot projects focusing on multi-hazard early warning systems with training in Papua New Guinea and Tonga.

   e. Developed a Pacific strategy for knowledge hubs on early warning systems with an emphasis on the use of geospatial data (June-December 2017):
   - The first expert group meeting was held in Fiji on 7-8 June 2017 in collaboration with Japan, SPREP, regional specialized meteorological centres and national hydrometeorological services; and
   - The second expert group meeting was held in Indonesia on 8-9 November 2017.

   f. Developing an e-learning platform for disaster risk reduction and space technology (April 2017 - March 2018):
   - The server will be at AIT; and
   - A team at AIT will continue to develop and update the platform.

   g. The final subregional workshop will be organized on 4-5 April 2018:
   - The focus will be on identifying collaborative actions to ensure that early warning systems and space technology applications in the Pacific contribute to the implementation of global

development agendas such as the SDGs, Sendai Framework for Disaster Risk Reduction and Paris Agreement on Climate Change.

3. **Time Frame:** May 2016 - April 2018 (24 months).

Source: Produced by ESCAP, based on information by Mr. Tae Hyung Kim, Economic Affairs Officer, Space Applications Section, ESCAP, (December 2016).

3.6 ICT Regulatory Policies

Another relevant driver of demand for broadband connectivity is a conducive regulatory policy for ICT infrastructure investment. Historically, the telecommunication industry was run and controlled by monopolies of national governments due to the high capital requirements. These monopolies often provided inefficient and costly services. However, technological changes, improving economic standards and the need for affordable ICT services consolidated the political will for regulatory reform in the sector in many Pacific Island countries. As a result, private investors who are often foreign companies invested heavily in the telecommunication infrastructure, which has led to improved access and affordability, and subsequently, a flourishing telecommunication sector that has contributed positively to the economic growth of countries.[96]

Specific policy interventions have been found to promote the growth of the telecommunication sector. For instance, the presence of a strong and independent judiciary system has been found to positively influence private investment on telecommunication infrastructure. Moreover, the quality of the regulatory bureaucracy has shown to impact infrastructure development.[97] Studies have also found positive effects of quality regulatory governance on telecommunication industry performance.[98] Some countries have established an independent regulator to enhance credibility in their regulatory governance.

The overall experience of the telecommunication sector's development in Pacific Island countries has revealed that introduced competition through regulatory reforms in the

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[96] Lars-Hendrik Röller and Leonard Waverman, "Telecommunications infrastructure and economic development: A simultaneous approach", WZB Discussion Paper FS IV 96-16, July 1996. Available from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.202.9393&rep=rep1&type=pdf.

[97] Brian Levy and Pablo T. Spiller, "The institutional foundations of regulatory commitment: A comparative analysis of telecommunications regulation", *Journal of Law, Economics and Organization*, vol. 10, no. 2 (October 1994), pp. 201-246; and Brian Levy and Pablo T. Spiller, *Regulations, institutions and commitment: Comparative studies of telecommunications* (Cambridge, Cambridge University Press, Cambridge, 1996).

[98] Siope Vakataki 'Ofa, *Telecommunications Regulatory Reform in Small Island Developing States: The Impact of the WTO's Telecommunications Commitment* (Newcastle upon Tyne, Cambridge Scholars Publishing, 2012); Carsten Fink, Aaditya Mattoo and Randeep Rathindran, "An assessment of telecommunications reform in developing countries", *Information Economics and Policy*, vol. 15, no. 4 (2003), pp. 443-466; and Scott J. Wallsten, "An econometric analysis of telecom competition, privatization, and regulation in Africa and Latin America", *Journal of Industrial Economics*, vol. 49, no. 1 (March 2001), pp. 1-19.

telecommunication sector achieves positive outcomes.[99] Pacific Island countries that have introduced competition in the mobile services sector (by allowing a second private telecommunication operator to enter) have experienced significant expansion in broadband access (see Figure 17).

Also, the role of an independent regulator in ensuring that the incumbent state-owned operator and private operators are providing productive efficiency considerations dictated by market size, is critical.[100] Papua New Guinea and Vanuatu have introduced an independent regulator to oversee the regulation of the sector. This is important progress towards enhancing the credibility of the policy reforms implemented by governments.

Generally, Pacific Island countries have progressed well in several key regulatory policy reforms in the telecommunication sector. Annex 3[101] provides a snapshot of regulations in each of the Pacific Island countries.

Nevertheless, the lack of technical expertise in some of these regulatory authorities often limits their effectiveness. Some regulatory authorities have been seeking assistance from regional and international organizations in addressing specific technical issues on spectrum management, licensing management and implementing universal service funds, among others.

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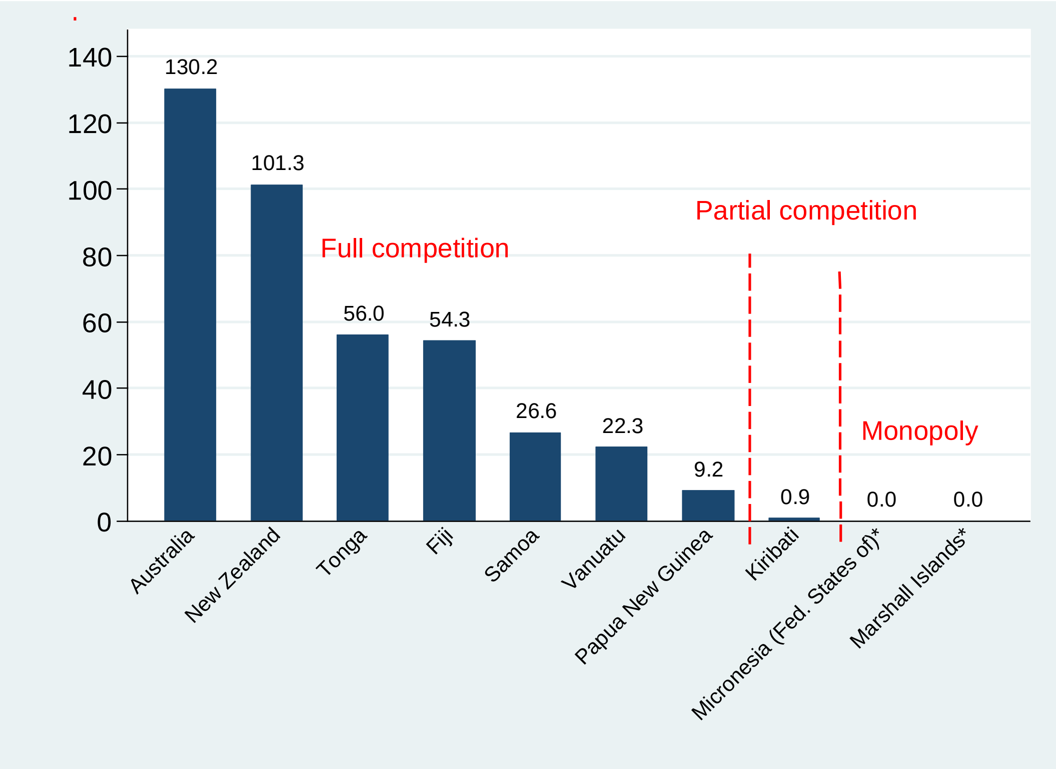
[99] Siope Vakataki ʻOfa, *Telecommunications Regulatory Reform in Small Island Developing States: The Impact of the WTO's Telecommunications Commitment* (Newcastle upon Tyne, Cambridge Scholars Publishing, 2012).

[100] Pavlos C. Symeou and Michael G. Pollitt, "Telecommunications in small economies: The impact of liberalization and alternative technologies on universal service", Working Paper Series 19/2007, Judge Business School, University of Cambridge. Available from https://www.jbs.cam.ac.uk/fileadmin/user_upload/research/workingpapers/wp0719.pdf.

[101] Momar Mbengue is kindly acknowledged for undertaking the review of regulations in the Pacific Island countries.

Figure 17: Mobile-broadband adoption and level of competition, 2016



Sources: Produced by ESCAP, based on data from ITU's World Telecommunication/ICT Indicators Database 2016; and World Bank, *The Little Data Book on Information and Communication and Technology 2017* (Washington, D.C., 2017).

3.7 Governance

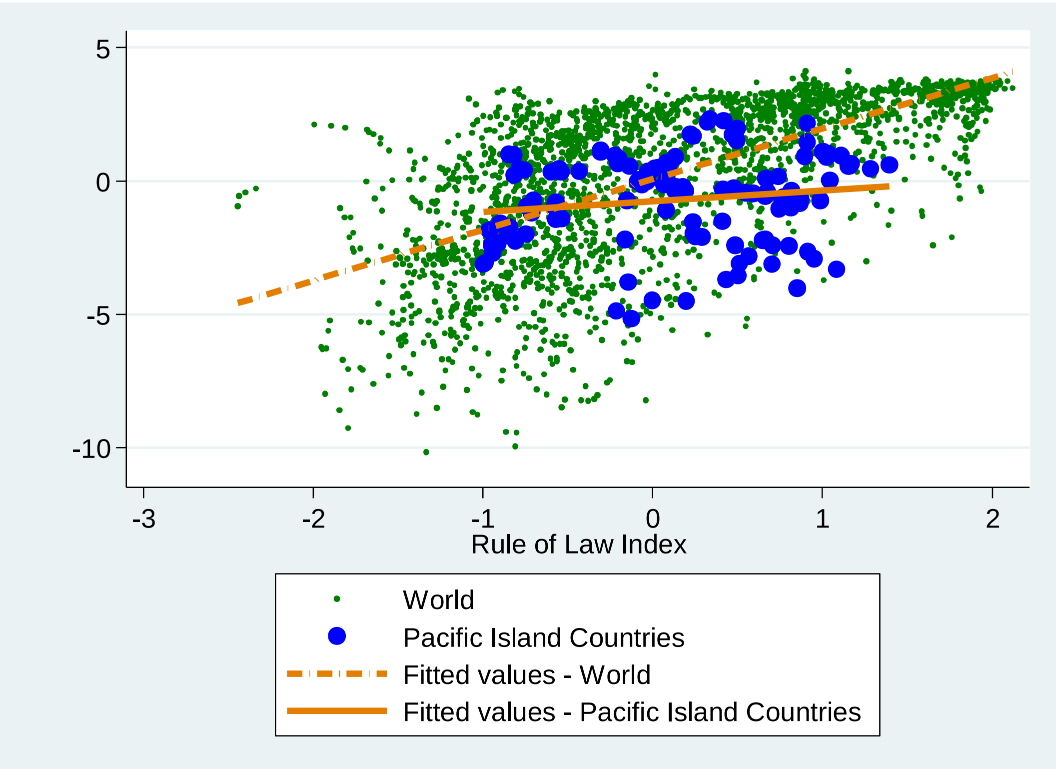
Governance[102] is found to be positive and strongly correlated (>0.60) with fixed-broadband connectivity in the case of ESCAP countries (with the exception of voice and accountability). However, this relationship is less significant in the case of Pacific Island countries with four governance indicators (<0.24), while two governance indicators have a negative relationship with broadband connectivity. This is partly due to the low quality of governance in most Pacific Island countries compared to the ESCAP sample.

For example, the perception on regulatory quality over time for Pacific Island countries appears to be stagnant and remained in the lower range (less than 0). However, when all countries (world sample) are included in the analysis, the correlation coefficients between

[102] One way to examine the relationship between governance and the development of broadband connectivity is to use the Worldwide Governance Indicators. There are six dimensions quantified by the Worldwide Governance Indicators dataset, namely: (1) rule of law; (2) regulatory quality; (3) political stability; (4) control of corruption; (5) government effectiveness; and (6) voice and accountability. For more information, see: http://info.worldbank.org/governance/wgi/#home.

regulatory quality and mobile broadband (0.58)[103] and fixed-broadband (0.79) are positive and statistically significant. Similar patterns are found for other governance indicators. While rule of law (Figure 18) is found to have a positive and statistically significant correlation with broadband connectivity for all countries (correlation coefficient = 0.67), a slightly weaker coefficient is found for Pacific Island countries (0.64). Two other governance indicators are found to be positively correlated with fixed-broadband penetration in the Pacific, namely, political stability (0.46) and government effectiveness (0.69).

Figure 18: Rule of law and broadband access, 2000-2016



Source: Produced by ESCAP, based on data sourced from ITU's World Telecommunication/ICT Indicators Database (21th Edition, June 2017); and World Bank's Worldwide Governance Indicators 2017.

A study[104] that examined the linkage between governance, institutions and regional infrastructure in selected Asian countries found that governance and institutions are crucial for regional infrastructure development. A one-point improvement in governance was

[103] Outliers with mobile-broadband subscriptions per 100 inhabitants of more than 200 have been omitted.
[104] Prabir De, "Governance, Institutions, and Regional Infrastructure in Asia", Working Paper No. 183, Asian Development Bank Institute, December 2009. Available from https://www.adb.org/sites/default/files/publication/156038/adbi-wp183.pdf.

estimated to result in a 1 to 1.5-point rise in regional infrastructure expansion.

ICT is an "enabling tool" for enhancing the effectiveness of government services by increasing transparency and inclusiveness. In particular, vulnerable groups who are unable to travel from their homes in the outer islands or rural communities to the main towns where government offices are physically located can benefit from e-government services.[105] Several Pacific Island governments have exploited this opportunity of using ICT to deliver public services to its citizens. For instance, respective governments have implemented online business registries in Tonga,[106] Samoa[107] and Vanuatu,[108] online taxation service in Fiji and Solomon Islands,[109] online form for request of national passport in Papua New Guinea,[110] online ship registry in Kiribati,[111] online reference to legislations in Tuvalu,[112] and online birth and death registration throughout the Pacific subregion.[113]

Increased delivery of government services through electronic means in turn motivates further adoption of broadband connectivity. Recent data from the *United Nations E-government Survey 2016* highlighted: "a sharp rise in the number of countries that are using e-government services. In 2003, only 45 countries had a one-stop-platform, and only 33 countries provided online transactions. By 2016, 90 countries offered one or more single entry portal on public information or online services, or both and 148 countries provided at least one form of online transactional services."[114] Using the 2016 e-government survey data, positive and statistically significant correlation exist between the use of e-government services worldwide and mobile-broadband adoption (see Figure 19). Similar correlation is also found for fixed-broadband adoption.

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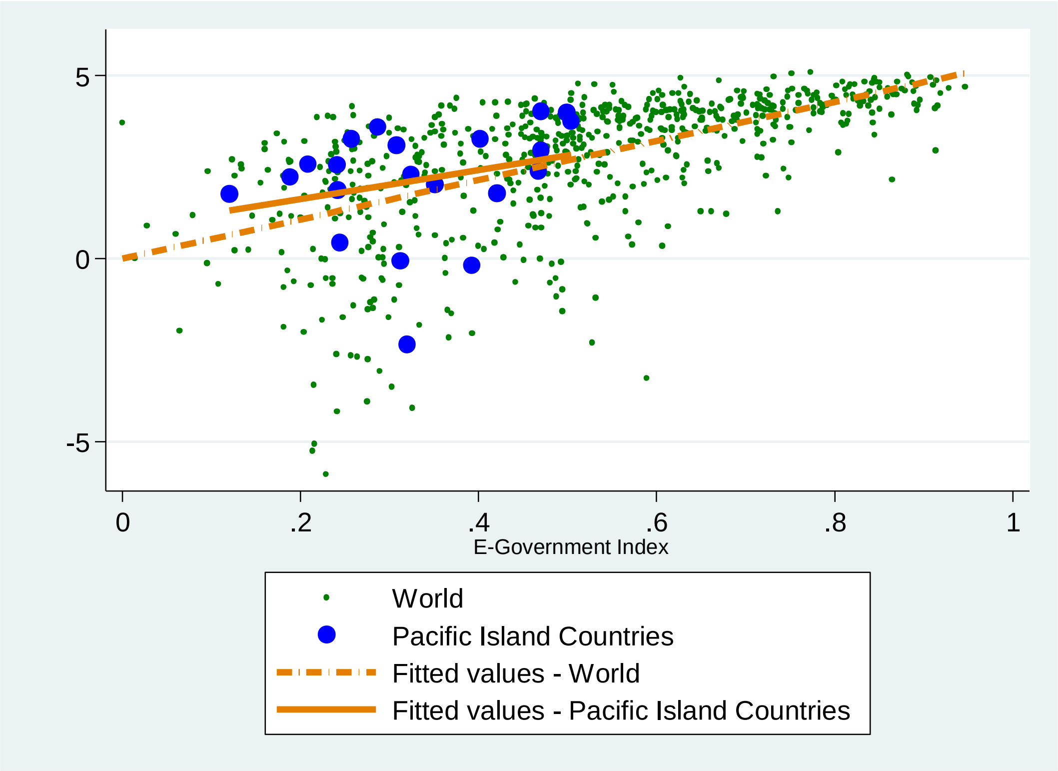
[105] Zhiyuan Fang, "E-Government in Digital Era: Concept, Practice, and Development", *International Journal of The Computer, The Internet and Management*, vol. 10, no. 2 (2002), pp. 1-22.
[106] Business Registries Office of Tonga. Available from https://www.businessregistries.gov.to/.
[107] Samoa Business Registry. Available from https://www.businessregistries.gov.ws/.
[108] Vanuatu Financial Services Commission. Available from https://www.vfsc.vu/.
[109] Fiji Revenue and Customs Service. Available from http://www.frcs.org.fj/.
[110] Papua New Guinea Immigration and Citizenship Service Authority, "Form Downloads". Available from https://www.immigration.gov.pg/form-downloads.html.
[111] Kiribati Ship Registry, "Registry Certificates". Available from http://www.kiribaship.com/EN/services/registration_certificate.aspx.
[112] Tuvalu Legislation Online. Available from https://tuvalu-legislation.tv/cms/.
[113] Pacific Civil Registration and Vital Statistics. Available from http://www.pacific-crvs.org/.
[114] United Nations, "UN E-Government Survey 2016". Available from https://publicadministration.un.org/egovkb/en-us/reports/un-e-government-survey-2016.

Figure 19: Mobile-broadband adoption and use of e-government services worldwide, 2016



Sources: Produced by ESCAP, based on data sourced from ITU's World Telecommunication/ICT Indicators Database 2016; and United Nations, *E-Government Survey 2016: E-Government in Support of Sustainable Development* (New York, 2016). Available from http://workspace.unpan.org/sites/Internet/Documents/UNPAN96407.pdf.

Note: Similar positive relationship is found for fixed-broadband connectivity.

4. Estimating Drivers of Broadband Adoption

Drawing from the discussions in the previous section on factors that influence demand for broadband connectivity, this section seeks to estimate and triangulate the statistical effects of some of these factors (with available data) on broadband access.

4.1 Data, Methodology and Econometric Model

The econometric model used a panel dataset with 202 countries over a period of 17 years (2000-2016). Sources of the dependent, independent and control variables are listed in Annex 2.

Two dependent variables used to represent broadband access were fixed-broadband subscriptions per 100 inhabitants[115] and mobile-broadband subscriptions per 100 inhabitants. The mobile-broadband variable was included as a control variable in the estimates on fixed-broadband variable to control for any effect between the two, and vice versa.

The predictor variables included the following:

- Population density (total population/square kilometre) was used to proxy geographic concentration/dispersion of population settlements, which has significant cost implication on ICT infrastructure deployment;
- Urban population (per cent of total) was used to proxy the level of urbanization in a country, which influences decisions on private investment in broadband infrastructure expansion—the higher the urbanization rate, the higher the chance that private investment will invest in broadband expansion;
- Per capita access to electricity (electricity consumption kWh per capita) was used because ICT infrastructure and technologies usage depend on access to electricity;
- GDP per capita was used to measure individuals' economic level in a country;[116]
- Imports of ICT goods (per cent of total imports) was used to proxy availability of ICT devices. A higher percentage compared to total imports implies that more ICT devices are

[115] As used in studies by: Michael R. Ward and Shilin Zheng, "Mobile telecommunications service and economic growth: Evidence from China", *Telecommunications Policy*, vol. 40, nos. 2-3 (March 2016), pp. 89-101; Siope Vakataki 'Ofa, "The WTO's telecommunications commitments and the credibility of telecommunications regulatory reforms in small island developing states", *Pacific Economic Bulletin*, vol. 24, no. 3 (2009), pp. 39-57; Scott Wallsten, "Of Carts and Horses: Regulation and Privatization in Telecommunications Reforms", *Journal of Policy Reform*, vol. 6, no. 4 (2003), pp. 217–231; and Carsten Fink, Aaditya Mattoo and Randeep Rathindran, "An assessment of telecommunications reform in developing countries", *Information Economics and Policy*, vol. 15, no. 4 (2003), pp. 443-466.

[116] It is calculated by dividing nominal GDP by real GDP and then multiplying by 100.

available domestically for use; and

- Governance was measured using the rule of law variable[117] from the World Bank's Worldwide Governance Indicators.[118] Effective governance is crucial for regional infrastructure development, with every one-point improvement in governance resulting in a 1 to 1.5-point rise in regional infrastructure.[119]

An interaction variable was included to test the specific effects of predictor variables on Pacific Island countries and other country groupings.[120] The Pacific Island countries grouping contained limited observations in several variables rendering some countries unusable. As a result, the SIDS country grouping was used instead.[121] Also, landlocked developing countries (LLDC) grouping was chosen to examine any effect of geographic characteristic (remoteness) on broadband access. Three additional country groupings were used based on income levels (lower middle, upper middle and high-income country groups) to assess any differences in broadband access due to income levels of countries. Technological progress was controlled for, by using a time dummy (year).[122]

The econometric model adapted from De[123] has the following form:

$$Broadband\_access_{it} = \alpha_0 + \alpha_i + \beta_1 X_{it} + \beta_2 K_{it} + \beta_3 (C_i \times M_{it}) + \varepsilon_{it}$$

i (1,2,3…)	: Country;
t	: Time dimension (2000, 2001, 2002…);
$Broadband\_access$	: Dependent variables – fixed-broadband subscriptions per 100 inhabitants and mobile-broadband subscriptions per 100 inhabitants (log);
X_{it}	: Vector of predictor variables (log);
K_{it}	: Fixed-broadband subscriptions per 100 inhabitants or mobile-broadband subscriptions per 100 inhabitants, included in the estimates as control variable, and vice versa;
C_i	: Income-country group dummies (small islands developing states (SIDS), landlocked developing countries (LLDC), lower middle-income, upper middle-income and high-income);
$C_i \times M_{it}$	: Interacted Income-country group dummy variables with selected predictor variable;

[117] As used in: Noorihsan Mohamad, "Telecommunications reform and efficiency performance: Do good institutions matter?" *Telecommunications Policy*, vol. 38, no. 1 (February 2014), pp. 49-65.
[118] Worldwide Governance Indicators. Available from http://info.worldbank.org/governance/wgi/#home.
[119] Prabir De, "Governance, Institutions, and Regional Infrastructure in Asia", Working Paper No. 183, Asian Development Bank Institute, December 2009. Available from https://www.adb.org/sites/default/files/publication/156038/adbi-wp183.pdf.
[120] Pacific Island countries' dummy was not included since there was not enough observations. However, the SIDS dummy variable was a good proxy for Pacific Island countries with similar socioeconomic and geographical characteristics.
[121] For the list of SIDS, see: https://sustainabledevelopment.un.org/topics/sids/list.
[122] As in studies by: Pavlos C. Symeou and Michael G. Pollitt, "Telecommunications in small economies: The impact of liberalization and alternative technologies on universal service", Working Paper Series 19/2007, Judge Business School, University of Cambridge. Available from https://www.jbs.cam.ac.uk/fileadmin/user_upload/research/workingpapers/wp0719.pdf; Federica Maiorano and Jon Stern, "Institutions and telecommunications infrastructure in low and middle income countries: The case of mobile telephony", *Utilities Policy*, vol. 15, no. 3 (September 2007), pp. 165–181; and Carsten Fink, Aaditya Mattoo and Randeep Rathindran, "An assessment of telecommunications reform in developing countries", *Information Economics and Policy*, vol. 15, no. 4 (2003), pp. 443-466.
[123] Prabir De, "Governance, Institutions, and Regional Infrastructure in Asia", Working Paper No. 183, Asian Development Bank Institute, December 2009. Available from https://www.adb.org/sites/default/files/publication/156038/adbi-wp183.pdf.

β	: Coefficients to be estimated;
α_i	: Unobserved country fixed effect;
ε_{it}	: Error term.

The estimation adopted the fixed effects method. The Hausman[124] test rejected random effects. The fixed effects model is ideal since it is interested in analysing the impact of predictor variables that varies over time. The fixed effect form of panel data model estimation explores the relationship between predictor variables and dependent variables within an entity (country i). Hence, fixed effects take into account unobservable characteristics within a country that may impact the predictor variable, effectively addressing omitted variable bias induced by the omission of time-invariant controls.

While the dataset consolidated observations from 202 countries over a period of 17 years (2000-2016) (total observations of 3,434), missing data for some countries resulted in limited matched observations across the variables in the estimations for the econometric analysis (unbalanced panel dataset). As a result, only 57 countries with 285 observations for regressions on fixed-broadband access, and 174 countries with 1,016 observations for mobile-broadband access were available. Despite the limited data, the overall ability of the model to explain variations in broadband access was satisfactory (R-squared (within) 0.54-0.63 for the estimates on fixed-broadband access, and 0.39-0.40 for mobile-broadband). In addition, the inclusion of the vector of predictor variables was statistically significant (F-test results for all country groupings produced coefficients with p-values of zero to four decimal places) compared to a model without it.

4.2 Results

The econometric results are given in Table 9 (with fixed-broadband access as the dependent variable) and Table 10 (with mobile-broadband access as the dependent variable). Overall, the estimates on fixed-broadband access (Table 9) show that on average, the size of the urban population (characterizing private investment in profitable areas) and economic levels (GDP per capita) are strong factors influencing (positively) fixed-broadband access in the global sample (57 countries). However, when controlling for different country groupings, different factors appear to be influencing fixed-broadband access. In the case of Pacific Island countries (SIDS sample), economic level seems to have a statistically significant influence on fixed-broadband access. However, the size of the urban population is an important factor for upper middle-income countries, and the availability of ICT devices is an important factor for high-income countries. Access to mobile broadband seems to have a positive and statistically significant influence on fixed-broadband access in the global sample.

[124] J. A. Hausman, “Specification Tests in Econometrics”, *Econometrica*, vol. 46, no. 6 (November 1978), pp. 1251-1271.

Table 9: Fixed-broadband access estimates

Dependent variable: Fixed-broadband subscriptions per 100 inhabitants (log)	(1) Small island developing states (SIDS)	(2) Landlocked developing countries (LLDC)	(3) Lower middle-income	(4) Upper middle-income	(5) High-income
Urban population (% of total) (log)	14.24***	12.09***	12.09***	2.090	10.17***
	(1.907)	(1.901)	(1.896)	(3.123)	(1.948)
GDP per capita (constant 2010 USD) (log)	0.562	1.103***	1.101***	0.514	0.741*
	(0.416)	(0.415)	(0.408)	(0.422)	(0.414)
Mobile-broadband subscriptions per 100 inhabitants (log)	0.103***	0.0845***	0.0843***	0.0735***	0.0689***
	(0.0257)	(0.0268)	(0.0262)	(0.0255)	(0.0261)
Electric power consumption (kWh per capita) (log)	-0.386	-0.282	-0.280	-0.219	-0.140
	(0.375)	(0.391)	(0.387)	(0.375)	(0.381)
ICT goods imports (% total goods imports) (log)	0.139	0.0945	0.0950	0.0733	-1.050***
	(0.119)	(0.124)	(0.123)	(0.119)	(0.372)
Population density (population/km^2) (log)	0.393	0.722	0.722	0.873*	0.618
	(0.459)	(0.469)	(0.468)	(0.454)	(0.459)
Rule of law (log)	-0.0534	-0.0494	-0.0493	-0.0562	-0.0412
	(0.0592)	(0.0615)	(0.0613)	(0.0593)	(0.0600)
SIDS*GDP per capita	3.762***				
	(0.929)				
LLDC*ICT goods imports		0.0355			
		(0.969)			
Lower middle-income			..		
			..		
Upper middle-income*urban population				13.74***	
				(3.474)	
High-income*ICT goods imports					1.251***
					(0.385)
Constant	-65.22***	-61.93***	-61.92***	-22.63*	-50.50***
	(8.959)	(9.261)	(9.236)	(13.36)	(9.698)
Observations	285	285	285	285	285
R-squared (within)	0.573	0.540	0.540	0.571	0.562
Number of countries	57	57	57	57	57
Country fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
F test	43.16***	40.50***	42.42***	41.21***	41.35***

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; for list of the 57 countries included in the estimates see Annex 4 – Note 2 (a); .. - omitted because of collinearity.

Using the same parameters to test mobile-broadband access (Table 10), results show that on average, the geographic spread of settlements and access to electricity are strong factors influencing (positively) mobile-broadband access in the global sample (57 countries). However, when controlling for different country groupings, the size of the urban population seems to be the important factor influencing (positively) mobile-broadband access in Pacific Island countries (SIDS).

The geographic spread of settlements appears to be an important factor influencing (positively) mobile-broadband access in LLDC and upper middle-income groups. For high-income countries, however, the important factor influencing (positively) mobile-broadband access is the availability of ICT devices. Access to fixed broadband seems to have a positive and statistically significant influence on mobile-broadband access in the global sample.

Overall, when comparing the factors driving fixed-broadband and mobile-broadband access, results point to two important issues. Firstly, different factors are found to be important influencers of broadband access in each country grouping. As such, policy measures must be tailored to the specific circumstances of the different country groupings.

Secondly, the effects of fixed-broadband access on mobile-broadband access (and vice versa) is positive for the global sample. This implies that when fixed-broadband access increases, mobile-broadband access is found to increase as well (and vice versa). However, when controlling for different country groupings, differences emerge (see Tables 14 and 15 in Annex 5). In the Pacific, there appears to be an inverse relationship between fixed-broadband and mobile-broadband access (Table 14). The same relationship is found when swapping the predictor variables from mobile broadband to fixed broadband) (see Table 15). Yet, in the case of LLDC, a positive relationship is found between the two variables (and vice versa). These findings are indicative of a possible variation in substitutability versus complementarity between fixed broadband and mobile broadband in different country groupings.

It must be noted that these results are based on a country-level panel dataset with no disaggregated data at the household or firm-level, which would be more appropriate for addressing this question. But other studies that have used disaggregated data have also revealed varied results. Studies[125] from Hong Kong (China), Japan, Republic of Korea, Portugal and Singapore that used disaggregated data found evidence of complementarity between the two broadband technologies—fixed and mobile. But another similar study in the European

[125] ANACOM, "Study on substitutability between fixed broadband and mobile broadband", 2015. Available from https://www.anacom.pt/streaming/subst_fixedmobilebroadband2015.pdf?contentId=1385792&field=ATTACHED_FILE; Jinsoo Bae, Yun Jeong Choi and Jong-Hee Hahn, "Fixed and mobile broadband: Are they substitutes or complements?" Economic Research Institute, Yonsei University, July 2014. Available from ftp://ftp.repec.org/opt/ReDIF/RePEc/yon/wpaper/2014rwp-68.pdf; and Wan-Ying Lin and others, "From the wired to wireless generation? Investigating teens' Internet use through the mobile phone", *Telecommunications Policy*, vol. 37, no. 8 (September 2013), pp. 651-661.

Union using household-level data found evidence of substitution.[126] The reasons for Internet use and characteristics of service supply may be unique to a country thereby influencing the choices of substitution or complementarity between fixed broadband and mobile broadband.[127]

Table 10: Mobile-broadband access estimates

Dependent variable: Mobile-broadband subscriptions per 100 inhabitants (log)	(1) Small island developing states (SIDS)	(2) Landlocked developing countries (LLDC)	(3) Lower middle-income (LMI)	(4) Upper middle-income (UMI)	(5) High-income (HI)
Population density (population/km^2) (log)	4.608***	4.642***	4.907***	4.702***	4.704***
	(1.134)	(1.133)	(1.148)	(1.109)	(1.144)
Electric power consumption (kWh per capita) (log)	4.185***	3.992***	3.777***	3.438***	3.912***
	(0.946)	(0.938)	(0.950)	(0.921)	(0.946)
Fixed-broadband subscriptions per 100 inhabitants (log)	0.751***	0.525***	0.544***	0.450***	0.458***
	(0.182)	(0.167)	(0.169)	(0.165)	(0.173)
Urban population (% of total) (log)	-2.662	4.912	5.016	-5.909	2.737
	(5.820)	(5.158)	(5.243)	(5.715)	(5.329)
GDP per capita (constant 2010 USD) (log)	-1.242	-1.982*	-1.553	-2.577**	-2.023*
	(1.037)	(1.042)	(1.048)	(1.042)	(1.067)
ICT goods imports (% total goods imports) (log)	-0.111	0.0200	-0.0737	-0.000400	-1.916**
	(0.308)	(0.310)	(0.313)	(0.303)	(0.969)
Rule of law (log)	0.0846	0.0950	0.0769	0.0337	0.0847
	(0.153)	(0.153)	(0.156)	(0.151)	(0.155)
SIDS*urban Population	70.63***				
	(24.80)				
LLDC*population Density		36.61***			
		(12.77)			
Lower middle-income			..		
			..		
Upper middle-income*population density				18.31***	
				(4.456)	
High-income*ICT goods imports					2.022**
					(1.008)

[126] Lukasz Grzybowski, “Fixed-to-Mobile Substitution in the European Union”, 2013. Available from https://econrsa.org/system/files/workshops/papers/2013/grzybowski.pdf.
[127] ANACOM, “Study on substitutability between fixed broadband and mobile broadband”, 2015. Available from https://www.anacom.pt/streaming/subst_fixedmobilebroadband2015.pdf?contentId=1385792&field=ATTACHED_FILE.

Constant	-48.22*	-57.40**	-61.01**	-11.44	-46.12*
	(25.46)	(25.09)	(25.47)	(27.38)	(26.36)
Observations	285	285	285	285	285
R-squared	0.746	0.746	0.737	0.756	0.741
Number of countries	57	57	57	57	57
Country fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
F test	4.87***	5.20***	4.89***	5.48***	4.82***

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; for details on ICT goods imports, see Annex 4 – Note 1; for list of the 57 countries included in the estimates see Annex 4 – Note 2(b); .. - omitted because of collinearity.

5. Conclusions and Policy Implications

The development of broadband connectivity in Pacific Island countries has made inroads despite the vastness of the subregion. Yet, for broadband connectivity to be accessible and affordable to all, many more steps need to be taken, including by other sectors such as the energy sector. While improvement in broadband connectivity in recent years has been attributed to regulatory policy reforms,[128] the broadband divide continues to widen despite best-intentioned policy interventions.

The findings from this working paper show that in addition to commonly known factors that influence broadband adoption, such as broadband affordability and regulatory policies (introduction of competition, privatization of incumbent operators and establishment of an independent regulator), there are other factors that need to be considered. They include: country's socioeconomic condition; availability of e-government services; electricity access; skills and education level; emerging technologies; investment in resilient ICT infrastructure; and trade policy and ICT device imports.

Accordingly, promoting broadband connectivity in the Pacific islands should be addressed in a holistic manner with a multi-stakeholder approach. While regulatory reform is important for enabling much needed private investment on the broadband infrastructure, remote Pacific Island countries also need:

- Affordable broadband connectivity for productive use;
- Access to affordable ICT devices (mobile and fixed telephony devices);
- Access to affordable energy source for powering the broadband infrastructure and devices;
- Access to education for acquiring appropriate skills and literacy levels in rural areas to meaningfully use the opportunities offered by broadband connectivity;

[128] Reforms include introduction of competition, establishment of independent regulatory authorities and privatization of state-owned monopolies.

- Investment in resilient ICT infrastructure; and
- Opportunities to explore the benefits provided by emerging technologies.

Pacific Island countries have experienced significant progress in broadband adoption following the entrance of private telecommunication operators into the subregion, which has led to increased domestic ICT infrastructure investment. The subsequent subscription and usage increases have resulted in a further need for increased international bandwidth, and several Pacific Island countries have opted for enhanced international connectivity via submarine fibre-optic cable and bigger-capacity satellite communication.

Investing in fibre-optic cables and supporting infrastructure are costly for any one country in the Pacific. Therefore, regional (including subregional) cooperation on enhancing broadband connectivity through pooling of financial and human resources is essential. Furthermore, regional cooperation facilitates dialogue and collaboration between different stakeholders, including donors and financiers, governments, regulators, private operators, research institutions and think tanks, and subregional organizations, among others.

5.1 Way Forward

The discussion in this paper has flagged several key policy areas for advancing broadband connectivity in Pacific Island countries, as follows:

- **Establish a subregional intergovernmental platform.** A subregional governance structure for effective coordination and cooperation on the development of ICT connectivity in the Pacific needs to be developed. As referenced above, the University of the South Pacific is currently chairing the CROP ICT Working Group, which is overseeing ICT development in the Pacific. Other key subregional actors such as the Pacific Community and Pacific Islands Forum used to have mandates on ICT development, but not anymore. While the CROP ICT Working Group may convene an ICT ministerial meeting, there is no regular subregional intergovernmental platform on ICT to coordinate and promote collaboration between governments and other stakeholders.

  Therefore, a subregional intergovernmental platform (with a multi-stakeholder approach) should be established using existing subregional governance structures to avoid duplications. The existing CROP ICT Working Group could be further strengthened to take up this task by engaging with member governments and reporting to CROP agencies on a regular basis. By doing so, Pacific governments would be given an appropriate platform to discuss common opportunities and challenges on advancing broadband connectivity that could be tackled with a subregional solution. In addition, private sector organizations (for public-private partnerships on ICT projects), donors and other regional/international partners could communicate directly with this subregional intergovernmental platform on issues related to ICT infrastructure investment in the Pacific.

- **Enable investment in resilient ICT infrastructure.** This working paper highlights a common challenge for most Pacific Island countries—natural disasters. Hence, the reliability and resilience of ICT infrastructure (e-resilience)[129] is critical during and after natural disasters. The challenge for Pacific Island governments is how best to develop and implement specific policies and regulations to enhance e-resilience. A harmonized subregional regulatory environment can enable open, transparent and inclusive processes, and help drive the competitiveness of the industry and facilitate investment for the benefit of consumers. In addition, a harmonized regulatory environment can assist telecommunication operators reduce costs, anticipate technical requirements, and increase productive and innovative efficiency. Resilient ICT infrastructure implies that there is redundancy in the network to ensure continuity of service if one cable/satellite fails. Investing in a second submarine cable for a Pacific Island country may be a very costly exercise due to the geographic distances between island countries. Consequently, opportunities for better use of dark fibre-optic cables, and connecting to existing fibre-optic cables and new cables that are being planned could improve redundancy.

- **Conduct technical studies on specific issues identified in this working paper.** Some of the specific findings in this working paper require further detailed studies for evidence-based policymaking. The following areas could be further looked at:

    - Affordability impact study – Although several countries in the Pacific subregion have connected to submarine fibre-optic cables, findings from this study show that affordability remains a challenge throughout the subregion. Hence, a study is needed to examine the regulatory mechanisms (market structure, broadband legislation, independent regulator, pricing strategies, among others) to identify the key deterrents on affordability and provide policy recommendations;

    - Skills and development of online content survey – The discussions in this paper point to a disconnect between the existing educational system and the need for skills to develop online local content. It would be useful to conduct a subregional survey on the current capacity (through the education system and research institutions) of individual Pacific Island countries to develop local content for government services (e-government) and e-commerce;

    - Broadband for productivity study – While the findings of this study have highlighted

[129] In recognition of the prominence of ICT infrastructure, increased emphasis has been placed on the concept of e-resilience—ICT infrastructure that is built or strengthened to withstand the rigours of the disaster-prone Pacific subregion so that it can be effective and accessible despite natural disasters and other shocks.

that several Pacific Island countries (such as Tonga and Fiji) have significantly improved mobile-broadband adoption, it is however less clear how better access to broadband connectivity has improved local business productivity or created new economic opportunities;

- Innovative funding mechanism study – Investment in the deployment of new submarine cables is costly. Therefore, a future study could examine and document the existing and planned funding mechanisms in the Pacific. The focus would be to highlight the lessons learnt from successes and challenges. The study could also explore the effectiveness of existing public-private partnerships on ICT infrastructure investment;

- Shared infrastructure study – The working paper has highlighted that introduction of competition has improved broadband expansion in several Pacific Island countries. One way for policymakers to facilitate domestic competition between private operators is the promotion of shared infrastructure policies. While this may be a viable policy option for Pacific Island countries, a study to examine the feasibility of such policy measure in the context of Pacific Island countries is required. Drawing experiences from other ESCAP countries on mandatory infrastructure sharing could be a useful starting point. Bangladesh is one country that mandates infrastructure sharing, and Australia, Mongolia and New Zealand have established public-owned network companies. In some cases, a clear demarcation lies between owners of the broadband infrastructure (government) and owners who use this infrastructure for delivering services (private operators). As a result, competition is encouraged due to decrease in entry barrier for less established private operators;[130] and

- Leveraging emerging technologies and artificial intelligence – While the scope of the working paper is on improving broadband connectivity in the Pacific subregion, member governments may wish to explore the potential use of emerging technologies and artificial intelligence to achieve the SDGs. The working paper has dedicated a section towards examining emerging smart technologies used by some Pacific Island countries. This is the future. As such, a study is needed to document the use of emerging technologies that could be useful lessons for Pacific Island countries.

Last but not least, it is important to note that the recent ESCAP Commission adopted resolution 73/6 on the implementation of the Asia-Pacific Information Superhighway (AP-IS) through regional cooperation, which could assist ESCAP Pacific member countries in advancing broadband connectivity. Further, the AP-IS Master Plan has concrete actionable initiatives in

[130] Thanks to David Butcher for raising this point.

these areas that Pacific member countries could adopt.

Annexes

Annex 1

Table 11: Diesel contribution in energy generation, June 2016

Country	Diesel contribution (% of total national energy mix)	Generation capacity (MW)	Generation capacity (KW)	Generation capacity (KW per capita)	Total population (2015)
Cook Islands	100	10	10,000	n/a	n/a
Guam	100	552	552,000	5.2	169,885
Nauru	100	4	4,000	0.02	10,122
Niue	100	1	1,000	n/a	n/a
Tuvalu	100	3	3,000	0.01	9,916
American Samoa	98	54	54,000	1.0	55,538
Palau	98	28	28,000	0.00	21,291
Tonga	98	12	12,000	1.2	106,379
Federated States of Micronesia	90	28	28,000	n/a	n/a
Marshall Islands	90	17	17,000	1.7	52,993
Papua New Guinea	77	700	700,000	0.1	7,631,819
Tahiti	74	186	186,000	1.7	282,764
New Caledonia	73	499	499,000	1.9	263,147
Vanuatu UNELCO*	71	24	24,000	0.1	263,888
Samoa	64	41	41,000	0.1	193,228
Kiribati	52	5	5,000	0.1	105,555
Fiji	49	245	245,000	1.4	892,727
Solomon Islands	45	36	36,000	0.1	584,482
Vanuatu VUI*	21	4	4,000	0.02	263,888

Source: Utilities Regulatory Authority of Vanuatu, "Comparative Report: Pacific Region Electricity Bills," June 2016. Available from http://www.ura.gov.vu/attachments/article/106/Comparative%20Report%20-%20Pacific%20Region%20Electricity%20Bills%20June%202016%20(2).pdf.

Notes: * In Vanuatu, the two electricity service providers (UNELCO and VUI) operate separate networks in different islands. The figures shown in the table reflect the operators' respective energy mix; n/a = not available.

Annex 2

Table 12: Variable summaries and sources

Variables	Mean	Std. Dev.	Obs.	Source
Fixed-broadband subscriptions per 100 inhabitants (log)	0.19	2.84	2,497	ITU, "World Telecommunication/ICT Indicators Database 2016 (20th Edition/December 2016)". Available from http://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.
(E) Electricity power consumption (kWh per capita) (log)	7.47	1.54	1,886	World Bank, "World Development Indicators". Available from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed 13 December 2017).
ICT goods imports (% total goods imports) (log)	1.72	0.73	2,237	
Population density (population/km^2) (log)	4.31	1.6	3,228	
GDP per capita (constant 2010 USD) (log)	8.45	1.52	2,921	
Urban population (% of total) (log)	3.93	0.52	3,228	
Rule of law (log)	-0.39	1.02	1,276	World Bank, "Worldwide Governance Indicators". Available from http://info.worldbank.org/governance/wgi/#home.

Annex 3

Table 13: Regulatory policies in the telecommunication sector

Country	Fixed and mobile telephone					Regulation
	Number of mobile operators	Market share of mobile operator (%)	Major mobile operator	4G mobile available	Fixed operator	Regulation law
Cook Islands	1	100	Bluesky	No	Bluesky	
Federated States of Micronesia	1	100	FSM Telecom	No	FSM Telecom	
Fiji	2	78	Vodaphone, Digicel INKK (MVNO)	Yes	TFL, FINTEL	Telecommunications Promulgation of 2008
Kiribati	1	100	TSKL	Yes	TSKL	
Marshall Islands	1	100	NTA	No		
Nauru	1	100	Digicel	No		
Niue	1	100	Telecom Niue		Telecom Niue	
Palau	2	60	PNCC, Palau Mobile		PNCC	
Papua New Guinea	3	70	Bmobile-Vodaphone, Digicel, Telikom PNG	Yes	Telikom PNG	National ICT Policy 2006
Samoa	3	73	Digicel, Bluesky, NeTVO Limited	No	Bluesky	Telecommunications Act of 2005
Solomon Islands	2	75	Our Telekom, bmobile	No	Our Telekom	Telecommunications Act of 2009
Tonga	2	72	Digicel, U-CALL	Yes	TCC	2000 Communications Act
Tuvalu	1	100	Tuvalu Telecom	No	Tuvalu Telecom	
Vanuatu	2	84	Digicel, TVL	Yes	TVL	Telecom Radiocommunications Regulation Act of 2009

Country	Broadband roll-out plans			ICT infrastructure		
	Broadband roll-out plans	PICT providers have contingency and continuity plans	Public key infrastructure establishment	Submarine cables	O3B	Planned (year)
Cook Islands	Y	Y	N			
Federated States of Micronesia	Y	Y	N			Y (fibre 2017)
Fiji	Y	Y	N	Y		
Kiribati	Y	Y	N			
Marshall Islands	Y	Y	N	Y		
Nauru	Y	Y	N		Y	
Niue	Y	Y	N			
Palau	Y	Y	N		Y	Y- submarine fibre (2017)
Papua New Guinea	Y	Y	N	Y	Y	
Samoa	Y	Y	N	Y (American Samoa to Samoa)	Y	Y- submarine fibre (2017)
Solomon Islands	Y	Y	N		Y	Y- submarine fibre (2018)
Tonga	Y	Y	N	Y		
Tuvalu	Y	Y	N			
Vanuatu	Y	Y	N	Y		

Country	ICT education/health policy		E-learning	Cybercrime legislation	
	ICT health policy	ICT education	ICT education policy	Cybercrime legislation	Strategy to combat cybercrime
Cook Islands	N	Y	Y	N	N
Federated States of Micronesia		Y	Y	N	N
Fiji	Y	Y	Y	Y	N
Kiribati	N	N	N	N	N
Marshall Islands			Y	N	Y
Nauru		Y	N	N	N
Niue			N	N	N
Palau	Y	Y	Y	N	N
Papua New Guinea		Y	Y	Y	N
Samoa		Y	Y	Y	N
Solomon Islands	N	N	N	N	N
Tonga		Y	Y	Y	N
Tuvalu	N	N	N	N	N
Vanuatu		Y	Y	Y	N

Country	National ICT policies		
	National ICT policies	Electronic files admissible on court	Data protection legislation
Cook Islands	Y	N	N
Federated States of Micronesia	Y	N	N
Fiji	Y	N	N
Kiribati	Y	N	N
Marshall Islands	Y	N	N
Nauru	N	N	N
Niue	N	N	N
Palau	Y	Y	N
Papua New Guinea	Y	N	N
Samoa	Y	N	N
Solomon Islands	N	N	N
Tonga	Y	Y	Y
Tuvalu	N	N	N
Vanuatu	Y	N	N

E-government plans					
Country	**E-government plans**	**Ministries with websites/portals**	**E-services established**	**Programmes established to digitize historical records**	**Programmes established to capture traditional knowledge**
Cook Islands	N	Y	Y		Y
Federated States of Micronesia	N	Y			
Fiji	Y	Y	Y	Y	Y
Kiribati	N	Y	Y	N	N
Marshall Islands	N	Y	Y	Y	Y
Nauru	N	Y	N	N	N
Niue	N	Y	N	Y	Y
Palau	N	Y			
Papua New Guinea	Y	Y	Y		Y
Samoa	Y	Y	Y	Y	
Solomon Islands	N	Y	N	N	N

Sources: Consolidated by ESCAP, based on information collected from member governments' websites; ITU, "ICT Eye: Country Profile". Available from http://www.itu.int/net4/itu-d/icteye/CountryProfile.aspx; other online sources; media releases; and Mr. Kisione Finau (Pacific ICT Working Group studies).

Note: Y = Yes and N = No

Annex 4

Note 1: List of ICT goods included

The list of ICT goods is defined by the OECD. The list of ICT goods consists of five major categories of products:

1. Computers and peripheral equipment;
2. Communication equipment;
3. Consumer electronic equipment;
4. Electronic components; and
5. Miscellaneous.

Within these five categories, there are 93 goods defined at the 6 digit level of the 2012 version of the Harmonized System. For details on the 93 products, see http://unctad.org/en/PublicationsLibrary/tn_unctad_ict4d02_en.pdf.

Note 2 (a)

Australia; Austria; Bahrain; Belgium; Botswana; Brunei Darussalam; Canada; Chile; Costa Rica; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Ghana; Greece; Hong Kong SAR, China; Hungary; Iceland; Ireland; Israel; Italy; Japan; Jordan; Korea, Republic of; Kuwait; Latvia; Lithuania; Luxembourg; Malaysia; Malta; Mauritius; Montenegro; Namibia; Netherlands; New Zealand; Norway; Oman; Poland; Portugal; Qatar; Saudi Arabia; Singapore; Slovak Republic; Slovenia; South Africa; Spain; Sweden; Switzerland; Tunisia; Turkey; United Kingdom; United States of America; and Uruguay.

Note 2 (b)

Australia; Austria; Bahrain; Belgium; Botswana; Brunei Darussalam; Canada; Chile; Costa Rica; Croatia; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Ghana; Greece; Hong Kong SAR, China; Hungary; Iceland; Ireland; Israel; Italy; Japan; Jordan; Korea, Republic of; Kuwait; Latvia; Lithuania; Luxembourg; Malaysia; Malta; Mauritius; Montenegro; Namibia; Netherlands; New Zealand; Norway; Oman; Poland; Portugal; Qatar; Saudi Arabia; Singapore; Slovak Republic; Slovenia; South Africa; Spain; Sweden; Switzerland; Tunisia; Turkey; United Kingdom; United States of America; and Uruguay.

Note 2 (c)

Afghanistan; Albania; Algeria; Angola; Argentina; Armenia; Australia; Austria; Azerbaijan; Bahamas; Bahrain; Bangladesh; Barbados; Belarus; Belgium; Belize; Benin; Bhutan; Bolivia; Bosnia and Herzegovina; Botswana; Brazil; Brunei Darussalam; Bulgaria; Burkina Faso; Burundi; Cabo Verde; Cambodia; Cameroon; Canada; Chad; Chile; China; Colombia; Comoros; Congo, Republic of the; Costa Rica; Cote d'Ivoire; Croatia; Cyprus; Czech Republic; Denmark; Djibouti; Dominica; Dominican Republic; Ecuador; Egypt; El Salvador; Equatorial Guinea; Estonia; Ethiopia; Fiji; Finland; France; Gabon; Gambia; Georgia; Germany; Ghana; Greece; Greenland; Grenada; Guatemala; Guinea; Guyana; Haiti; Honduras; Hong Kong SAR, China; Hungary; Iceland; India; Indonesia; Iran, Islamic Republic of; Ireland; Israel; Italy; Jamaica; Japan; Jordan; Kazakhstan; Kenya; Kiribati; Korea, Republic of;

Kuwait; Kyrgyz Republic; Lao PDR; Latvia; Lebanon; Lesotho; Liberia; Lithuania; Luxembourg; Macao SAR, China; Macedonia, FYR; Madagascar; Malawi; Malaysia; Maldives; Mali; Malta; Mauritania; Mauritius; Mexico; Moldova; Monaco; Mongolia; Montenegro; Morocco; Mozambique; Myanmar; Namibia; Nepal; Netherlands; New Zealand; Nicaragua; Niger; Nigeria; Norway; Oman; Pakistan; Panama; Papua New Guinea; Paraguay; Peru; Philippines; Poland; Portugal; Puerto Rico; Qatar; Russian Federation; Rwanda; Samoa; Sao Tome and Principe; Saudi Arabia; Senegal; Serbia; Seychelles; Singapore; Slovak Republic; Slovenia; Solomon Islands; South Africa; Spain; Sri Lanka; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Sudan; Suriname; Swaziland; Sweden; Switzerland; Tajikistan; Tanzania; Thailand; Togo; Tonga; Trinidad and Tobago; Tunisia; Turkey; Turkmenistan; Uganda; Ukraine; United Arab Emirates; United Kingdom; United States of America; Uruguay; Uzbekistan; Vanuatu; Venezuela; Viet Nam; Yemen; Zambia; and Zimbabwe.

Note 2 (d)

Albania; Angola; Argentina; Armenia; Australia; Austria; Azerbaijan; Bahrain; Bangladesh; Belarus; Belgium; Bolivia; Bosnia and Herzegovina; Botswana; Brazil; Brunei Darussalam; Bulgaria; Cambodia; Canada; Chile; China; Colombia; Congo, Republic of the; Costa Rica; Cote d'Ivoire; Croatia; Cyprus; Czech Republic; Denmark; Dominican Republic; Ecuador; Egypt; El Salvador; Estonia; Ethiopia; Finland; France; Georgia; Germany; Ghana; Gibraltar; Greece; Guatemala; Honduras; Hong Kong SAR, China; Hungary; Iceland; India; Indonesia; Iran, Islamic Republic of; Ireland; Israel; Italy; Jamaica; Japan; Jordan; Kazakhstan; Kenya; Korea, Republic of; Kuwait; Kyrgyz Republic; Latvia; Lebanon; Libya; Lithuania; Luxembourg; Macedonia, FYR; Malaysia; Malta; Mauritius; Mexico; Moldova; Mongolia; Montenegro; Morocco; Mozambique; Myanmar; Namibia; Nepal; Netherlands; New Zealand; Nicaragua; Niger; Nigeria; Norway; Oman; Pakistan; Panama; Paraguay; Peru; Philippines; Poland; Portugal; Qatar; Russian Federation; Saudi Arabia; Senegal; Serbia; Singapore; Slovak Republic; Slovenia; South Africa; Spain; Sri Lanka; Sudan; Sweden; Switzerland; Syrian Arab Republic; Tajikistan; Tanzania; Thailand; Togo; Trinidad and Tobago; Tunisia; Turkey; Ukraine; United Arab Emirates; United Kingdom; United States of America; Uruguay; Uzbekistan; Venezuela; Viet Nam; Yemen; Zambia; and Zimbabwe.

Annex 5

Table 14: Mobile-broadband access effects on fixed-broadband access

Dependent variable: Fixed-broadband subscriptions per 100 inhabitants (log)	(1) Small island developing states (SIDS)	(2) Landlocked developing countries (LLDC)	(3) Lower middle-income (LMI)	(4) Upper middle-income (UMI)	(5) High-income (HI)
Mobile-broadband subscriptions per 100 inhabitants (log)	0.123***	0.0837***	0.108***	0.124***	0.112***
	(0.0188)	(0.0188)	(0.0190)	(0.0193)	(0.0182)
Urban population (% of total) (log)	4.904***	4.775***	5.320***	5.150***	4.595***
	(0.969)	(0.972)	(0.976)	(0.966)	(1.012)
GDP per capita (constant 2010 USD) (log)	0.840***	0.669**	0.817***	0.837***	0.681**
	(0.285)	(0.287)	(0.288)	(0.286)	(0.291)
SIDS*mobile-broadband subscriptions per 100 inhabitants	-0.0968***				
	(0.0305)				
LLDC*mobile-broadband subscriptions per 100 inhabitants		0.0891***			
		(0.0256)			
LMI*mobile-broadband subscriptions per 100 inhabitants			-0.0115		
			(0.0242)		
UMI*mobile-broadband subscriptions per 100 inhabitants				-0.0609***	
				(0.0232)	
HI*mobile-broadband subscriptions per 100 inhabitants					-0.0721**
					(0.0325)
Constant	-26.26***	-24.25***	-27.69***	-27.18***	-23.67***
	(4.264)	(4.337)	(4.335)	(4.259)	(4.575)
Observations	1,016	1,016	1,016	1,016	1,016
R-squared (within)	0.396	0.398	0.389	0.394	0.393
Number of countries	174	174	174	174	174
Country fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
F test	39.09***	39.00***	38.70***	38.05***	37.57***

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.; for list of the 174 countries included in the estimates see Annex 4 – Note 2(c).

Table 15: Fixed-broadband access effects on mobile-broadband access

Dependent variable: Mobile-broadband subscriptions per 100 inhabitants (log)	(1) Small island developing states (SIDS)	(2) Landlocked developing countries (LLDC)	(3) Lower middle-income (LMI)	(4) Upper middle-income (UMI)	(5) High-income (HI)
Fixed-broadband subscriptions per 100 inhabitants (log)	0.387***	0.281***	0.392***	0.317***	0.378***
	(0.0851)	(0.0990)	(0.110)	(0.0946)	(0.0853)
Population Density (population/km^2) (log)	4.827***	5.038***	4.929***	5.040***	4.885***
	(1.095)	(1.092)	(1.102)	(1.095)	(1.137)
Electric power consumption (kWh per capita) (log)	2.925***	2.747***	2.861***	2.783***	2.892***
	(0.495)	(0.498)	(0.499)	(0.498)	(0.503)
SIDS*fixed-broadband subscriptions per 100 inhabitants	-0.738*				
	(0.428)				
LLDC*fixed-broadband subscriptions per 100 inhabitants		0.293*			
		(0.155)			
LMI*fixed-broadband subscriptions per 100 inhabitants			-0.0308		
			(0.148)		
UMI*fixed-broadband subscriptions per 100 inhabitants				0.233	
				(0.158)	
HI*fixed-broadband subscriptions per 100 inhabitants					0.0738
					(0.327)
Constant	-44.17***	-43.52***	-44.09***	-43.92***	-44.19***
	(5.478)	(5.488)	(5.563)	(5.487)	(5.505)
Observations	580	580	580	580	580
R-squared	0.696	0.697	0.694	0.696	0.694
Number of countries	126	126	126	126	126
Country fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
F test	9.34***	9.37***	9.22***	9.15***	8.82***

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.; for list of the 126 countries included in the estimates see Annex 4 – Note 2(d).

Annex 6

Table 16: Broadband sub-baskets as per cent of GNI, 2015

Summary table (2015)	Fixed-broadband sub-basket as % of GNI per capita		Mobile-cellular sub-basket as % of GNI per capita
Average (Simple)	32		5
Median	3		2
Lowest value	0.26		0.09
Highest value	1832.36		52.55
Number of countries	182		182
Less than 5%	109		137
% of total number of countries	60		75
Country	**Fixed-broadband sub-basket as % of GNI per capita**	**Country**	**Mobile-cellular sub-basket as % of GNI per capita**
Kuwait	0.26	Macao, China	0.09
Macao, China	0.27	Austria	0.16
United States of America	0.35	Singapore	0.17
Mauritius	0.36	United Arab Emirates	0.18
United Kingdom	0.42	Hong Kong, China	0.18
Andorra	0.46	Norway	0.21
Norway	0.47	Estonia	0.21
Switzerland	0.48	Sweden	0.23
Japan	0.51	Qatar	0.24
Luxembourg	0.52	Lithuania	0.25
Austria	0.57	Australia	0.27
Russian Federation	0.6	Finland	0.27
Singapore	0.63	Germany	0.28
Iran (I.R.)	0.64	Brunei Darussalam	0.29
France	0.65	Sri Lanka	0.3
Australia	0.7	Iran (I.R.)	0.31
Finland	0.74	Cyprus	0.31
Iceland	0.74	Russian Federation	0.34
Denmark	0.75	Kuwait	0.35
Bahrain	0.76	Latvia	0.35
Belgium	0.77	Luxembourg	0.36
Cyprus	0.81	Slovenia	0.39
Qatar	0.83	New Zealand	0.39
Netherlands	0.83	Greece	0.41
Sweden	0.85	United Kingdom	0.42

Kazakhstan	0.88
Brunei Darussalam	0.9
Poland	0.91
Romania	0.91
Ukraine	0.92
Czech Republic	0.93
Brazil	0.93
Latvia	0.95
Italy	0.97
Germany	0.98
Turkey	0.98
Lithuania	1
Greece	1.03
Slovenia	1.07
United Arab Emirates	1.09
Spain	1.09
Malaysia	1.11
Estonia	1.12
Slovakia	1.12
Israel	1.13
Canada	1.15
Belarus	1.17
Tunisia	1.19
Seychelles	1.28
Korea (Rep.)	1.29
Ireland	1.29
Oman	1.3
Trinidad and Tobago	1.3
New Zealand	1.32
Uruguay	1.32
Portugal	1.37
Croatia	1.37
Sri Lanka	1.43
Malta	1.49
Hong Kong, China	1.53
Azerbaijan	1.54
Bulgaria	1.59
Bosnia and Herzegovina	1.67
Bahamas	1.72
Panama	1.73
Viet Nam	1.79
Mongolia	1.85
Saudi Arabia	1.9

Costa Rica	0.46
Switzerland	0.47
Iceland	0.56
Malaysia	0.56
Canada	0.58
Kazakhstan	0.6
Oman	0.62
Mauritius	0.63
Bahrain	0.63
Italy	0.64
Netherlands	0.65
China	0.65
Poland	0.67
Saudi Arabia	0.68
Denmark	0.69
Belarus	0.7
Belgium	0.72
Turkmenistan	0.73
United States of America	0.78
Korea (Rep.)	0.8
Portugal	0.8
Mongolia	0.82
Andorra	0.83
Japan	0.84
Romania	0.84
Ireland	0.86
Czech Republic	0.87
Croatia	0.9
Slovakia	0.91
Namibia	0.92
France	0.94
Thailand	0.94
Tunisia	0.95
Trinidad and Tobago	0.98
Mexico	0.98
Libya	0.98
Ukraine	1
Bahamas	1
Israel	1.11
Malta	1.12
Seychelles	1.13
Maldives	1.14
Jordan	1.15

Hungary	1.91
Colombia	2.03
Peru	2.07
Chile	2.09
Lebanon	2.1
Costa Rica	2.17
Turkmenistan	2.19
Venezuela	2.19
South Africa	2.28
Barbados	2.33
Armenia	2.5
Montenegro	2.51
TFYR Macedonia	2.51
Egypt	2.56
Albania	2.57
Mexico	2.68
St. Kitts and Nevis	2.83
Sudan	2.85
Gabon	2.92
Serbia	2.94
China	3.12
Libya	3.34
Algeria	3.38
Belize	3.45
Cape Verde	3.46
Argentina	3.66
Uzbekistan	3.78
Georgia	3.84
Maldives	3.87
Thailand	3.89
Morocco	3.96
Ecuador	3.97
Dominican Republic	3.98
Bhutan	4.14
Fiji	4.14
Grenada	4.3
Moldova	4.41
Suriname	4.47
Botswana	4.75
Bangladesh	4.92
Antigua and Barbuda	4.96
India	5.11
Iraq	5.22

Venezuela	1.21
Brazil	1.24
Uruguay	1.25
South Africa	1.25
Azerbaijan	1.27
Spain	1.29
Bhutan	1.3
Paraguay	1.34
Panama	1.36
Georgia	1.44
Botswana	1.45
St. Kitts and Nevis	1.52
Montenegro	1.59
Chile	1.61
Bangladesh	1.7
Albania	1.71
Myanmar	1.76
Pakistan	1.79
Indonesia	1.8
Iraq	1.86
Lebanon	1.88
Egypt	1.9
Hungary	1.93
Jamaica	1.99
Turkey	2.01
Colombia	2.01
Suriname	2.05
Gabon	2.06
Peru	2.07
Armenia	2.1
Antigua and Barbuda	2.11
India	2.11
Nigeria	2.12
Ghana	2.16
Barbados	2.18
Algeria	2.24
Sudan	2.25
Equatorial Guinea	2.43
TFYR Macedonia	2.47
Uzbekistan	2.6
Argentina	2.74
Dominican Republic	2.79
Viet Nam	2.81

Jamaica	5.46
Dominica	5.58
Pakistan	5.7
Namibia	5.83
St. Lucia	5.98
Bolivia	5.99
El Salvador	6.5
Palestine	6.73
Yemen	6.77
Guatemala	6.81
Lesotho	7
Jordan	7.04
St. Vincent and the Grenadines	7.33
Guyana	7.38
Philippines	7.53
Paraguay	7.81
Tuvalu	8.43
Kyrgyzstan	8.58
Angola	8.94
Tonga	9.08
South Sudan	9.48
Indonesia	9.51
Mauritania	10.17
Nepal	10.75
Samoa	11.43
Papua New Guinea	11.61
Equatorial Guinea	11.92
Federated States of Micronesia	12.38
Tajikistan	12.44
Nigeria	13.23
Lao PDR	13.31
Marshall Islands	13.65
Ghana	13.85
Cambodia	14.12
Nicaragua	15.39
Honduras	16.39
Swaziland	16.61
Myanmar	17.2
São Tomé and Príncipe	19.92
Zambia	20.69
Vanuatu	20.86
Zimbabwe	21.43
Ethiopia	26.31

Serbia	2.94
Kyrgyzstan	3.08
Bosnia and Herzegovina	3.18
Moldova	3.23
Tonga	3.29
Kenya	3.36
Angola	3.37
Ecuador	3.38
Bulgaria	3.42
Philippines	3.42
Congo (Rep.)	3.61
Dominica	3.66
Grenada	3.97
Nepal	3.98
Morocco	4
Guyana	4.01
Swaziland	4.08
Fiji	4.18
El Salvador	4.22
Cuba	4.31
Bolivia	4.48
St. Lucia	4.54
St. Vincent and the Grenadines	4.68
Tajikistan	4.75
Samoa	4.89
Lao PDR	4.94
Palestine	5.69
Zambia	5.7
Marshall Islands	6.07
Ethiopia	6.74
Honduras	7.43
Yemen	7.76
Lesotho	7.85
Tuvalu	8
Cambodia	8.02
Cape Verde	8.3
Vanuatu	8.32
São Tomé and Príncipe	8.37
Kiribati	8.47
Belize	8.62
South Sudan	8.66
Tanzania	8.68
Cameroon	9.18

Côte d'Ivoire	28.82
Tanzania	29.47
Mozambique	32.51
Senegal	34.78
Cuba	36
Congo (Rep.)	36.07
Afghanistan	36.72
Kenya	40.65
Sierra Leone	41.82
Cameroon	44.94
Malawi	49.26
Gambia	50.56
Benin	56.99
Mali	62.12
Comoros	63.35
Burkina Faso	63.77
Kiribati	76.4
Togo	79.36
Guinea-Bissau	106.98
Guinea	130.46
Madagascar	138.52
Niger	147.22
Rwanda	166.44
Solomon Islands	180.48
Burundi	368.46
Uganda	537.31
Chad	613.19
Central African Republic	1832.36

Guatemala	9.58
Afghanistan	9.58
Federated States of Micronesia	9.68
Rwanda	10.04
Solomon Islands	10.26
Uganda	10.93
Benin	11.4
Côte d'Ivoire	11.71
Papua New Guinea	12.04
Gambia	12.25
Comoros	13.56
Guinea	13.87
Mauritania	14.21
Senegal	15.82
Mozambique	16.2
Burkina Faso	16.71
Nicaragua	17.31
Zimbabwe	18.39
Chad	19.29
Sierra Leone	20.59
Mali	22.85
Guinea-Bissau	26.91
Niger	27.75
Togo	28.07
Burundi	35.56
Madagascar	41.49
Central African Republic	43.13
Malawi	52.55

Annex 7

Table 17: Mean electricity consumption (kWh per capita)

Year	World	ESCAP	SIDS	LLDC	LDC
2000	3,636	2,644	2,453	1,302	103
2001	3,722	2,674	2,521	1,319	119
2002	3,790	2,728	2,540	1,318	124
2003	3,871	2,826	2,786	1,400	134
2004	3,936	2,909	2,772	1,415	143
2005	4,014	2,972	2,914	1,462	150
2006	4,075	3,039	2,972	1,516	154
2007	4,148	3,116	2,979	1,517	155
2008	4,262	3,111	2,842	1,511	157
2009	4,135	3,096	2,796	1,438	167
2010	4,299	3,233	2,959	1,488	177
2011	4,282	3,272	2,997	1,534	184
2012	4,358	3,346	3,055	1,587	207
2013	4,360	3,391	3,140	1,596	216

Source: Produced by ESCAP, based on data sourced from World Bank's World Development Indicators 2016.