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ORIGINAL ARTICLE

Artificial intelligence and broadband development through the Asia-Pacific Information Superhighway

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ABSTRACT

This exploratory study aims to identify the main characteristics and relationships between artificial intelligence (AI) and broadband development in Asia and the Pacific. Broadband networks are the foundation and prerequisite for the development of AI. However, what types of broadband networks would be conducive are not adequately discussed so far. Furthermore, in addition to broadband networks, other factors, such as income level, broadband quality, and investment, are expected to influence the uptake of AI in the region. The findings are synthesized into a set of policy recommendations at the end of the article, which highlights the need for regional cooperation through an initiative, such as the Asia-Pacific Information Superhighway.

Keywords: *artificial intelligence; broadband; digital divide; infrastructure; investment*

1. Introduction

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Asia and the Pacific[1] have witnessed significant growth in information and communications technology (ICT) infrastructure coverage, user base, and usage over the past decade; some of the member countries are now considered as global leaders in broadband development, ICT applications, and usage. For instance, the latest United Nation (UN) E-Government Survey 2018 lists the Republic of Korea, Singapore, and Japan among the top 10 countries out of 193 surveyed countries, based on three components of telecommunications infrastructure, capacity, and online services (UN, 2018).

However, most of the member countries in the region are not catching up fast enough. Broadband infrastructure is the foundation for digital transformation needed for the achievement of the Sustainable Development Goals, mediated by applications, such as e-government, e-health, e-education, and e-commerce, and e-agriculture (Heeks, 2017) and supported by human and institutional capacity, enabling policy ecosystem among others (ESCAP, 2018a). The broadband access is highly concentrated in East and Northeast Asia2 where 78% of total

1 In this article, Asia and the Pacific is defined as the member countries of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). The list of 62 member countries is available at https://www.unescap.org/about/member-states.

2 China, Japan, Mongolia, Democratic People's Republic of Korea and Republic of Korea.

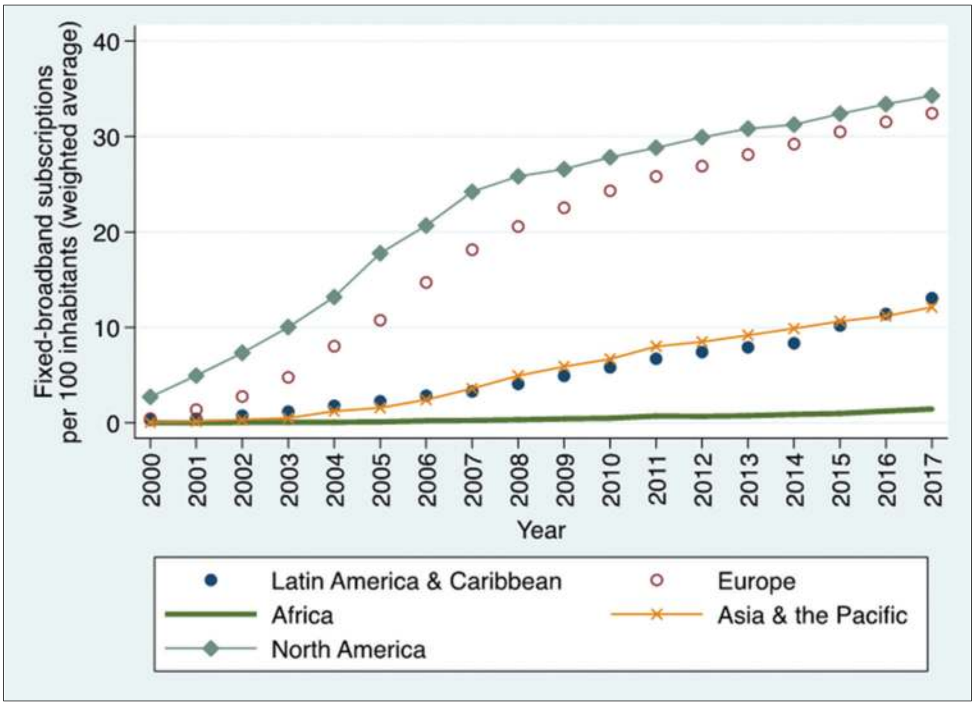

Figure 1. Fixed broadband subscriptions per 100 inhabitants by major regions, 2000-2017.
Source: Produced by the authors, based on data from International Telecommunication Union World Telecommunication/ information and communications technology Indicators Database. Available from https://www.itu.int/en/ITU-D /Statistics/ Pages/ publications/wtid.aspx. [Last accessed on 2018 Sep 16]

fixed broadband subscriptions are registered, followed by South and Southwest Asia (7%), North and Central Asia (7%), Southeast Asia (6.%), and the Pacific (2%) as detailed in Figure 1. Mobile broadband subscriptions demonstrate similar growth paths, although the pace of growth has picked up across all the subregions since 2013.

This is a worrying trend from three viewpoints. First, the expansion of telecommunications infrastructure and deepened use of ICT are evidenced to have a positive impact on economic growth. According to an estimate by the Asian Development Bank (ADB), the economic benefits from infrastructure in the form of total net income gains are expected to be US$12.98 trillion. The benefits will be significant among countries which rely on trade. The improved communication and transport infrastructure, in particular, are expected to lower barriers to market access (ADB, 2009). Using a dynamic fixed effect method estimation method and the data of 22 Organisation for Economic Co-operation and Development (OECD) countries, Datta and Agarwal (2004) show that the telecommunication infrastructure is positively correlated with growth in gross domestic product (GDP) per capita. A similar finding is reported by Röller and Waverman (2001) who analyze the data of 21 OECD countries over 20 years and find a significant causal link between telecommunication infrastructure and economic growth especially when the infrastructure availability reaches a level of universal service. Without such extensive telecommunications infrastructure and productive usage, economic activities and growth would be constrained, while those countries with such infrastructure would benefit from accelerated growth.

Second, the differential access to ICT infrastructure, capacity, applications, and services, widely known as the digital divide, poses a serious development challenge not only between countries but also within countries. A recent ESCAP report analyzes economic, social, and environmental inequalities in Asia and the Pacific and identifies converging patterns (ESCAP, 2018b). The report characterizes the digital divide as accumulated technological inequalities over time and is expected to widen unless concerted and targeted interventions are made as a matter of urgency, given the rapid development of emerging technologies such as artificial intelligence (AI) and blockchain.

Third, the critical role of ICT in emergency situations gained an increasing level of attention in the region which is disproportionately affected by natural disasters. One of the topics brought up by the 2018 E-Government Survey of UNDESA is the concept of e-resilience (UN, 2018). The report highlights the importance attached to protecting ICT infrastructure at a time of natural disasters as well as its role in facilitating disaster risk reduction and emergency responses. Establishing a robust, reliable and resilient broadband network before a natural disaster strike is increasingly seen as a development imperative.

On top of these underlying dimensions of broadband development, emerging technologies, in particular, AI, have become an additional driving force in broadband development and usage and vice versa. It appears that those countries with abundant bandwidth, financial and human resources, and markets are investing heavily in artificial technology and are reaping the benefits in the form of competitiveness, business insights and solutions, and services unmatched by conventional technologies. Thus, it is feared that the rapid advancement of AI and other emerging technologies would widen the digital divide even further.

In this context, the relationship between the AI development and broadband divide is examined for the purpose of achieving the Sustainable Development Goals (SDGs) in a report entitled "AI and Broadband Divide: State of ICT Connectivity in Asia and the Pacific 2017" (ESCAP, 2017a). Based on the findings and wide-ranging policy recommendations emanating from this report, this article aims to deepen understanding of the relationship between the development of AI and broadband technologies which are deemed essential to the uptake of AI.

AI is still evolving and expanding. Therefore, it may not be useful to estimate its comprehensive economic and social implications especially among developing countries in Asia and the Pacific. Instead, this article aims to focus on broadband technology elements and factors which are needed to ensure the uptake of AI more widely and equitably in the region. The findings are expected to help prioritize policy interventions and investment which are conducive to the mutually reinforcing development of AI and broadband networks, thus creating a virtuous cycle and narrowing the digital divide. While encouraging the uptake of AI, the new dimensions of ethical, privacy, and cybersecurity should also be taken into account (ESCAP, 2018c).

2. Review of literature

In this context, this exploratory study first aims to identify the main characteristics and relationships between AI and broadband development in Asia and the Pacific. Broadband networks are the foundation and prerequisite for the development of AI. However, what types of broadband networks would be conducive are not adequately discussed so far. Furthermore, in addition to broadband networks, other factors, such as income level, broadband quality, technology absorption capacity, and investment, are expected to influence the uptake of AI in the region. These factors will be synthesized into a set of policy recommendations and focus areas at the end of the article.

The term "AI" refers generally to "a set of computer science techniques that enables system to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and language translation" (Economist Intelligence Unit [EIU], 2016a. p. 3). With more focus on machine learning, it is also defined as "the mechanical simulation system of collecting knowledge and information and processing intelligence of universe: Collating and interpreting and disseminating it to the eligible in the form of actionable intelligence" (Grewal, 2014).

In terms of what AI includes, this study uses the conceptual framework developed by the Ministry of Science and Information Technology of the Republic of Korea which captures the elements of AI in Figure 2 as follows:

Each of the AI elements performs distinctive functions as its own independently. According to a 2016 EIU report, Cloud computing, Big Data, and analytics, and Internet of Things (IoT) were identified by public and private sector leaders and managers as the top three most important technology trends in Southeast Asia (Figure 3) (EIU, 2016b).

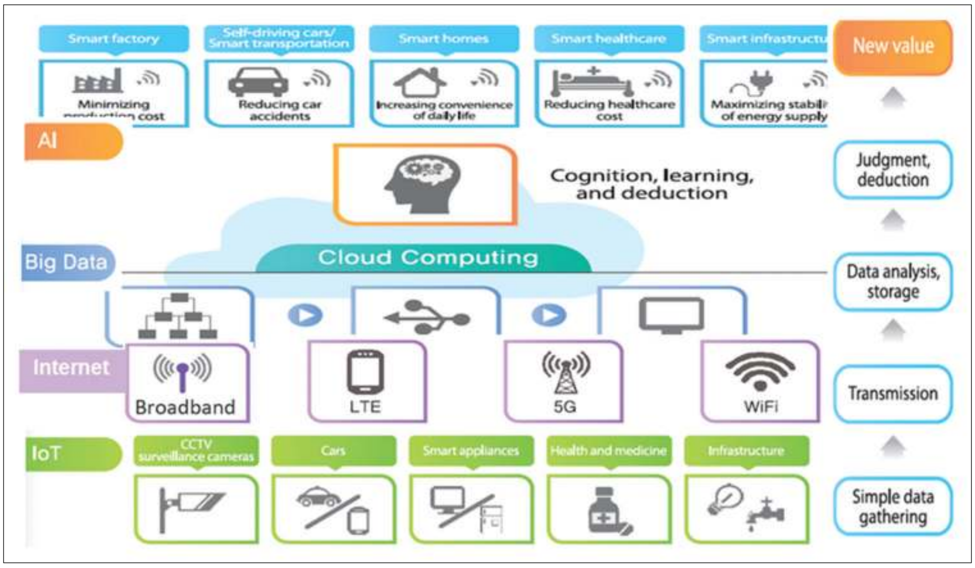

Figure 2. Artificial intelligence and the emerging information and communications technology landscape.
Source: Ministry of science, information and communications technology and future planning of the Republic of Korea (2016), "Mid - to long-term master plan in preparation for the intelligent information society: Managing the fourth industrial revolution," Undated. Available from: http://www.msip.go.kr/dynamic/file/afieldfile/msse56/1352869/2017/07/20/Master%20Plan%20for%20the%20intelligent%20information%20society.pdf.

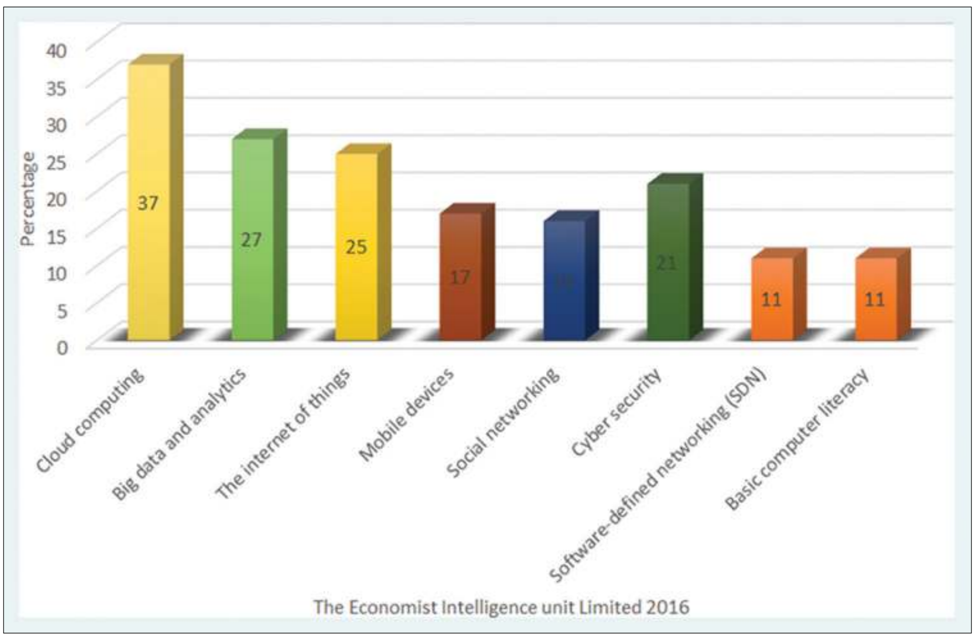

Figure 3. Most important technology trends identified by private and public sector leaders in Southeast Asia, 2016.
Source: EUI, 2016b. Available from https://www.eiuperspectives.economist.com/sites/default/files/EIU_Microsoft%20DigitisingGov_briefing%20paper_Jan2016.pdf

In this section, each element is briefly introduced for the purpose of explaining its interdependence with broadband infrastructure. The IoT at the bottom layer, in Figure 2, enables collection and exchange of data, such as biometric data, behavioral information, and unstructured information, through network-connected sensors and devices that operate mostly without human interventions. Mobile and broadband technologies enable voice and data transmissions to data storage locations, mostly using cloud computing technologies. The collected data, known as Big Data, are then provided for analysis (ESCAP, 2017a).

The term "IoT," was first used in 1999 to link radio-frequency identification sensors in the supply chain to the internet (Ashton, 2009). Since then, the mobile and ubiquitous nature of IoT devices, such as sensors, tablets, and mobile phones, has exponentially expanded its reach to virtually all corners of society and economy. The International Telecommunication Union (ITU) defines it as a "global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information, and communication technologies" (ITU, 2012). A report by ITU and Cisco Systems further suggests that the key elements of IoT are machine-produced data and the subsequent transmission of that data through connectivity technologies (ITU and Cisco Systems, 2016).

Cloud computing can be defined as "a model for enabling a shared pool of computing resources (e.g., networks, servers, storage, applications, and services) on demand that can be rapidly released" (Mell and Grance, 2009. p. 3). Cloud services perform complex, large-scale computing tasks and span a range of ICT functions from storage and computation to database and application services (Hashem *et al*., 2015). In cloud computing, the various applications, platforms, and databases are stored in large data centers, referred to as the cloud.

Big Data is a term for "the large amounts of digital data continually generated from various devices being used by the global population" (UN, 2013), often including emerging technological capabilities in solving complex tasks. Big Data is linked to IoT in that the sensors and devices are channels for data collection. The extremely large datasets are then analyzed using various tools. Data analysis tools have become more advanced in the past few years, including predictive analytics, data mining (Client Global Insights, 2013), case-based reasoning (El-Sappagh and Elmogy, 2015), and machine learning (Pantic, 2006).

This article covers two types of broadband technology; fixed and mobile. Fixed broadband is defined as "(f)ixed (wired) broadband network: Refers to technologies at advertised download speeds of at least 256kbit/s, such as DSL[3], cable modem, high speed leased lines, fiber-to-the-home/building, powerline, and other fixed (wired) broadband" while mobile, or terrestrial wireless broadband, is defined as "technologies at advertised download speeds of at least 256 kbit/s, such as WiMAX[4] and fixed CDMA[5]" (ITU, 2014).

An Massachusetts Institute of Technology report concluded that AI tends to take off when all the elements are put in place, characterized as a "big bang phenomenon" (MIT, 2016). Each of the above elements functions on its own, but when aggregated and consolidated, the components can produce synergistic and transformative impacts, culminating into AI applications that bring new values, as illustrated in the top layer in Figure 2. Empowered by the capability to improve on past iterations, AI applications do not necessarily rely on pre-defined behavioral algorithms, known as machine

3 Digital subscriber line
4 Worldwide interoperability for microwave access
5 Code division multiple access.

learning or deep learning (ESCAP, 2017a). AI may take the form of natural language generation and processing, speech recognition, decision management, biometrics, and robotic process automation which have led to the development of virtual agents and assistants (Press, 2017a). Extending these AI capabilities, a plethora of innovative use cases, such as driverless cars, medical diagnosis, and personal assistance for elderlies, has sprung up across the world, as described below.

3. Methodology

This article uses the framework of the Asia-Pacific Information Superhighway (AP-IS) initiative for guiding the scope of analysis. The AP-IS initiative is a UN-resolution based regional broadband connectivity initiative which aims to enhance the availability, affordability, resilience, and reliability of broadband networks in the region (ESCAP, 2018d). Mandated by ESCAP resolutions 71/10 [6]and 73/6[7], the initiative has four pillars as the focus of the initiative and has been operationalized with intergovernmental governance structure (ESCAP, 2018e). The four pillars are illustrated in Figure 4.

As the AP-IS Master Plan 2019–2022 (ESCAP, 2018e) stipulates, the implementation of the initiative takes place along the four pillars and at the subregional level, supported by research and analyses. While other aspects of AI and broadband development, such as institutional and individual capacity, higher education (ESCAP, 2017b), financing (ESCAP, 2017c), and cybersecurity (ESCAP, 2018c), are equally important, this article focuses on the above four pillars to develop targeted policy recommendations to member countries.

Although there is complementarity, this article focuses on fixed broadband over mobile broadband for three reasons. One is technological - according to the 2017 Cisco Virtual Networking Index, 60% of mobile data traffic is offloaded to fixed broadband through Wi-Fi and femtocell in 2016 globally (Cisco Systems, 2017). In 2021, the percentage is expected to increase to 63%. While mobile-broadband services are enjoyed on user devices such as mobile phones and tablets, the bulk of data traffic relies mainly on fixed broadband networks. Furthermore, fixed broadband connectivity continues to be an important complementary technology for mobile broadband services. The same study by Cisco Systems estimates that by 2018, internet traffic through fixed broadband connections[8] will account for 39% of the total, compared with 12% on mobile connections[9] and 49% on Wi-Fi hotspots. Second, the data capacity, which is required for the prevalent use of AI, would be significantly more with fixed broadband connections than mobile broadband, as evidenced in various network speed tests[10]. Another factor is financial - mobile-broadband services may remain unaffordable to the vast majority of people in Asia and the Pacific, and the issue of affordability is expected to remain on the introduction of 5G technology, at least initially. With an imminent increase in the number of IoT devices and their data communication requirements, ESCAP member countries may need to strategically prioritize the network configurations and expansion to enable new and emerging services, and meet various bandwidth demands.

To identify the characteristics and relationships between the development of AI and broadband networks in Asia and the Pacific, this research uses a mixed method approach. According to Blaikie,

6 http://www.un.org/ga/search/view_doc.asp?symbol=E/ESCAP/RES/71/1

7 https://www.unescap.org/commission/73/document/E73_RES6E.pdf

8 The number of consumer fixed-Internet users was not taken directly from an analyst source but was estimated from analyst forecasts for consumer broadband connections.

9 Mobile data traffic includes handset-based data traffic, such as text messaging, multimedia messaging and handset video services.

10 http://www.speedtest.net/.

Figure 4. Four pillars of the Asia-Pacific Information Superhighway initiative.
Source: Economic and Social Commission for Asia and the Pacific (2018e))

there are four types of mixed method approaches (1) triangulation, (2) embedded, (3) explanatory, and (4) exploratory (Blaikie, 2010). Moses and Knutsen (2012) in their book elaborate examples and approaches of mixed methods as an emerging trend in social research. This article uses the embedded procedures which are defined as "one type of data plays a supplementary role in helping to design the study, elaborate the procedures and/or interpret the results" (Blaikie, 2010. p. 224).

Based on the overall qualitative approach, this study aims to embed quantitative analysis to supplement additional characteristics based on fixed effects method. The article is structured to start with a literature review on global trends in AI development with a focus on its impacts on developing countries in Asia and the Pacific. It then continues with summaries of case studies and descriptive statistics to discern distinctive characteristics of broadband development in Asia and the Pacific as AI-readiness indication. It is followed by regression and descriptive statistical analysis which aims to identify correlating factors between AI development and broadband development. By combining qualitative and quantitative research methods, this research obtains deeper insights into the phenomena of interest and increase the validity of the findings.

4. Findings and results

As the AI development is still emerging and evolving, a comprehensive literature review is limited. However, international and regional organizations, research institutes and private sector companies have ventured to estimate possible impacts of AI on various aspects of the economy and society and shed light on requirements and necessary policy, including infrastructure development.

Recently, a World Economic Forum (WEF) report estimated the economic impacts of AI on employment and investment in technology attracted global attention. The report depicted a future where robots and automated factories would replace both blue-collar and white-collar workers (WEF, 2016). According to the report, AI and automation are estimated to replace 5 million human jobs in major developed and emerging economies by 2020. The report further noted that 7.1 million jobs could disappear due to redundancy and automation, while 2.1 million new jobs would be created mainly in specialized areas such as computing, mathematics, architecture, and engineering. Moreover, 78% of predictable physical work (such as welding and soldering on an assembly line) and 25% of unpredictable physical work (such as construction and forestry) are estimated to be automated by adapting currently demonstrated technology (McKinsey Global Institute, 2017).

Businesses that use AI, Big Data and IoT technologies to uncover new business insights "will steal $ 1.2 trillion per annum from their less informed peers by 2020" (Press, 2017b). The McKinsey Global Institute report also predicted that there would be a 300% increase in AI investment in 2017 compared with 2016, and the number of digital analytics vendors offering IoT insights capabilities would double in 2017. In addition, it further noted that industries that are digitally ready and willing to invest in new technologies tend to be the lead adopters of machine learning and AI, particularly those in financial services, high technology and telecommunication sectors (McKinsey Global Institute, 2017). According to a survey conducted by the EIU, the pace of adoption in AI is already picking up. AI will be "actively implemented" within the next 3 years, according to 75% of surveyed business executives. Another 3% said that AI is already actively implemented in their firms (EIU, 2016).

AI is expected to generate both direct and indirect economic gains. Direct economic effects will come from the industries developing AI technologies. Employment, as well as revenue, will be created in these sectors, which will boost GDP growth (Purdy and Daugherty, 2016). Indirect economic growth can be spurred by AI through three channels (Chen *et al*., 2016). First, an AI innovation in one industry can cascade to multiple industries. For example, car manufacturers may innovate and improve their products by incorporating AI solutions. This can then create opportunities to innovate in other sectors linked to the automotive industry such as the insurance sector. Second, the efficiency of the labor force and capital can be enhanced with AI. AI may not necessarily be a substitute for existing inputs in the production process. Rather, AI has the potential to supplement labor and capital. For example, AI-based industrial robotics can reduce factory downtime, and AI has the potential to help employees augment their natural intelligence by providing new tools. Third, a new virtual workforce as briefly mentioned above, may be able to solve problems and perform complex tasks across job types and industries with more adaptability and agility than traditional solutions.

At the same time, there is a call for attention to the potential risks of AI adoption. It is argued that economic inequality and polarization would deepen as economies continue to be automated with the introduction of AI (Lee and Choi, 2016). The technological progress of AI may also put least developed and emerging economies at risk of losing opportunities for manufacturing and customer service employment, among others. Telemarketing jobs, for example, are deemed highly susceptible to computerization. This is worrisome for countries such as the Philippines, where the business process outsourcing industry employs some 1.2 million people and accounts for about 8% of GDP (Economist, 2016). Developed economies may also be affected by the introduction and proliferation of AI. A report by the Nomura Research Institute estimated that nearly half of all jobs in Japan could be performed by robots by 2035 (Tarantola, 2015). Moreover, not only blue-collar work but also jobs currently carried out by highly trained white-collar workers may be vulnerable to automation as a result of advances in deep learning and other forms of AI. Asia-based senior executives and experts of multinational companies that participated in a recent MIT survey on AI adoption believed that the impact of AI will be felt most in manufacturing and transport/logistics followed by ICT and other professional services (MIT, 2016).

Interestingly, ICT infrastructure is no exception to the impact of AI. With the assistance of AI, broadband services, such as wireless sensor networks (WSNs), are able to transmit data and schedule tasks in a more simplified manner, thus significantly improving network performance

(Yau *et al.*, 2015). As technologies become more advanced and innovative, WSNs are expected to process multiple tasks and make decisions simultaneously, such as the selection of long-range or short-range radio for data transmission. The application of reinforcement learning (RL), an AI approach, uses algorism that covers most elements affecting network performance. Moreover, RL is designed to learn by itself, hence, requires no prior knowledge of the operating environment. Another research that focuses on WSNs suggests that AI approach has the potential to help WSNs minimize the use of energy, particularly, when performance is associated with cooperative diversity and lowered energy use (Gokturk and Gurbuz, 2014).

From the development point of view, there are also significant potentials and implications in AI applications, services, and products. The application of AI in medical research, for example, has enhanced the accuracy and efficiency of diagnosis for diseases such as breast cancer and thyroid disorders and has, therefore, been contributing to the reduction of women's health risks. An example is a model that has performed well in breast cancer prediction (Huang *et al*., 2017). In another breast cancer study, the algorithm has been employed to detect nuclei because typical cancer nuclei are clustered and have irregular texture and shape properties (Paramanandam, 2016).

Faced with an increasing demand for renewable energy, countries in the region are poised to benefit from AI in hybrid energy system optimization (Zahraee *et al*., 2016). Smart grids, in particular, present an important opportunity to transform the energy sector by making the electrical system more reliable, safe, and cost-effective. Data collected from smart grids makes possible the automated and real-time management of the electrical network, leading to opportunities for energy efficiency that can impact both the costs and the environment in a positive manner (Daki *et al.* 2017).

Given that Asia and the Pacific are the most disaster-prone region in the world with disasters killing 4987 people, affecting 34.5 million people and causing estimated damage of about US$77 billion in 2016 (ESCAP, 2017g), disaster risk reduction is of great importance. AI-based methods are being applied to regional flood frequency analysis, which is critical for the design, planning, and operation of infrastructure projects such as bridges and dams. Artificial neural networks have proven useful in regional flood modeling and have been applied successfully on a range of hydrological problems in Australia (Aziz *et al*., 2016).

The application of Big Data analytics (BDA) to the supply chain offers significant opportunities for the overall optimization of the supply chain performance, influencing individual organizations' financial performance as well as the overall efficiency and effectiveness of businesses. BDA capabilities allow organizations to make better decisions based on scalable data from internal and external sources by enabling them to connect the dots among the complex processes of the supply chain flow (Deepak *et al*., 2018). Some of the applications of BDA include inventory optimization, price optimization, and improved accuracy of demand forecasting, and among others. This can have a significant financial impact, as it can help to predict sales (Yu *et al*., 2018).

Smart cities are another avenue to implement numerous AI-enabled applications such as smart grids and intelligent energy management. As a consequence, an urban IoT system requires the existence of a vast network linking all existing technologies through multiple layers and covering a large geographical zone. This network also needs to carry large data flows (Zanella *et al*., 2014). Thus, the deployment of broadband infrastructure and technologies such as a programmable logic controller, fiber optic, LTE, or UMTS (described in more detail below) is essential to realize an urban IoT system. In addition to, the development of applications to run infrastructure and sectors of activity through participatory innovation processes, the creation of a broadband network is actually the critical task that cities must undertake to become smart according to Schaffers *et al*. (2011).

In practice, several existing smart cities policies or projects clearly recognize the need for broadband infrastructure. The National Telecommunications and Information Administration (NTIA), United States Department of Commerce, describes broadband deployment as a crucial prerequisite to enable innovations on which the “Smart Cities” initiative are launched. The “Smart Cities” project includes IoT as a key component and relies on existing federal initiatives, in particular, those encouraging broadband investment, to come into existence NTIA (2018).

AI is also expected to transform the transport sector, which is likely to lead to substantial benefits for both consumers and companies. For example, in some countries, the shortage of truck drivers is high due to the growth of the freight sector and a large number of retiring drivers. AI can help address the issue, and various approaches are currently being pursued by tech companies to develop driverless trucks. However, some challenges must first be tackled before making driverless vehicles available. For example, new computing and network infrastructure will be needed to handle and store the data in a secure way, as the amount of data between the cloud and vehicles is forecasted to be 10,000 times bigger by 2025 (Russel, 2017). Relatedly, an urban IoT system requires the existence of a vast network linking all existing technologies through multiple layers and covering a large geographical zone. This network also needs to carry large data flows (Zanella *et al*., 2014). Thus, the deployment of broadband infrastructure and technologies is essential to realizing an urban IoT system, among other AI-enabled solutions, as part of the AI landscape.

5. Discussion

At the heart of this emerging AI landscape is the expectation that affordable and resilient broadband connectivity would provide ubiquitous access to connect people and devices, as underlined in the above literature review. This section, therefore, focuses on the characteristics of broadband development as a technological foundation of AI development in Asia and the Pacific.

Despite the advancement of AI and broadband expansion in some countries in the region, Asia and the Pacific still trails behind North America, Europe, and Latin America when the number of fixed broadband subscriptions per 100 inhabitants is concerned, as illustrated in Figure 1.

One salient feature of broadband development in Asia and the Pacific is that there is an intensifying broadband concentration in East and Northeast Asia as illustrated in Figure 5. The share of East and Northeast Asia was 74.89% only in 2015 (ESCAP, 2016a. p.10).

Figure 6 illustrates different fixed broadband growth patterns across subregions. While the Pacific[11], East and Northeast Asia and Central Asia are expanding fixed broadband rapidly, the growth is much slower in South-East Asia, South and South-West Asia and Pacific, excluding Australia and New Zealand.

As part of the implementation of AP-IS, the challenges of developing affordable, resilient, and reliable broadband networks in the region and subregional specificities are extensively researched in the Pacific (ESCAP, 2018f), Central Asia (ESCAP, 2017d), and Southeast Asia (ESCAP, 2016b) together with studies on the Belt and Road Initiative (Kunavut *et al*., 2018, ESCAP, 2017e).

In additional to the subregional disparities, the fixed broadband growth seems to diverge across income groups as illustrated in Figure 7. Unless targeted interventions are planned and implemented, the divergence between high-income and low-income countries is expected to widen. To address the challenge, various studies have been conducted to identify key enablers in the areas of internet

11 Includes Australia and New Zealand.

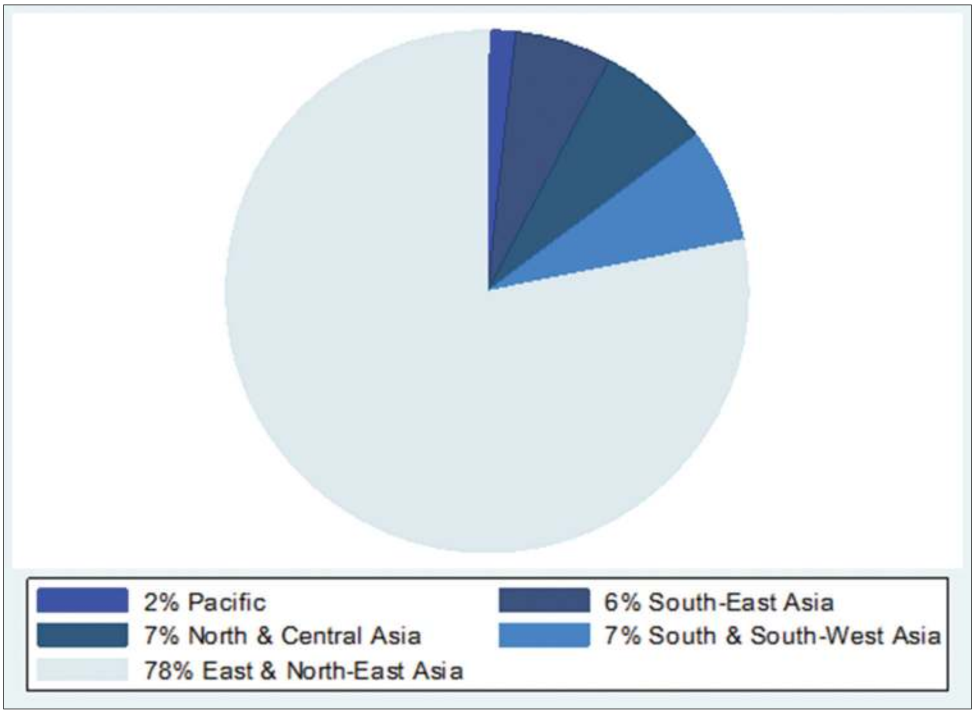

Figure 5. The total number of fixed broadband subscriptions by Economic and Social Commission for Asia and the Pacific subregion, 2017.
Source: Produced by the authors, based on data from International Telecommunication Union World Telecommunication/ information and communications technology Indicators Database. Available from https://www.itu.int/en/ITU-D/Statistics/ Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]

bandwidth demand projection (ESCAP, 2016c), international gateways liberalization (ESCAP, 2017f), enabling broadband ecosystem (ESCAP, 2018a) and ICT-transport codeployment (ESCAP, 2018g). According to a GSMA report, the pace to extend the networks in remote areas has been particularly slow because the capital expenditure is possibly double and operating expenditure 3 times more expensive in remote and rural areas than in urban areas (GSMA, 2017).

Additional salient features of broadband development in Asia and the Pacific is the e-resilience requirement. Resilience is important for broadband networks in general but will become critical when AI applications and services which depend on reliable transmission of an increasing amount of data become prevalent in society and economy. The UN E-Government Survey, 2018 (UN, 2018), defines e-resilience as “the use of ICTs during all phases of disaster risk management - prevention, reduction, preparedness, response, and recovery - toward reducing risk and impact and maintaining the gains made toward sustainable development, including through e-government” (p. 53).

The detrimental impacts of natural disasters on broadband infrastructure and delayed emergency operations have been well documented. A recent report documented the fiber-optic cable disruptions in the 2011 Great East Japan Earthquake and the 2004 Wenchuan Earthquake in China, among other natural disasters (ESCAP, 2018a). Subsequent to the lessons learned, various measures and initiatives have been implemented in China, Japan, and the Republic of Korea, which are chronicled and detailed as case studies in the same report. These lessons learned (ESCAP, 2016d; ESCAP, 2016e) are critical building blocks in planning and implementing resilient broadband networks which can underpin AI development and proliferation in the region.

The additional vulnerability is the way broadband network which is implemented in the region. While developed countries in the region have well developed, resilient, mesh

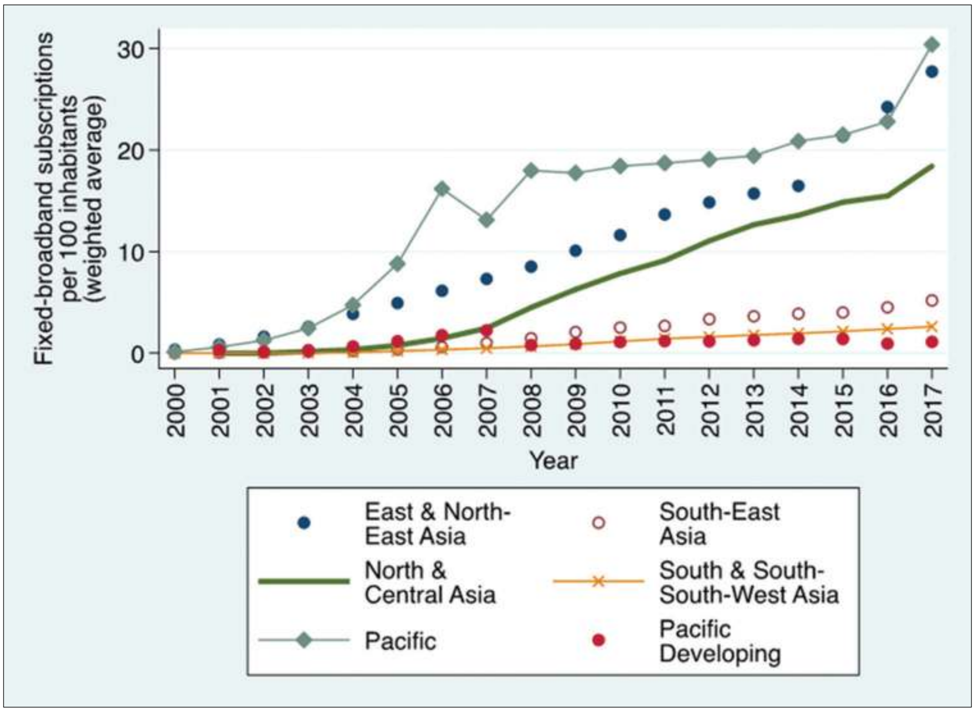

Figure 6. Fixed broadband subscriptions per 100 inhabitants by Economic and Social Commission for Asia and the Pacific subregions, 2017.
Source: Produced by the authors, based on data from International Telecommunication Union World Telecommunication/ information and communications technology Indicators Database, available from https://www.itu.int/en/ITU-D/Statistics/ Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]

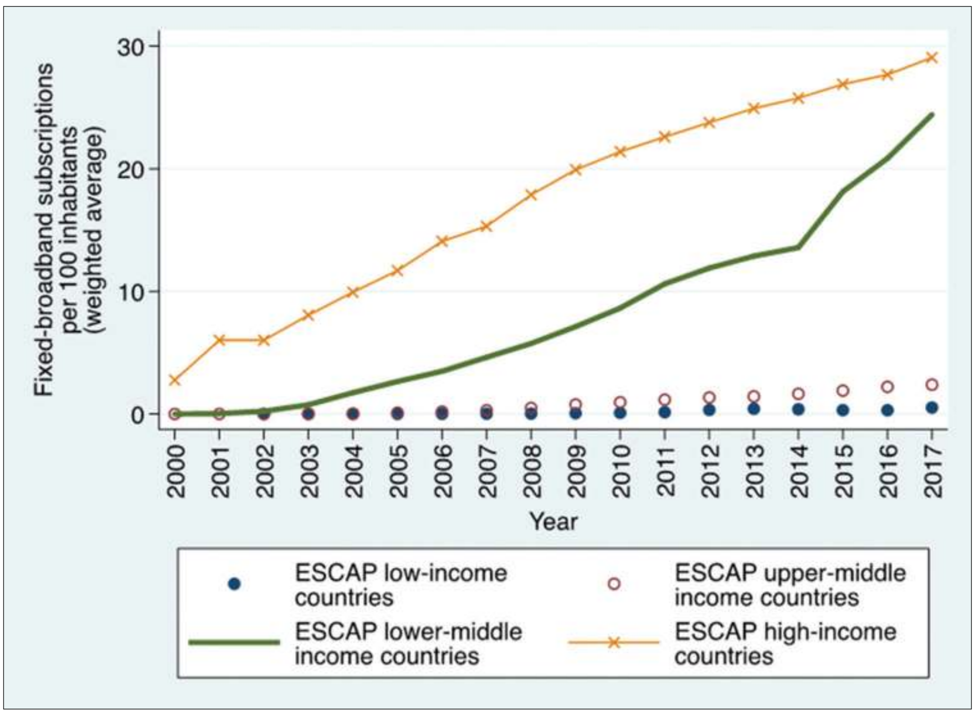

Figure 7. Fixed broadband subscriptions by income group (2000-2017).
Source: Produced by the authors, based on data from International Telecommunication Union World Telecommunication/ information and communications technology Indicators Database. Available from https://www.itu.int/en/ITU-D/Statistics/ Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]

networks, broadband networks in developing Asia are typically characterized as a river system, compared with mesh networks. Constrained by limited access to international transit, the developing countries' broadband networks spread from submarine landing stations to inland areas like a river (Inderst, 2016). From a resilience point of view, this topology poses a risk of single point of failure in case of cable disruptions due to natural disasters. When neighboring countries are connected to the "river system," any disruption could affect them as well.

With the exponential growth in data demand, the number of IoT sensors and devices has also increased dramatically. While there is no standard definition to collect data, the estimated number of IoT sensors and devices ranges from 2.1 billion to 50 billion by 2020 (ITU and Cisco Systems, 2016). This requires a different type of networks. In leveraging IoT, supporting technologies, such as the low-power, wide-area wireless technology (LPWA), Narrowband IoT, and long-range (LoRa) technology, are expected to play a catalytic role. These technologies are designed to connect a significantly higher number of devices at lower costs and higher coverage. For example, LPWA provides an alternative to the traditional wide-area network technologies that have relatively short range coverage and limited battery efficiency. LPWA is characterized with very low power consumption and improved battery efficiency, which means that battery life can span 10 years or more. LPWA optimizes data transfer at very low unit cost and provides extended coverage, enabling connectivity in rural and underground locations. LPWA's security is also well adapted to ensure appropriate authentication to the IoT applications (AT and T, 2016).

6. Quantifying the relationship between AI and broadband development

Based on the above characteristics of broadband development that supports AI development in Asia and the Pacific, this section aims to provide additional insights based on descriptive statistics and regression analysis.

The growth of AI (AI research and research citations) is first examined using scatterplots for correlations with other socioeconomic and telecommunications factors. These factors include GDP, technology absorption capacity, ICT investment, size of the telecommunication industries, and broadband infrastructure (ESCAP, 2017a).

Figure 8 plots the relationship between AI research, measured by the number of citable research documents in AI, and the size of economies in 2017 using the data of Scimago Journal & Country Rank. The bivariate relationship points to a positive correlation with bigger market economies tend to produce a larger number of AI-related research papers. Larger economies also imply that the size of university researchers on AI and subsequent labor force are larger (such as the United States and China), suggesting higher likelihood for introducing AI-based automated solutions in production processes. On the other hand, smaller economies with less AI-research capabilities in less developed economies (LDCs, LLDCs, and SIDS) could be further marginalized and unable to exploit the opportunities provided by AI-based solutions for sustainable development.

Quality of AI researches is also concentrated on more advanced economies. Figure 9 shows a positive relationship between the quality of AI researches, measured by the number of AI researchers, and GDP per capita. This scatterplot points to the increasing opportunities in advanced economies with higher quality AI researches in enhancing economic development, while less advanced economies risk of being left behind.

Advancement in AI is dependent on broadband connectivity. Figure 10 depicts a positive correlation between access to fixed broadband connectivity and quality of AI researches (h-index of AI researches).

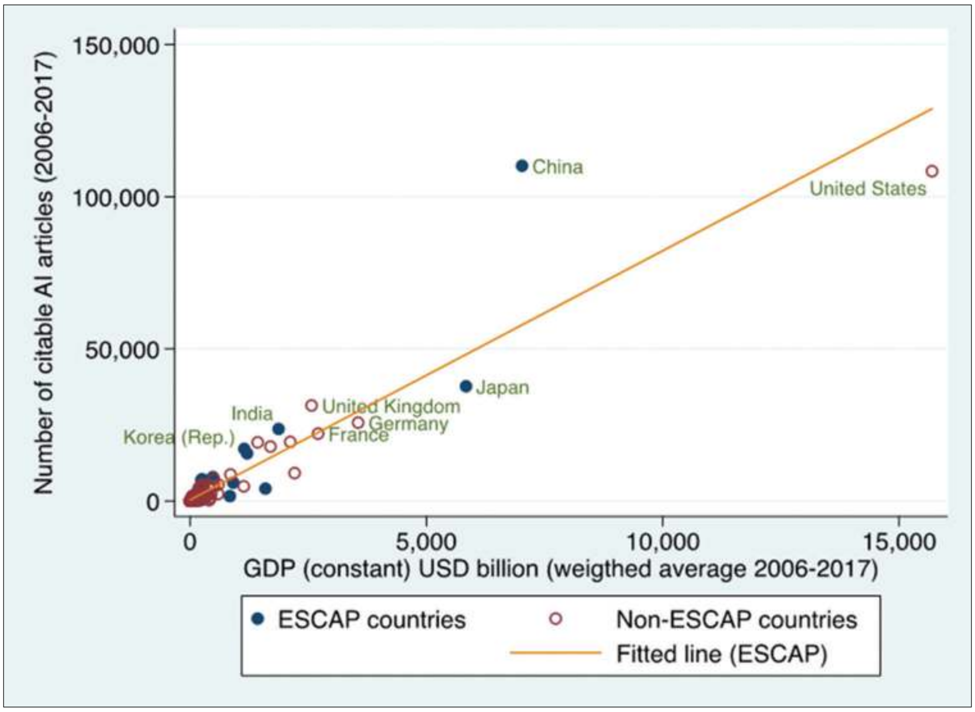

Figure 8. Researches in artificial intelligence and the size of the economy.
Source: Produced by the authors, based on data from World Bank World Development Indicators, available from https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]; and h-index on artificial intelligence researches from Scimago Journal and Country Rank. Available from https://www.scimagojr.com/countryrank.php. [Last accessed on 2018 Sep 16]

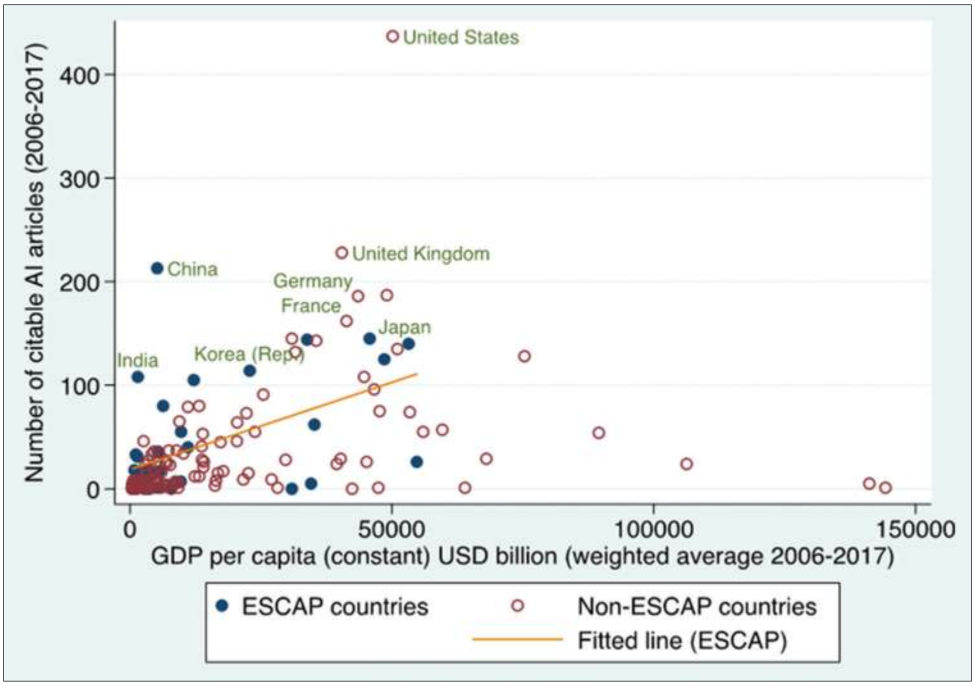

Figure 9. Artificial intelligence research quality and gross domestic product per capita.
Source: Produced by the authors, based on data from World Bank World Development Indicators, available from https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]; and h-index on artificial intelligence researches from Scimago Journal and Country Rank. Available from https://www.scimagojr.com/countryrank.php. [Last accessed on 2018 Sep 16]

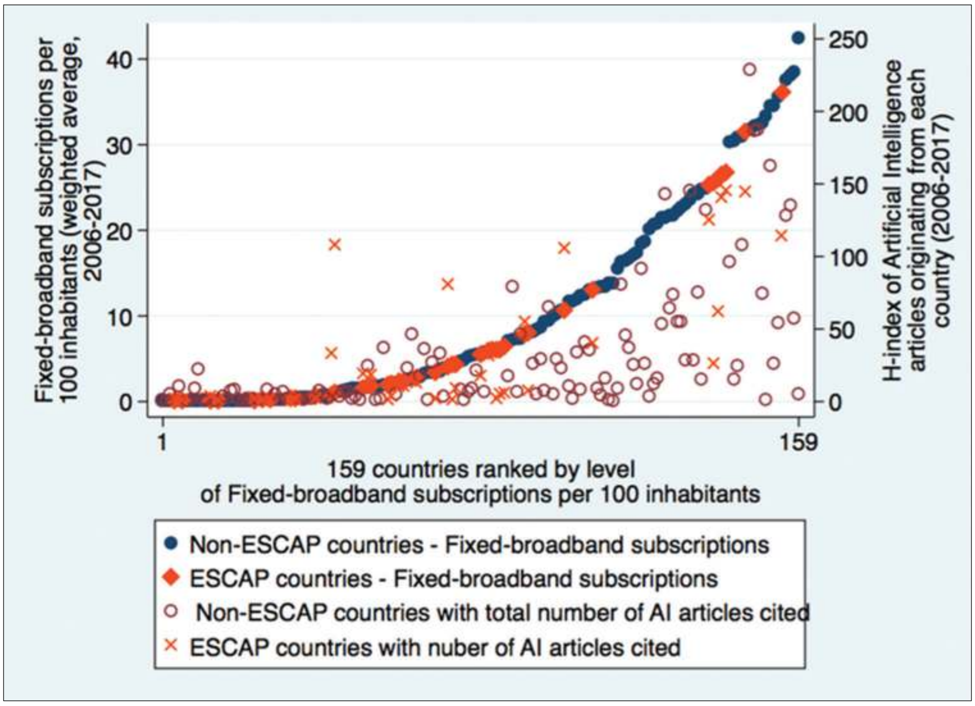

Figure 10. Researches in artificial intelligence and fixed broadband connectivity.
Source: Produced by the authors, based on data from International Telecommunication Union World Telecommunication/ information and communications technology Indicators Database, available from https://www.itu.int/en/ITU-D/Statistics/ Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]; and h-index on AI researches from Scimago Journal and Country Rank. Available from https://www.scimagojr.com/countryrank.php. [Last accessed on 2018 Sep 16]

The h-index is the total number of articles (h) that have at least been cited h times. This index developed by Jorge Hirsch is widely used in academia as a metric to assess research performance.

The interdependence of AI researches and fixed broadband connectivity is particularly robust when countries are examined over multiple years (Figure 10). When countries are ranked by their respective levels of fixed broadband connectivity (1 - a country with lowest fixed broadband connectivity and vice versa), the majority of the AI researches cited follows closely the level of fixed broadband connectivity pointing to a critical role of fixed broadband connectivity in supporting researches in AI. As a result, countries with higher fixed broadband connectivity tend to have more AI cited researches.

The relationship between the quality of AI researches and mobile-broadband connectivity is less clear. Figure 11 shows that the quality of AI researches originating from each country is less aligned with the trend on access to mobile-broadband connectivity. One possible reason is that researches in AI are not commonly conducted and distributed through mobile technologies but rather through computers often connected to fixed broadband connections.

The growth in the telecommunication sector has a positive influence on the development of AI researches. Countries with larger telecommunication sectors have higher research productivity resulting in a larger number of citable documents in the AI field in the Asia-Pacific region.

Analysis using coefficients of correlation (Pearson's and Spearman's methods) lend support to this finding. The correlation between the size of the telecommunication industry (revenue from telecommunication services) and the h-index in AI researches is the strongest, both in terms of magnitude and statistical significance, when compared with other industry sectors in Asia-Pacific economies (Table 1).

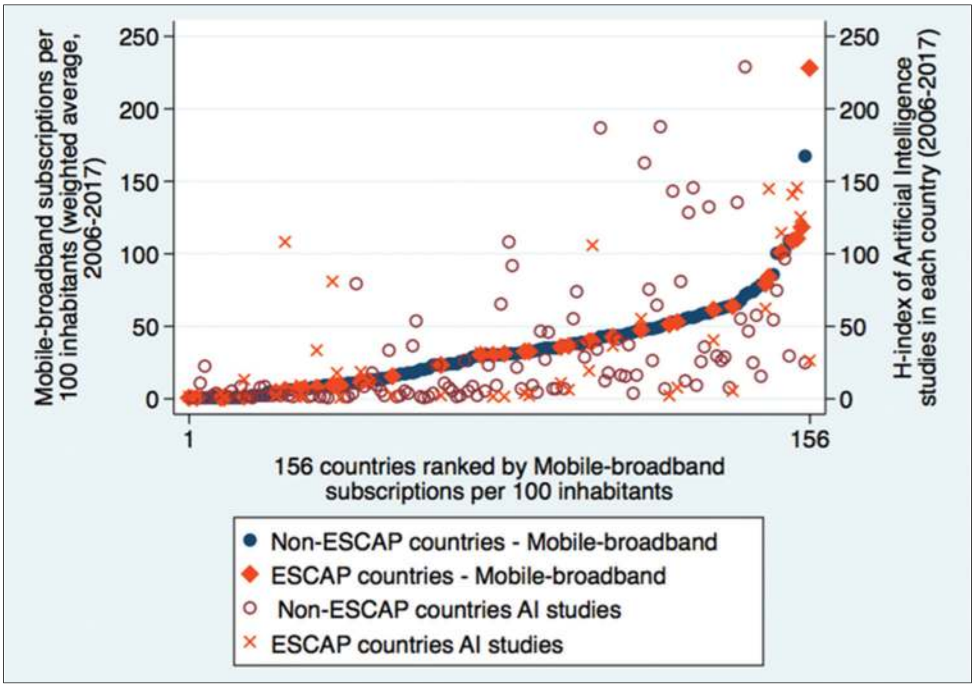

Figure 11. Researches on artificial intelligence and mobile-broadband connectivity.
Source: Produced by the authors, based on data from World Bank World Development Indicators. Available from: https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]

Table 1. Industry sectors and AI researches

Industry Sector	h-index on AI researches, 2015
Revenue from telecommunication services	0.73***
	0.73***
Manufacturing value added	0.49**
	0.46**
Transport, storage and communication, value-added	0.54**
	0.65***
Service value-added	0.58**
	0.68***
Mining, manufacturing, utility value-added	0.50*
	0.44*
Wholesale, retail trade, restaurants and hotels, value-added	0.52**
	0.61***
Agriculture, hunting, forestry, fishing value-added	0.1
	−0.02

Source: Data on agriculture, hunting, fishing, mining, manufacturing utilities, construction, wholesale, retail trade, restaurants and hotels, transport, storage, and communication value-added from ESCAP online statistical database based on data from the UNSD national accounts main aggregates database, February 17, 2017. Available from: http://data.unescap.org/escap_stat/. [Last accessed on 2017 Aug 29]; h-index and number of citable documents in AI research from Scimago *Journal and Country Rank*. Available from: http://www.scimagojr.com/countryrank.php?category=1702. (Last accessed on 2017 July); and data on industrial, agricultural, service, the manufacturing sector, textile and clothing, machinery and transport, food and beverage and chemistry value-added data from World Bank World Development Indicators. (Last accessed on 2017 Jul]. ***,**,*Indicate the level of significance at 1%, 5%, and 10%, respectively. In each cell, the number at the top is the coefficient of correlation calculated according to Pearson's method. The number at the bottom is the coefficient of correlation calculated according to Spearman's method. AI: Artificial intelligence

Quality (in term of speed - 10+ Mbits/s per 100 inhabitants) and access to fixed broadband connectivity are positively correlated (Figure 12) countries with higher access to fixed broadband subscriptions also

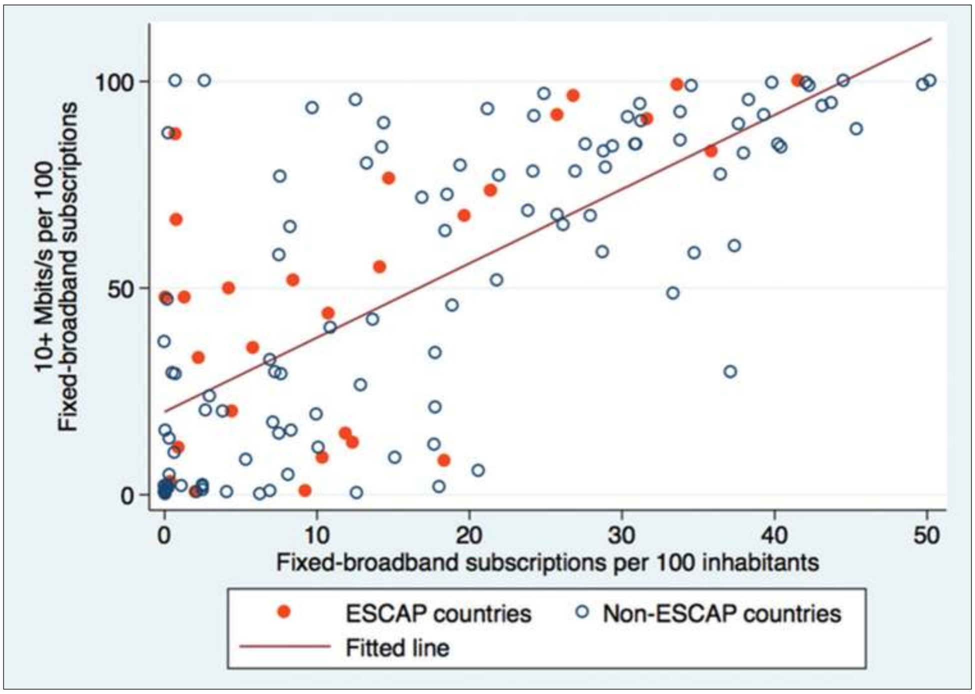

Figure 12. Fixed broadband connectivity speed and access, 2017.
Source: Produced by the authors, based on data from International Telecommunication Union World Telecommunication/ information and communications technology Indicators Database. Available from https://www.itu.int/en/ITU-D/Statistics/ Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16]

experience higher network speed. On the other hand, countries with lower access to fixed broadband connectivity have a slower speed. One reason that could explain this disparity is that higher investment on development of quality fixed broadband infrastructure not only increases network coverage throughout the country but also increases the efficiency and capacities of the network and improve network speed.

Using a panel dataset of 168 countries between 2000 and 2017, a fixed effects model is applied to test the relationship between fixed broadband connectivity and quality of AI researchers with the following specification adapted from Fink *et al*. (2003):

$$AI_{i,t} = \beta_1 + \beta_2 Bb_{i,t} * UniInv_{i,t} + \beta_3 C_{i,t} + \mu_i + \varphi_t + \varepsilon_{it}$$

Where variables in the model are as follows:

AI	Is the number of citable AI researches in country i at year t;
Bb	Is an interaction variable between broadband connectivity (fixed-broadband or mobile broadband) and Government expenditure on universities as percentage of GDP;
C	Is a vector of control variables (Fixed-broadband subscriptions per 100 inhabitants, Mobile-broadband subscriptions per 100 inhabitants, Government expenditure on universities as percentage of GDP, Ratio of university students enrolment to population, and GDP (constant 2010 US$));
μ_i	Is a country-specific dummy variable of country i to capture time-invariant country fixed effects;
φ_t	Is the coefficient on time trend t (year) to capture the effect of technological progress;
ε	Is the error term;
β	Representing the corresponding vector of coefficients to be estimated.

All variables are in log form. Fixed effects method is most efficient to controlling omitted variable bias. The results are shown in Table 2.

Table 2: Results

Dependent variable	**Number of AI citable researches (log)**	
	(1)	**(2)**
Fixed broadband subscriptions per 100 inhabitants *government expenditure on universities (log)	0.0905** (0.0444)	
Fixed broadband subscriptions per 100 inhabitants (log)	0.0953** (0.0475)	
Mobile-broadband subscriptions per 100 inhabitants *government expenditure on universities (log)		−0.0163 (0.0268)
Mobile-broadband subscriptions per 100 inhabitants (log)		0.0299 (0.0314)
Government expenditure on universities as percentage of GDP (log)	0.257 (0.165)	0.332 (0.215)
Ratio of university students enrolment to population (log)	2.633 (4.166)	9.878* (5.792)
GDP (constant 2010 US$) (log)	0.462 (0.497)	−0.724 (0.800)
Constant	−10.91 (11.85)	14.15 (19.88)
Observations	784	400
R^2	0.719	0.217
Number of countries	100	87
Country FE	Yes	Yes
Year FE	Yes	Yes

Robust standard errors in parentheses; ***P<0.01, **P<0.05, *P<0.1; Broadband connectivity variables were sourced from ITU World Telecommunication/ICT Indicators Database; Available from: https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx [Last accessed on 2018 Sep 16]; Government expenditure on universities, number of university student enrollments, GDP, and total population were sourced from the World Bank World Development Indicators, Available from: https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx. [Last accessed on 2018 Sep 16). AI: Artificial intelligence

The results of the regression show that controlling for the important role of universities (proxied by research capacity through government spending as a percentage of GDP), a 10% increase in access to fixed broadband connectivity results in a 0.9% increase in the number of citable AI researches. This relationship is statistically significant at 5% level. Intuitively, universities access to the internet facilitate researches and accessing information which further promotes innovation and creativity. The other control variables on the capacity of universities, the ratio of university students to total population, and level of economic development all behaved as expected (positive relationship) albeit statistically insignificant. The relationship between access to mobile-broadband connectivity and the number of citable AI researches is less clear with coefficients found to be statistically insignificant. This is partially due to the nature of technology with most universities predominantly have computer laboratories for students with fixed broadband connectivity for research.

7. Broadband requirements for AI development in Asia and the Pacific

From the above chapters, a set of broadband requirements for the development AI seems to emerge. Broadband networks are the prerequisite for the development and application of AI. AI has already been introduced to an increasing number of sectors and industries. With the focus on sustainable development, this study highlighted a few examples of where and how AI has been making progress, including medical diagnosis, smart grids, disaster risk reduction, transport, and smart cities. However, it also identifies that the underlying broadband capabilities are not distributed equitably across the region, and other factors seem to play a critical role. This section aims to summarize the characteristics and relationships between AI and broadband development emanating from the above analysis as well as research conducted for the implementation of AP-IS, to be followed by policy implications and the way forward in the subsequent chapter.

The most obvious challenge emanating from the above sections is the limited growth in fixed broadband networks among low-income countries and in certain subregions, while 76% of fixed broadband subscriptions concentrate on East and Northeast Asia, which creates opportunities for data collection and large markets for AI-enabled services and solutions. This concentration and the growth in the Pacific subregion (which includes Australia and New Zealand) also manifests in the fact that there is a diverging trend of growth between high-income and low-income countries. Unless targeted interventions are implemented, this divergence is unlikely to narrow in the future.

Another salient feature of broadband development in the region is the need for enhanced e-resilience, based on the case studies conducted by ESCAP. The network resilience will become even more critical as AI-based solutions and products hinge on reliable data transmission. The vulnerability also stems from the design, characterized as the “river system” in the region.

In addition, the importance of fixed broadband networks was underlined with a view to supporting AI development and implementation. Furthermore, another type of networks such as LPWA would be conducive to support the implementation of an increasing number of IoT devices and their frequent data transmission over a large geographical area.

From the descriptive statistics and regression analysis, the results provide support to the need for sustained development of fixed broadband network infrastructures as an enabling tool for improving the number and quality of researches in the AI field.

8. Conclusion and way forward

Based on the above findings, this section moves on to conclusions, outlined policy implications and the way forward.

First, there is a need for scaled-up regional cooperation. If the size of economy and market is a factor affecting the development of AI, regional cooperation may be able to help in many different ways for smaller economies, including information and knowledge sharing, aggregation of available resources and demand and policy and regulatory harmonization to encourage investment and infrastructure development. LLDCs could also help each other in case there are specific AI-enabled supply chain solutions or trade and transport facilitation systems.

Second, broadband infrastructure development should be a development imperative, especially when emerging technologies, such as AI, are taken into account. These technologies require affordable, reliable, and resilient broadband networks as a prerequisite. The development and uptake of AI would continue to be constrained without such broadband infrastructure. In particular, the importance of fixed broadband connectivity was underlined in the regression analysis.

In parallel, the broadband infrastructure development should be targeted at countries and a group of people left behind. The above section underlined the fact that some subregions, such as Southeast Asia, South, and South-West Asia and developing Pacific, demonstrated much slower growth with fixed broadband access. Low-income countries made virtually no progress in expanding fixed broadband access over the past 15 years. At the same time, there are various dimensions of digital divide within a country. Any international, regional and national interventions to address the digital divide should be targeted so as to leave no one behind.

Fourth, there are other external and internal factors which may improve broadband network resilience, reliance, capacity, and efficiency, including e-resilience and effective and efficient network management. The latter includes taking into account the need for addressing data transmission needs managing from an increasing number of IoT sensors and devices. This may require an update to ICT and telecommunications policies, regulations, and initiatives, for which the above mentioned regional cooperation may be of help.

All the above would not be possible unless multi-stakeholder cooperation and collaboration are put in place among government, the private sector, academia, and civil society groups, so as to identify challenges and opportunities from various socioeconomic angles. Cooperation and collaboration should not only take place at national levels but also at regional levels. In this context, regional cooperation platforms could again be a particularly important mechanism to address challenges and come up with common solutions and approaches. Such collaboration could also aim at an increase in technology absorption capacity and telecommunications investment.

In conclusion, a regional cooperation platform, such as the AP-IS, is expected to play an increasingly important role to address all the above policy implications and narrow the digital divide. It is envisaged that through targeted initiatives, broadband availability, and resilience increase, which then helps accelerate the development of uptake of AI more equitably across the region.

This study is conducted in support of the AP-IS implementation. It aims to stimulate discussions among policymakers, the private sector, academia, and think tanks on how regional broadband connectivity and AI could be shaped to achieve inclusive broadband, develop the digital economy in the region, and achieve the SDGs as outlined in the 2030 Agenda for Sustainable Development.

9. Limitation

AI is still evolving and expanding. Therefore, it may not be useful to try to estimate its comprehensive economic and social implications especially among developing countries in Asia and the Pacific. Instead, this article focuses on broadband elements and factors which are needed to ensure the uptake of AI more widely and equitably in the region. Due to this circumstance and reason, the data availability on AI was found limited. Thus, the findings are still preliminary. Furthermore, there have been questions regarding the use of ITU (2018) data and if there would be alternative sources of comparable data for triangulation. However, after exploring alternative sources, it is tentatively concluded that other data sources do not sufficiently cover the member countries in the region or time series data are not available.

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11. Disclaimer

The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations.

References

A Pre-Feasibility Study on the Asia-Pacific Information Superhighway in the ASEAN sub-Region (2016b). Available from: https://www.unescap.org/resources/pre-feasibility-study-asia-pacific-information-superhighway-asean-sub-region. [Last accessed on 2018 Feb 17].
A Pre-Feasibility Study on the Asia-Pacific Information Superhighway in the ASEAN sub-Region (2016b). Available from: https://www.unescap.org/resources/pre-feasibility-study-asia-pacific-information-superhighway-asean-sub-region. [Last accessed on 2018 Feb 17].
A Study of ICT Connectivity for the Belt and Road Initiative (BRI): Enhancing the Collaboration in China-Central Asia Corridor (2017e). Available from: https://www.unescap.org/resources/study-ict-connectivity-belt-and-road-initiative-bri-enhancing-collaboration-china-central. [Last accessed on 2018 May 17].
A Study of ICT Connectivity for the Belt and Road Initiative (BRI): Enhancing the Collaboration in China-Central Asia Corridor (2017e). Available from: https://www.unescap.org/resources/study-ict-connectivity-belt-and-road-initiative-bri-enhancing-collaboration-china-central. [Last accessed on 2018 May 17].
A Study on Cost-Benefit Analysis of Fibre-Optic Co-Deployment with the Asian Highway Connectivity. (2018g). Available from: https://www.unescap.org/sites/default/files/Cost-benefit%20analysis%20of%20fOC%20with%20Asia%20Highway.pdf. [Last accessed on 2018 May 17].
A Study on Cost-Benefit Analysis of Fibre-Optic Co-Deployment with the Asian Highway Connectivity. (2018g). Available from: https://www.unescap.org/sites/default/files/Cost-benefit%20analysis%20of%20fOC%20with%20Asia%20Highway.pdf. [Last accessed on 2018 May 17].
Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific 2017 (2017a). Available from: https://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017. [Last accessed on 2018 May 17].
Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific 2017 (2017a). Available from: https://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017. [Last accessed on 2018 May 17].
Ashton K (2009). That "Internet of things" Thing, RFID Journal. Available from: http://www.rfidjournal.com/articles/view?4986. [Last accessed on 2009 Jun 22].
Asia Development Bank and Asia Development Bank Institute (2009). Infrastructure for a Seamless Asia. Available from: https://www.adb.org/sites/default/files/publication/159348/adbi-infrastructure-seamless-asia.pdf. [Last accessed on 2017 Jun 21].
AT and T (2016). What you Need to Know about IOT Wide Area Networks: How to Choose the Right WAN Technology for the Internet of Things. Available from: https://www.business.att.com/content/whitepaper/what_need_know_iot_networks.pdf. [Last accessed on 2017 Jun 21].
Aziz K, Haque MM, Rahman A, Shamseldin AY and Shoaib M (2016). Flood estimation in un-gauged catchments: Application of artificial intelligence based methods for Eastern Australia. *Stochastic Environmental Research and Risk Assessment,* 31-6: 1499-1514. doi: 10.1007/s00477-016-1272-0.
Blaikie N (2010). *Designing Social Research.* Cambridge: Polity Press.
Broadband Connectivity in Pacific Island Countries (2018f). Available from: https://www.unescap.org/resources/broadband-connectivity-pacific-island-countries. [Last accessed on 2018 May 17].
Building a Resilient Digital Economy: Fostering SMEs in Central Asia. (2017d). Available from: https://www.unescap.org/resources/building-resilient-digital-economy-fostering-smes-central-asia. [Last accessed on 2018 May 17].
Building e-Resilience: Enhancing the Role of ICTs for Disaster Risk Management (DRM) (2016e). Available from: https://www.unescap.org/resources/building-e-resilience-enhancing-role-icts-disaster-risk-management-

drm. [Last accessed on 2018 May 17].

CGI (2013). Predictive Analytics: The Rise and Value of Predictive Analytics in Enterprise Decision Making, White Paper. Available from: https://www.cgi.com/sites/default/files/white-papers/Predictive-analytics-white-paper.pdf. [Last accessed on 2017 Jun 21].

Chen N, Christensen L, Gallagher K, Mate R and Rafert G (2016). Global Economic Impacts Associated with Artificial Intelligence, Analysis Group. Available from: http://www.analysisgroup.com/uploadedfiles/content/news_and_events/news/ag_executive_summary_economic_impact_of_ai.pdf. [Last accessed on 2017 Jun 21].

Cisco Systems (2017). Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2016-2021, White Paper. Available from: https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html. [Last accessed on 2018 Jan 11].

Daki H, Hannani AE, Aqqal A, Haidine A and Dahbiel A (2017). Big data management in smart grid: Concepts, requirements and implementation. *Journal of Big Data*, 4: 13. doi: 10.1186/s40537-017-0070-y.

Datta A and Agarwal S (2004). Telecommunications and Economic Growth: A Panel Data Approach. Available from: https://www.researchgate.net/publication/24075319_Telecommunications_and_Economic_Growth_A_Panel_Data_Approach. [Last accessed on 2017 Jun 21]. doi: 10.1080/0003684042000218552.

Deepak A, Kumar N and Kawalek JP (2018). Understanding big data analytics capabilities in supply chain management: Unraveling the issues, challenges and implications for practice. *Transportation Research Part E: Logistics and Transportation Review*, 114: 416-436. doi: 10.1016/j.tre.2017.04.001.

Disaster Resilience for Sustainable Development: Asia-Pacific Disaster Report 2017 (2017g). Available from: https://www.unescap.org/sites/default/files/1_Disaster%20Report%202017%20Low%20res.pdf. [Last accessed on 2018 May 17].

Economist (2016). Call Centres: The End of the Line. Available from: http://www.economist.com/news/international/21690041-call-centres-have-created-millions-good-jobs-emerging-world-technology-threatens. [Last accessed on 2016 Feb 06].

Economist Intelligence Unit (2016a). Artificial Intelligence in the Real World. The Business Case Takes Shape. Available from: https://www.eiuperspectives.economist.com/sites/default/files/Artificial_intelligence_in_the_real_world_1.pdf. [Last accessed on 2017 Feb 17].

Effect of Open International Gateways on the Broadband Connectivity Market (2017f). Available from: https://www.unescap.org/resources/effect-open-international-gateways-broadband-connectivity-market. [Last accessed on 2018 May 17].

El-Sappagh SH and Elmogy M (2015). Case based reasoning: Case representation methodologies. *International Journal of Advanced Computer Science and Applications*, 6-11: 192-208.

Enhancing Cybersecurity for Industry 4.0 in Asia and the Pacific (2018c). Available from: https://www.unescap.org/resources/enhancing-cybersecurity-industry-40-asia-and-pacific. [Last accessed on 2018 May 17].

E-Resilience: A Review of National Broadband Policies, Regulations, Strategies and Initiatives of China, Japan and the Republic of Korea (2018a). Available from: https://www.unescap.org/resources/e-resilience-review-national-broadband-policies-regulations-strategies-and-initiatives. [Last accessed on 2018 May 17].

Fink C, Mattoo A and Rathindran R (2003). An assessment of telecommunications reform in developing countries. *Information Economics and Policy*, 15: 443-466. doi: 10.1016/S0167-6245(03)00007-6.

Gokturk MS and Gurbuz O (2014). Cooperation with multiple relays in wireless sensor networks: Optimal cooperator selection and power assignment. *Wireless Networks*, 20-2: 209-225. doi: 10.1007/s11276-013-0585-x.

Grewal DS (2014). A critical conceptual analysis of definitions of artificial intelligence as applicable to computer engineering. *IOSR Journal of Computer Engineering*, 16-2: 9-13.

GSMA (2017). Unlocking Rural Coverage: Enablers for Commercially Sustainable Mobile Network Expansion. Available from: https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2016/07/Unlocking-Rural-Coverage-enablers-for-commercially-sustainable-mobile-network-expansion_English.pdf. [Last accessed on 2018 Jun 21].

Hashem IA, Yaqoob I, Anuar NB, Mokhtara S, Gania A and Khan SU (2015). The rise of 'big data' on cloud computing: Review and open research issues. *Information Systems*, 47: 98-115. doi: 10.1016/j.is.2014.07.006.

Heeks R (2017). Routledge perspectives on development. *In: Information and Communication Technology for Development (ICT4D).* London: Taylor and Francis Ltd. doi: 10.4324/9781315652603.

High Aspirations, Stark Realities: Digitizing Government in South-East Asia, 2016; (2016b). Available from: https://

www.eiuperspectives.economist.com/sites/default/files/EIU_Microsoft%20DigitisingGov_briefing%20 paper_Jan2016.pdf. [Last accessed on 2017 Feb 17].

Huang MW, Chen CW, Lin WC, Ke SW and Tsai CF (2017). SVM and SVM ensembles in breast cancer prediction. PLoS One, 12(1): e0161501. doi: 10.1371/journal.pone.0161501.

ICT in Disaster Risk Management Initiatives in Asia and the Pacific (2016d). Available from: https://www.unescap.org/resources/ict-disaster-risk-management-initiatives-asia-and-pacific. [Last accessed on 2018 May 17].

Implementation of the Master Plan for the Asia-Pacific Information Superhighway and the Asia-Pacific Information Superhighway Regional Cooperation Framework Document (2018d). p. 2. Available from: https://www.unescap.org/sites/default/files/ESCAP_CICTSTI_2018_2_Implementation%20of%20master%20plan%20of%20AP-IS_English_0.pdf. [Last accessed on 2018 May 17].

Inderst G (2016). Infrastructure Investment, Private Finance and Institutional Investors: Asia from a Global Perspective, ADBI Working Paper Series, No. 555. Tokyo: Asian Development Bank Institute. Available from: https://www.adb.org/sites/default/files/publication/179166/adbi-wp555.pdf. [Last accessed on 2017 Feb 17].

Inequality in Asia and the Pacific in the era of the 2030 Agenda for Sustainable Development (2018b). Available from: https://www.unescap.org/publications/inequality-asia-and-pacific-era-2030-agenda-sustainable-development. [Last accessed on 2018 May 17].

International Telecommunication Union (2012). New ITU Standards Define the Internet of Things and Provide the Blueprints for its Development. Available from: http://www.itu.int/ITU-T/newslog/New+ITU+Standards+Define+The+Internet+Of+Things+And+Provide+The+Blueprints+For+Its+Development.aspx. [Last accessed on 2017 Jan 11].

ITU and Cisco Systems (2016). Harnessing the Internet of Things for Global Development: A Contribution to the UN Broadband Commission for Sustainable Development. Available from: https://www.itu.int/en/action/broadband /Documents/Harnessing-IoT-Global-Development.pdf. [Last accessed on 2017 Feb 17].

Kunavut K, Okuda A and Lee D (2018). Belt and road initiative (BRI): Enhancing ICT connectivity in China-Central Asia corridor. *Journal of Infrastructure*, *Policy and Development*, 2-1: 116-141. doi: 10.24294/jipd.v2i1.164.

Lee HW and Choi Y (2016). What is Korea's Strategy to Manage the Implications of Artificial Intelligence? World Bank. Available from: http://www.blogs.worldbank.org/ic4d/ what-korea-s-strategy-manage- implications-artificial- intelligence. [Last accessed on 2018 Feb 17].

Manual for Measuring ICT Access and use by Households and Individuals (2014). Available from: https://www.itu.int/dms_pub/ itu-d/opb/ind/D-IND-ITCMEAS- 2014-PDF-E.pdf. [Last accessed on 2017 Jan 11].

Master Plan for the Asia-Pacific Information Superhighway, 2019-2022 (2018e). Available from: https://www.unescap.org/sites/ default/files/ESCAP_CICTSTI _2018_INF1.pdf. [Last accessed on 2018 May 17].

McKinsey Global Institute (2017). Artificial Intelligence: The Next Digital Frontier? Discussion Paper. Available from: http://www.mckinsey.com/~/media/McKinsey/Industries/Advanced% 20Electronics/Our%20Insights/How%20artificial %20intelligence%20can%20deliver%20real %20value%20to%20companies /MGI-Artificial-Intelligence- Discussion-paper.ashx. [Last accessed on 2018 Feb 17].

Mell P and Tim G (2009). The NIST Definition of Cloud Computing. Available from: https://www.nist.gov/sites / default/files/documents/itl /cloud/cloud-def-v15.pdf. [Last accessed on 2017 Feb 17].

Ministry of Science, ICT and Future Planning (2016). Mid-to Long-Term Master Plan in Preparation for the Intelligent Information Society: Managing the Fourth Industrial Revolution, Republic of Korea. Available from: http://www.msip.go.kr /dynamic/file/afieldfile/msse56 /1352869/2017/07/20/Master%20 Plan%20 for%20the%20intelligent %20information%20society.pdf. [Last accessed on 2018 Jun 18].

MIT (2016). How Asia is Speeding up Global Artificial Intelligence Adoption, Technology Review. Available from: https://www.s3.amazonaws.com /mittrasia/AsiaAI.pdf. [Last accessed on 2018 Jun 12].

Moses J and Knutsen T (2012). *Ways of Knowing: Competing Methodologies in Social and Political Research*. 2nd ed. England: Palgrave Macmillan. doi: 10.1007/978-1-137-00841-1.

National Telecommunications and Information Administration (2018). Broadband, United States Department of Commerce. Available from: https://www.ntia.doc.gov/category/broadband. [Last accessed on 2018 Jun 21].

Pantic M (2006). Introduction to Machine Learning and Case-Based Reasoning. Available from: https://www.ibug.doc.ic. ac.uk/media/uploads/documents /courses/syllabus-CBR.pdf. [Last accessed on 2018 Feb 17].

Paramanandam M (2016). Automated segmentation of nuclei in breast cancer histopathology images. *PLoS One*, 11(9): e0162053. doi: 10.1371/journal.pone.0162053.

Planning Processes, Policies and Initiatives in ICTD Education at Institutions of Higher Learning (IHLs) in Asia and the Pacific (2017b). Available from: https://www.unescap.org/ resources/planning-processes-policies- and-initiatives-ictd-education- institutions-higher-learning. [Last accessed on 2018 May 17].

Press G (2017a). Top 10 Hot Artificial Intelligence (AI) Technologies, Forbes. Available from: https://www.forbes.com/ sites/gilpress/2017/ 01/23/top-10-hot-artificial- intelligence-ai-technologies/. [Last accessed on 2017 Jan 23].

Press G (2017b). Forrester Predicts Investment in Artificial Intelligence will Grow 300% in 2017, Forbes. Available from: https://www.forbes.com/sites/gilpress/2016/11/01/forrester-predicts-investment-in-artificial-intelligence-will-grow- 300-in-2017/. [Last accessed on 2018 Jun 21].

Purdy M and Daugherty P (2016). Why Artificial Intelligence is the Future of Growth, Accenture. Available from: https:// www.accenture.com/lv-en /_acnmedia/PDF-33/Accenture -Why-AI-is-the-Future-of- Growth.pdf. [Last accessed on 2017 Feb 17].

Röller LH and Waverman L (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American Economic Review*, 91-4: 909-923. doi: 10.1257/aer.91.4.909.

Russell J (2017). Toyota, Intel and Others form Big Data Group for Automotive Tech, TechCrunch. Available from: https://www.techcrunch.com /2017/08/11/toyota-intel- automotive-big-data/. [Last accessed on 2017 Aug 11].

Scimago Journal (2018). Scimago Institutions Country Rank, Online Database. Available from: https://www.scimagojr.com /countryrank.php. [Last accessed on 2018 Jun 17].

Schaffers H, Komninos N, Pallot M, Trousse B, Nilsson M, Oliveira A. *Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation*. Berlin: Springer; 2011.

Sequans Communications (2016). CAT-M vs. NB-IoT: Energy Consumption vs. Payload; 2016.

Tarantola A (2015). Robots Expected to Run Half of Japan by 2035, Engadget. Available from: https://www.engadget.com /2015/12/04/robots-expected -to-run-half-of-japan-by-2035. [Last accessed on 2018 Jun 18].

The Impact of Universal Service Funds on Fixed Broadband Deployment and Internet Adoption in Asia and the Pacific (2017c). Available from: https://www.unescap.org/ resources/impact-universal-service -funds-fixed-broadband- deployment-and-internet- adoption-asia-and. [Last accessed on 2018 May 17].

The UN E-Government Survey 2018 (2018). Chapter 3: E-Resilience though E-Government: Global and Regional Perspectives. Available from: https://www.publicadministration.un.org /egovkb/en-us/Reports/UN-E-Government-Survey-2018. [Last accessed on 2018 May 18].

United Nations (2013). Global Pulse Big Data for Development: Harnessing Big Data for Real-Time Awareness. Available from: http://www.unglobalpulse.org /sites/default/files/Primer %202013_FINAL%20FOR%20PRINT.pdf. [Last accessed on 2018 Jun 17].

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) (2016a). State of ICT in Asia and the Pacific 2016: Uncovering the Widening Broadband Divide. Available from: https://www.unescap.org/ resources/state-ict-asia-and -pacific-2016-uncovering-widening- broadband-divide. [Last accessed on 2018 Jun 17].

Updated Analysis of the Broadband Infrastructure in Asia Pacific (2016c). Available from: https://www.unescap.org/resources/updated-analysis-broadband- infrastructure-asia- pacific. [Last accessed on 2018 May 17].

World Economic Forum (WEF) (2016). The Future of Jobs, Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. Available from: http://www.3.weforum.org/docs/ WEF_Future_of_Jobs.pdf. [Last accessed on 2018 May 17].

World Telecommunication/ICT Indicators Database (2018). Online Database. Available from: https://www.itu.int/en/ITU- D/Statistics/Pages/ publications/wtid.aspx. [Last accessed on 2018 Jun 21].

Yau KL, Goh HG, Chieng D and Kwong KH (2015). Application of reinforcement learning to wireless sensor networks: Models and algorithms. *Computing*, 97-11: 1045-1075. doi: 10.1007/s00607-014-0438-1.

Yu W, Chavez R, Jacobs MA and Mengying F (2018). Data-driven supply chain capabilities and performance: A resource-based view. *Logistics and Transportation Review*, 114: 371-385. doi: 10.1016/j.tre.2017.04.002.

Zahraee SM, Assadi MK and Saidur R (2016). Application of artificial intelligence methods for hybrid energy system optimization. *Renewable and Sustainable Energy Reviews*, 66: 617-630. doi: 10.1016/j.rser.2016.08.028.

Zanella A, Bui N, Castellani A and Michele Z (2014). Internet of things for smart cities. *IEEE Internet of Things Journal*, 1-1: 22-32. doi: 10.1109/JIOT.2014.2306328.