AUGUST 2018

DISCUSSION PAPER SERIES NO. 2018-11

Preparing the Philippines for the Fourth Industrial Revolution: A Scoping Study

Elmer P. Dadios, Alvin B. Culaba, Jose Ramon G. Albert, Vicente B. Paqueo, Aniceto C. Orbeta Jr., Ramonette B. Serafica, Argel A. Bandala, and Jose Carlos Alexis C. Bairan

Philippine Institute for Development Studies

CONTACT US:

RESEARCH INFORMATION DEPARTMENT
Philippine Institute for Development Studies

18th Floor, Three Cyberpod Centris - North Tower
EDSA corner Quezon Avenue, Quezon City, Philippines

publications@mail.pids.gov.ph
(+632) 372-1291/(+632) 372-1292

https://www.pids.gov.ph

Preparing the Philippines for the Fourth Industrial Revolution: A Scoping Study

Elmer P. Dadios
Alvin B. Culaba
Jose Ramon G. Albert
Vicente B. Paqueo
Aniceto C. Orbeta Jr.
Ramonette B. Serafica
Argel A. Bandala
Jose Carlos Alexis C. Bairan

PHILIPPINE INSTITUTE FOR DEVELOPMENT STUDIES

August 2018

Abstract

Technological breakthroughs and the interplay of a number of fields, including advanced robotics, artificial intelligence (AI), nanotechnology, neurotech, data analytics, blockchain, cloud technology, biotechnology, Internet of Things (IOT), and 3D printing, have ushered in the Fourth Industrial Revolution (FIRe). These various FIRe technologies are already being adopted by Philippine industries, although in varying degrees of diffusion. The extent to which all the potential benefits will be realized from these technologies depends on the country's ability to overcome its capacity to aptly adapt to the global disruptions that are expected to come along with the FIRe.

The country needs to focus on establishing a solid basic foundation for sustained learning and on accumulating various types of capital, while progressively and systematically closing the existing technological and knowledge gaps. Both the public and private sectors need to pay attention to the miniscule investment it has been putting in R&D; concomitantly, the Government must have an informed view on how to improve the efficiency of its deployment. Other interrelated measures needed to be able to catch up technologically and benefit from FIRe include: (i) openness to international trade and investment, which can be useful vehicles for faster transfer of innovative ideas and technology; (ii) reduced anti-competition practices and more competition in key industries like ICT; (iii) better educated and more trainable workers and more flexible and less costly labor market regulatory environment; (iv) development of the education and training systems, including both Government and private sectors, that can efficiently and equitably produce malleable human capital; (v) accumulation of other types of complementary capital like institutional, organizational and physical capital; (vi) progressive establishment of a universal social protection system to keep the people secure, especially the poor and vulnerable, in the face expected unprecedented business and employment disruptions; and (vii) more investment in data collection, monitoring, testing and evaluation.

The opportunities and challenges are multifaceted and complex. To harness the FIRe, Government as a whole should systematically review and adapt its policies, institutions and development efforts in light of upcoming revolutionary changes.

Keywords: Fourth Industrial Revolution, Industry 4.0, innovation, R&D, technology, digital, ICT, robotics, artificial intelligence

Table of Contents

List of Boxes

List of Tables

List of Figures

Preparing the Philippines for the Fourth Industrial Revolution: A Scoping Study

Elmer P. Dadios, Alvin B. Culaba, Jose Ramon G. Albert, Vicente B. Paqueo, Aniceto C. Orbeta Jr., Ramonette B. Serafica, Argel A. Bandala, and Jose Carlos Alexis C. Bairan [*]

1. Introduction

From being the sick man of Asia, the Philippines is once again poised for rapid and sustainable economic growth. With a GDP growth of 6.7 percent in 2017, the Philippines is one of fastest growing economies in Southeast Asia. ADB (2018) expects the country to sustain its performance and grow further at 6.8 percent and 6.9 percent in 2018 and 2019, respectively, on the back of rising domestic demand. Because of the promising economic prospects, the country is deemed to be currently experiencing a "golden age of economic growth" (de Vera 2017). Apropos, there are indeed grounds for optimism about the country's future given strong macroeconomic fundamentals and the planned expansion of infrastructure investments across the country. Amidst this economic development are the rapid technological changes shaping the economic, social and possibly, even political outcomes.

According to the World Economic Forum (WEF, 2016), developments in genetics, artificial intelligence, robotics, nanotechnology, 3D printing, biotechnology, and other technologies have ushered in the Fourth Industrial Revolution (FIRe). Smart systems—homes, factories, farms, grids or cities—are expected to tackle many problems from supply chain management to climate change. At the same time, these technologies are expected to alter the patterns of consumption, production and employment which will require proactive adaptation by corporations, governments and individuals.

The Philippines and the world will undoubtedly see rapid expansion of opportunities for productivity growth and the emergence of new business models as well as new goods and services in the years to come. But the extent to which the potential benefits will be realized depends on the country's ability to overcome its capacity to aptly adapt to the global disruptions that are expected to come along with the FIRe. This adaptation will involve greater thoughtfulness and agility in the way society balances the benefits from disruptive technologies against the need for stability, security and social cohesion. Moreover, the effectiveness of the adaptation will undoubtedly depend on the timeliness of its preparation and implementation.

What are the implications of FIRe for Philippine development policy, strategy and institutions? While technological changes offer tremendous benefits and opportunities, the advent of FIRe will also present several risks and challenges that could frustrate the pursuit of sustained economic growth and block the country's ability to reach its zero poverty ambitions by 2040.

[*] Elmer P. Dadios and Alvin P. Culaba are full professors at the Gokongwei College of Engineering, De La Salle University (DLSU). Jose Ramon G. Albert, Aniceto C. Orbeta, and Ramonette B. Serafica are senior research fellows at the Philippine Institute for Development Studies (PIDS). Vicente B. Paqueo and Jose Carlos Alexis C. Bairan are visiting fellow and research analyst at PIDS, respectively while Argel A. Bandala is an associate professor at the Gokongwei College of Engineering, DLSU.

A systematic analysis of these questions is critical to ensure that the country's economic take-off is sustained in the long run and leads to even faster and more inclusive growth. An initial scoping study will help identify the trends and critical issues which need to be prioritized.

1.1 Significance of the study

New technologies bring with it risks and challenges that could affect manufacturing resurgence, reverse the significant strides in services trade, affect attempts to improve agricultural productivity, and block the country's ability to reach its zero poverty ambitions by 2040. The nature of the impact will be systemic as well as sector-specific. It would also be global as well as specific to geographic areas. The speed of change is expected to be exponential rather than linear. Those risks and challenges will be on top of the current threats of political, economic and military turmoil that could disrupt rule-based global trade, investment, finance and security.

Clearly, we may not precisely predict the specifics of the businesses that will flourish or wither away as a consequence of new technologies. This uncertainty raises questions about the best ways for countries and their citizens to prepare for those changes in detail. However, the consequences would be tragic, if people realize too late that familiar jobs are gone, and emerging jobs require competencies beyond their reach. Therefore, the Filipino people need to collectively and individually have a broad (albeit necessarily imperfect) sense of the technological disruptions and the nature of needed adaptations of our mindset, policies and institutions.

1.2 Objectives of the study

To improve the country's appreciation and knowledge of the nature of FIRe as well as its contours, drivers, possible directions, risks and reach as well as the time frame of its unfolding towards a new normal, this initial scoping study on the key trends and critical issues will:

1. Analyze the technological landscape and discuss how new and emerging technologies are likely to shape Philippine industries directly (e.g. adoption by domestic industries of labor saving technologies) and indirectly through changes in trade and investment patterns (e.g. reversal of production offshoring in developed economies).
2. Examine if our industries are agile and resilient enough to face the challenges/risks presented by the mainstreaming of disruptive technologies and if the country's policy environment is conducive to the development of resilient industries.
3. Identify the implications of FIRe for the country's human development (HD), trade and industrial strategies and examine supply-side and demand-side constraints that need to be addressed to ensure that Philippine industries and workforce are able to adjust and flourish under FIRe's new normal.

1.3 Organization of report

The next chapter presents a historical account of past industrial revolutions and a brief overview of disruptive and frontier technologies. In Chapter 3, the emerging technological landscape is discussed in further detail. A description of each technology is presented along with global trends, applications, and current status in the Philippines. Chapter 4 draws from existing literature to look at the impacts and implications of the FIRe on the labor market, human capital development, social protection, trade & investment, and the achievement of sustainable development goals. This is followed by discussion of the drivers and constraints to technology adoption and innovation in the Philippines in Chapter 5, which critically reviews the policy and regulatory landscape of the country. The report concludes with key insights for policy and research obtained from this scoping exercise.

2. Background

2.1 Industrial revolutions

Throughout history, humankind has improved industry by migrating from utilizing established production methods to making use of cutting-edge technologies; with the reinventions of industry resulting in several radical impacts and consequently being dubbed as an industrial revolution (Landes 1969). However, the benefits brought by an industrial revolution are not limited to the increase in production. It has also improved the accuracy and precision of manufacturing processes, as well as reduced the cost of labor (Landes 1969; Horn *et al*. 2010). Throughout history, three industrial revolutions have thus far transpired, and a fourth one is currently taking shape. This section will describe these past industrial revolutions, as well as discuss the contours of the emerging FIRe.

The **First Industrial Revolution** refers to several developments which greatly influenced the manufacturing processes spanning from 1760 to 1840 (Horn *et al*. 2010). This industrial revolution is characterized largely by the emergence of mechanization, which replaced agriculture with industry as the main engine of economic activity of societies. Some of the changes include migration of certain activities to machine processes. These activities include hand production methods (especially in the textile industry), manufacturing of certain chemicals, production processes of iron, design and use of machine tools, and upsurge of factory systems (Landes 1969; Horn *et al*. 2010). The fuel of the first industrial revolution can be traced to mechanical innovations, and with it, steam power, which in turn, brought the coal-powered external combustion engine. Contributions from Europe, America, and Asia were notable. In the middle of the 18th century, Great Britain was the leading global trader together with its major colonies, India and North America (Landes 1999). During this period, several opposition groups actively denounced the change brought by the (first) industrial revolution. The Romantic Movement, which is referred to as supporters of the Romanticism, are the most active of the critics of the industrial revolution (George 1955; Löwy and Sayre 2001). Romanticism admired the traditional way of life and feared that urbanization and technology were double-edged swords that would bring benefits and drawbacks to society.

The **Second Industrial Revolution,** which is also called the technological revolution, took place towards the end of 19th century up to the beginning of the 20th century (Muntone n.d.). This industrial revolution is characterized by rapid industrialization brought about by the use of oil-powered internal combustion engine, electrical communication, electrification of the factory, and mass production (typified by the installation of the assembly line by Henry Ford). The main features of this revolution include electrical machines and equipment such as telegraphs and telephones. This period is characterized by a great industrial development led by European countries, which, primarily, also led the first industrial revolution. Cheaper manufacturing method of iron and steel propelled trade and transportation because of cheap train, locomotive systems, automobiles and airplanes (Misa 1995). The main highlight of this era is the widespread use of electricity and electrical machines. Because of this, the countries undergoing (the second) industrial revolution fully propelled their economies as fully industrialized economies in the world (Faraday 1911). This revolution caused an improved standard of living, but also caused a major increase in unemployment as machines were starting to take over tasks that used to be part of the jobs of humans. Production costs and prices fell dramatically and there was a rapid growth in productivity. Vaclav Smil called the period 1867–1914 "The Age of Synergy" during which most of the great innovations were developed. In contrast with the innovations in the first industrial revolution, the innovations during the second industrial revolution were engineering and science-based (Smil 2005).

In 1947 the transistor was invented (Ament 2015), leading the way to more advanced digital computers. In the 1950s and 1960s, the military, governments and other organizations of wealthy countries established computer systems. From 1969 to 1971, Intel developed the Intel 4004, an early microprocessor that laid the foundations for the microcomputer revolution that began in the 1970s. These developments paved the way for the third industrial revolution.

The **Third Industrial Revolution** is marked as the start of the Information Age. Disruptions started with migration of the mechanically dominated industries and analogue electronics technology to digital electronics; this transpired around the 1950s to the 1970s (Freeman and Louçã 2002; Schoenherr 2004). Central to this revolution is the mass production and widespread use of digital logic circuits, and their derived technologies, including the computer, digital cellular phone, and the internet. The third industrial revolution was also dubbed as the Digital Revolution as most of the new processes were influenced by digital computers. The increase in popularity of computers was due to the accuracy and simplicity in process control and digital record keeping. While there were huge benefits from the third industrial revolution, especially in terms of the accessibility of information, there were also concerns about civil and human rights. The expanded powers of communication and information sharing opened a new age of mass surveillance and intrusion which risks personal privacy. Piracy of data, movies, songs also proliferated and became profitable because digital format was very easy to replicate and mass produce.

The **Fourth Industrial Revolution** (FIRe) builds on the Digital Revolution with cyber-physical systems providing new mechanisms and allowing technology to be embedded within societies and even the human body (Davis 2016). The FIRe is marked by emerging technology breakthroughs in a number of fields including robotics, artificial intelligence, nanotechnology, quantum computing, biotechnology, internet of things (IoT), 3D printing and autonomous vehicles (Bernard 2016). In the book entitled "The Fourth Industrial Revolution," Professor Klaus Schwab (Founder and Executive Chairman of the WEF), describes how the FIRe is fundamentally different from the previous three industrial revolutions. These new and emerging technologies have great potential to continue to connect billions more people to the web, drastically improve the efficiency of business and organizations, and help regenerate the natural environment through better asset management. The FIRe holds unique opportunities to improve human communication and conflict resolution (Bernard 2016).

With the impressive progress made in artificial intelligence (AI) in recent years, primarily driven by huge gains in computing power and by the increased availability of vast amounts of digital data, the speed of current breakthroughs in FIRe is evolving at an exponential pace. Software has been developed to discover new ailments and to mimic human behavior, even voice. The fusion of machines, computing, and biological capabilities gave birth to self-driving cars and drones, as well as virtual assistants like Siri and Cortana. These innovations will be further enhanced through emerging technology breakthroughs in the fields of AI, robotics, IoT, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, data science, and quantum computing.

Beyond the use of emerging technologies, the FIRe has the potential to raise income levels and improve the quality of life. New products and services that increase efficiency and quality of life has also been made possible by new technologies. Services like getting a ride, ordering pizza, booking a flight, shopping for books, and watching a film can now be done remotely. However, these advancements have also led to the disruption of business models in almost every industry. The potential depth of these changes could eventually lead to the transformation of entire systems of production, management, and governance (Schwab 2015). In addition, robots and other emerging technologies are being designed to imitate not only human actions but also cognitive skills. According to Uzair Younus, a monumental sign of FIRe happened in 2017 when Bill Gates, a person who made his fortune from technological innovations, argued two things. First, he argued that robots that replace and take away human jobs must be taxed by the government. Secondly, the government should intervene when automation has the potential of creating mass unemployment (Younus 2017). As may be gleaned, although the FIRe comes with a lot of potential, especially in terms of increasing industries' efficiency and consumers' convenience, its rapid advancements toward replicating human actions and intelligence could also displace a large number of workers and businesses, particularly those undertaking routine tasks.

Each of the industrial revolutions is built upon the progress developed in the previous period, and certainly some countries, particularly the poorest in the world, are still having economies largely dependent on past industrial revolutions. **Table 1** below summarizes the key features of the prior three industrial revolutions and the ongoing FIRe.

Table 1. Industrial revolution transitions

	Timeline and Tagline	Description	Outcome
First Industrial Revolution	1760-1840 "Mechanization using Water and Steam"	Began in Britain with the mechanization of the textile industry. Beforehand most manufacturing was done in homes and small shops. Transition from using hand tools and basic machines to powered, special purpose machinery and factories.	Groups of workers attacked factories and destroyed machinery as a means of protest. Improved transportation, communication and banking. Increase in manufactured goods. Improved standard of living. Caused the growth of industries in coal, iron and textile.
Second Industrial Revolution	1870-1914 "Mass Production using Electricity"	Marked by the birth of assembly lines and mass production. New innovations in steel, petroleum and electricity production led to the introduction of automobiles and airplanes. Steel replace iron, it was utilized in construction,	First electric railroad and electric cars. Birth of radio communications and the first radio wave transmission across the Atlantic Ocean happened. Inventions include refrigerator, typewriter, telephone, elevator, phonograph, washing machine and diesel engine to name a few.

		industrial machines, railroads, ships and others. Birth of power stations and power generators. Birth of telephone and perfection of the light bulb. Inventions and innovations were engineering and science-based	Due to the benefits and wealth of new inventions and new ideas, the second industrial revolution is regarded to be positive and beneficial. Each new thing led to another and therefore created a new age of discoveries and inventions.
Third Industrial Revolution	1950s-1970s "Automation using digital electronics and information technology"	When manufacturing became digital. Known as the Digital Revolution. Mechanical and analog electronic technologies were replaced by digital electronics.	Birth of computer, digital mobile phone, and the Internet Birth of technologies like cellular phones for digital communication, digital camera, CD-ROM, Automated teller machines, industrial robots, electronic bulletin boards, video games and CGI to name a few. Privacy and piracy became a concern.
Fourth Industrial Revolution	"Innovation based on fusion of physical, digital and biological"	Emerging technology breakthroughs in fields of artificial intelligence, robotics, the Internet of Things, autonomous vehicles, nanotechnology, biotechnology, materials science, energy storage, and quantum computing.	Birth of self-driving cars, drones, virtual assistants. Birth of software that translates, invests, analyze and identify. Birth of Social media and the demand for better service. Companies with great vision are currently reexamining the way they do business.

The FIRe is expected to transform the lives of the people in the coming years. As an example, the Google self-driving car program called Waymo was initiated in 2009 to drive fully autonomously over ten uninterrupted 100-mile routes in Toyota Prius vehicles. As of 2017, the program logged over two million miles on U.S. streets and has only had fault in one accident, thus proving to be safer than the vehicles operated by humans (Boon 2016). The application of IoT, in which objects equipped with electronic sensors and actuators are connected to the internet, allowing them to capture, filter, and exchange data about themselves and their environment (and/or to each other) is expected to further automate people's daily activities. For instance, this technology could be applied to our refrigerators for enabling it to send us a text message when we run out of food, to air-conditioners for automatically switching on and adjusting temperatures when we get into our bedroom, we fall asleep or step out of the room.

Nevertheless, like every major technological advancement in human history, we can expect the technologies associated with the FIRe to engender fresh problems even as they promise numerous benefits (Boon 2016). Autonomous Mobile Vehicles and Advanced Robotics are likely to eliminate an enormous number of jobs in the manufacturing, transportation and service sector. The convenience associated with 3D printing could lead many retailers, manufacturers and even global supply chains to falter. In the last three industrial revolutions, machines substituted manual labour but living standards improved over time because more value-added work was created. What might presumably be different this time with the FIRe is that subsequent job growth could be minimal because many of the new jobs created might well be filled by sophisticated robots. Evidently the era of FIRe will introduce and undergo Disruptive Technologies.

2.2 Disruptive technologies

In the 1997 best-selling book entitled, “The Innovator’s Dilemma,” Harvard Business School professor Clayton M. Christensen elaborated on the two different types of technology that affect organizations, namely, “sustaining technologies” and “disruptive technologies” (Christensen 1997). The former refers to new technologies that help organizations “improve product performance (Ibid., p. 10)” while the latter refers to “wild and unexpected technological breakthroughs that require corporations to radically rethink their very existence” (The Economist, 2009). Christensen further explained that disruptive technologies generally underperform compared to established products due to lack of refinement but are usually cheaper and more convenient to use (Christensen 1997). Later on, Christensen (2003) changed the term to “disruptive innovations” explaining that innovations on the use of new technologies and not the technologies themselves caused disruptions. Examples of which are as follows:

- Small off-road motorcycles introduced by Honda, Kawasaki, and Yamaha as disruptive technologies to over-the-road motorcycles made by Harley-Davidson and BMW.

- Personal computers (PC) and electronic mails (e-mails) replaced typewriters in terms of work and communication.

- Wireless cellular phones allowed people to communicate outside home, disrupting the telecommunication industry.

- Smartphones, later on, displaced these cellular phones as well as disrupted other electronic industries (e.g. cameras, music, calculators) because of the easily accessible software applications (often referred to as apps).

2.2.1 Identifying the technologies that can disrupt the current status

The technologies that have the potential to disrupt the economy and society can come from different fields and areas. However, because of the rampant increase in technological “breakthroughs”, we can find it very challenging to identify the technologies that will have a huge impact on the lives of the people in the future. Below are some indicators that can be observed in technologies to assess its potential to greatly impact our society and economy.

- <u>Rapid advancement or Technological breakthroughs</u> - Most of the disruptive technologies are fast improving in terms of price and performance relative to competition or other similar or alternative technologies. This is primarily because of the demand of the consumers in harnessing these technologies. This reason drives the developers and researchers in this area/technology.

- <u>The scope of impact is wide</u> - Disruptive technologies are usually influencing the flow of financial processes and transactions. Most of the time, this is due to the eagerness of the companies and industry to employ such technologies affecting production via rapid development of machines, products and services.

- Great effect on economic value - An economic disruption of technology must have the capability to impact the current economic status in great scale. In the perspective of consumers, disruptive technologies can create a new way of living or work process.

2.2.2 Potential technologies that are candidates to be disruptive

In May 2013, the McKinsey Global Institute (MGI) reported popular technologies that are rapidly developing in the past years and have the potential to disrupt the economy and society. (**Table 2**)

Table 2. Potential disruptive technologies and their financial scope and worth

Illustrative rates of technology improvement and diffusion		Illustrative groups, products and resources that could be impacted	Illustrative pools of economic value that could be impacted
Mobile Internet	**$5million vs $400** Price of the fastest supercomputer in 1975 vs that of an Iphone X. Iphone X has more computing performance. **6x** Growth sales of smarthphones and tablets since Iphone in 2007	**4.3 billion** People remaining to be connected to the internet using mobile data connection **1 billion** Transaction and interaction workers, 40% of global work force	**$1.7 trillion** GDP related to the Internet **$25 trillion** Interaction and transaction worker employment costs, 70% of global employment costs
Internet of Things (IoT)	**300%** Increase in connected machine to machine devices over the past 5 years **80-90%** Price decline in Micro-Electro-Mechanical Systems (MEMS) sensors in the past 5 years	**1 trillion** Things that could be connected to the internet across industries such as manufacturing, health care and mining **100 million** Global machine to machine device connections across sectors like transportation, security, health care and utilities	**$36 trillion** Operating costs of key affected industries (manufacturing, health care and mining)
Cloud technologies	**18 months** Time to double server versus per dollar **3x** Monthly cost of owning a server	**2 billion** Global users of cloud-based email services like Gmail, Yahoo, and Hotmail **80%** North American institution hosting or planning to host	**$1.7 trillion** GDP related to the internet **$3 trillion** Enterprise IT spend

	versus renting in the cloud	critical applications on the cloud	
Advanced Robotics	**75-85%** Lower price for Baxter than a typical industrial robot **170%** Growth in sales of industrial robots, 2009-2011	**320 million** Manufacturing workers, 12% of global workforce **250 million** Annual major surgeries	**$6 trillion** Manufacturing worker employment costs, 19% of global employment costs **$2-3 billion** Cost of major surgeries
Next generation genomics	**10 months** Time to double sequencing speed per dollar **100x** Increase in acreage of genetically modified crops	**26 million** Annual deaths from cancer, cardiovascular diseases, or type 2 diabetes **2.5 billion** People employed in agriculture	**$6.5 trillion** Global health care costs **$1.1. trillion** Global value of wheat, rice, maize, soy and barley
Energy Storage	**40%** Price decline in lithium-ion battery pack in an electric vehicle since 2009	**1 billion** Cars and trucks globally **1.2 billion** People without access to electricity	**$2.5 trillion** Revenue from global consumption of gasoline and diesel **$100 billion** Estimated value of electricity for households currently without access
3D Printing	**90%** Lower price for a home 3D printer vs 4 years ago **4x** Increase in additive manufacturing revenue in past 10 years	**320 million** Manufacturing workers, 12% of global workforce **8 billion** Annual number of toys manufactured globally	**$11 trillion** Global manufacturing GDP **$85 billion** Revenue from global toys sales
Advanced Materials	**$1,000 vs $50** Difference in price of 1 gram of nanotubes over 10 years **115x** Strength to weight ration of carbon nanotubes vs steel	**7.6 million tons** Annual global silicon consumption **45,000 metric tons** Annual global carbon fiber consumption	**$1.2 trillion** Revenue from global semiconductor sales **$4 billion** Revenue from global carbon fiber sales

Renewable Energy	**85%** Lower price for a solar photovoltaic per watt since 2000 **10x** Growth in solar photovoltaic and wind generation capacity since 2000	**21,000 TerraWatthours (TWh)** Annual global electricity consumption **13 billion tons** Annual carbon dioxide emission from electricity generation	**$3.5 trillion** Value of global electricity consumption **$80 billion** Value of global carbon market transactions
Autonomous and semi-autonomous vehicles	**300,000+** Miles driven by Google's autonomous cars with only 1 accident which was caused by human error **1,540+** Cummulatively miles driven by cars competing Defense Advanced Research Projects Agency (DARPA) Grand Challenge	**1 billion** Car and trucks globally **450000+** Civilian, military and general aviation aircraft in the world	**$ 4 trillion** Automobile industry revenue **$ 155 billion** Revenue from sales of civilian, military and general aviation aircraft

Source: McKinsey Global Institute, 2013.

2.3 Frontier technologies

Technologies that "have the potential to disrupt the status quo, alter the way people live and work, rearrange value pools, and lead to entirely new products and services" are referred to as "frontier technologies" (UNESCAP 2018, p. 1). While there is no universally agreed definition of frontier technologies, many frontier technologies can be considered as general-purpose technologies (GPT), which have the following characteristics (Bresnahan and Trajtenberg1996 as cited in UNESCAP 2018):

- Pervasiveness – the GPT should spread to most sectors.
- Improvement – the GPT should become more efficient and effective over time and keep lowering costs for users.
- Innovation spawning – the GPT should enable the invention and development of new products or processes.

A GPT has the potential to re-shape the economy and boost productivity across all sectors and industries. Examples of GPTs include steam, electricity, internal combustion, and information technology (IT).

As **Table 3** shows, among the frontier technologies identified by various organizations, the most common are 3D printing, the Internet of Things, AI, and robotics.

Table 3. Frontier technologies identified by different organizations

OECD	World Bank	World Economic Forum	McKinsey Global Institute	Institute of Development Studies	MIT Technology Review 2018
Internet of Things	Fifth-generation (5G) mobile phones	Artificial intelligence	Mobile internet	3D printing	3D Metal Printing
Big data analytics	Artificial intelligence	Robotics	Automation of knowledge work	Collaborative economy tools	Artificial Embryos
Artificial intelligence	Robotics	Internet of Things	Internet of Things	Alternative internet delivery	Sensing City
Neuro technologies	Autonomous vehicles	Autonomous vehicles	Cloud technology	Internet of Things	Artificial intelligence for Everybody
Nano/micro satellites	Internet of Things	3D printing	Advanced robotics	Unmanned aerial vehicles/drones	Dueling Neural Networks
Nanomaterials	3D printing	Nanotechnology	Autonomous and near-autonomous vehicles	Airships	Babel-Fish Earbuds
3D printing (additive manufacturing)		Biotechnology	Next-generation genomics	Solar desalination	Zero-Carbon Natural Gas
Advanced energy storage technologies		Materials science	Energy storage	Atmospheric water condensers	Perfect Online Privacy
Synthetic biology		Energy storage	3D printing	Household-scale batteries	Genetic fortune-telling
Blockchain		Quantum computing	Advanced materials	Smog-reducing technologies	Materials' Quantum Leap
			Advanced oil and gas exploration		
			Renewable energy		

Source: UNESCAP (2018, p. 3)

3. The emerging technological landscape

To better grasp the Fourth Industrial Revolution (FIRe) and its impacts, this chapter looks at each of the different technologies. The basic features are described along with the latest trends and commercial applications. Examples of how they are being adopted in the Philippines are also presented.

3.1 Internet of Things

3.1.1 Basic description

The Internet of Things (IoT) refers to the connectivity and association of electronic devices, vehicles (also called as "connected devices" and "smart devices"), structures, buildings, and other devices with electronics, software, sensors, actuators, and communication capabilities which equip the said items to send, transmit and process information. IoT enables objects to be monitored and controlled remotely using established communications networks, opening the potential of mergence between the physical systems in computerized and digital systems, increasing efficiency, accuracy and productivity while reducing human interactions. Integration of IoT with sensors and actuators, it is referred to as a general classification of cyber-physical organization. Some examples are smart power grids, virtual power plants, intelligent transportation systems, and automated homes which is classified as components of smart cities.

Characteristics of IoT:

- Inter-networking of physical devices
- Connected devices
- Connected smart devices
- Items embedded with electronics, software, sensors, actuators, and network connectivity.
- Objects to collect and exchange data
- Objects are sensed or controlled remotely across existing network infrastructure
- Creating opportunities for direct integration of the physical world into computer-based systems

3.1.2 Trends and applications

In a typical internet of things (IoT) architecture, we can commonly see integration of different devices with different distinct functions. IoT is segregated into three (3) layers: perception, network, and application layers (Zhao & Ge, 2013). Perception layer acts as the “sensors” layer which acquires data from the environment using sensors and actuators. The network layer transmits all the transferred data of the perception layer via internet. Internet gateways can be in the form of Wi-fi, LTE, Bluetooth, 3G, Zigbee etc. This layer mediates to and from different sensor by aggregating, filtering and transmitting data. Application layer, on the other hand, is where the creation of the smart environment such as smart city and smart government (Mahmoud et al, 2015).

Manufacturing is benefitting most of the advances in internet of things (Rham, 2017). Rapid development in manufacturing technology requires development and changes in the setup and situation. Globalization and digitalization contributes to the transformation in the manufacturing (Eyers & Potter, 2017). IoT made its way to various industries such as manufacturing and agriculture as well as the consumer market which came convenient in the likes of smart connected homes and wearable health devices (Rijmenam, n.d.). These products brought ease and simplification to several personal tasks (Monostori, 2016). Applications of IoT are best explained in Box 1.

Box 1. Internet of Things Application

Imagine a smart home where all your appliances are connected with each other, and being controlled by a remote control, smartphone or computer. With a simple touch of button, lights can go dim, or be switched on or off. The ambiance inside the home is controlled automatically as we enter or leave a room. This has become possible with the advancement of wireless connectivity. Devices and sensors can now be remotely connected, allowing us to operate conventional appliances and systems using wireless networks. This network of things is referred to as the Internet of Things (IoT). Gadgets are connected that enable monitoring, detection, control and automation.

In the Philippines, some expensive houses and condominiums are equipped with IoT devices. Smart farms are also controlled by IoT equipment. Traffic lights and weather monitoring devices may also be interconnected, and urban areas are now beginning to have smart cities.

To capitalize in the IoT technology would require investments in information and communications technology (ICT) infrastructure such as the acquisition of equipment and computer software. Globally, the United States is the top investor ICT with a 32.14% share of investments (OECD, 2010).

While the Philippines is not well known in the IoT, a number of opportunities are currently present in the country. Furthermore, the Philippine government is setting up facilities in anticipation of the expected growth of IoT in the country. The Department of Information and Communications Technology (DICT), laid out its Philippines Roadmap for Digital Startup. The roadmap is divided into three parts: (1) The Internet-Related (Digital) Startup Ecosystem (2) Patterns of Technology Startup Ecosystem (3) Action Plan. The Internet Related Startup Ecosystem.

The Philippine government through the Department of Science and Technology-Philippine Council for Industry, Energy and Emerging Technologies Research and Development (DOST-PCIEERD) is conducting basic to intensive training in data science. AI Pinas Moving Forward, #EMERGENT: Artificial Intelligence Forum and Data Science Track are some of the training activities conducted by the agency. The DOST-PCIEERD, through its Emerging Technology Development Division (ETDD), is a chief advocate of enhancing knowledge in data science. Several higher education institutions in the country have also begun or are in the midst of starting graduate programs in data science.

3.2 Artificial Intelligence

3.2.1 Basic description

Artificial intelligence, commonly called as AI or machine intelligence, is the programmed reasoning and thinking skills applied to machines to mimic human or animal intelligence. AI is also defined in the computer science discipline as the design and implementation of intelligent agents. Agents are referred to as units that senses the environment and create decisions to be carried out as a response in the environment. AI also greatly deals with the study of humans' ability to learn and solve problems which is generally referred to as cognitive skills.

Goals of AI:

- Reasoning, problem solving
- Knowledge representation
- Planning
- Learning
- Natural language processing
- Perception
- Motion and manipulation
- Social intelligence
- Creativity
- General intelligence

Tools of AI:

- Search and optimization
- Logic
- Probabilistic methods for uncertain reasoning
- Classifiers and statistical learning methods
- Neural networks
- Deep feed-forward neural networks
- Deep recurrent neural networks
- Control theory
- Languages
- Evaluating progress

3.2.2 Trends and applications

AI revolutionizes the way humans experience things; it also has potential in future economic growth. However, considerations regarding adaptation and application must be taken into account. Examples of such are security and safety, accountability, ethical issues, and socio-economic impacts. AI systems are now utilized in the healthcare, social services, education, financial services, transportation, public safety, environment and infrastructure (IBM, n.d.).

A rather promising application of AI is on the use of driverless cars, which offer lesser road traffic incidents (Mannino *et al*., 2015). Several establishments, such as Audi, BMW, Ford, Google, General Motors, Volkswagen and Volvo are currently experimenting with driverless cars. IHS Automotive projects that self-driving cars will replace all cars on the road by 2025-2055.

AI systems are also being employed by hospitals for their various services. These systems have the capacity to improve diagnosis and care delivery outcomes by 30-40% (Frost & Sullivan, 2016) and can advance and optimize cancer care (Liu, 2017).

ASEAN's four biggest economies have the potential for automation by adapting current technologies: Indonesia (52% of all activities), Malaysia (51%), the Philippines (48%) and Thailand (55%). These tasks currently generate more than $900 billion in wages (Citturu *et al.*, 2017).

In the Philippines, about a third (35%) of occupations identified by PSA (2017) have a high possibility of automation. These occupations include secretarial support workers, maintenance and sales workers, craft and related trades workers and plant and machine operators and assemblers. However, low labor cost automation in sectors employing these occupations are likely to be moderate.

A report by the McKinsey Global Institute on the uses and effects of AI in Southeast Asia suggests that the Philippines is currently at the average level of adoption of AI in telecommunications, manufacturing, financial services, consumer package goods and transportation and logistics (MGI, 2017). AI adoption in high tech and telecommunication has little effect in the labor market because it focuses on internet base services. Thus, internet infrastructure needs to improve if the Philippines is to compete with nearby countries.

In transportation, AI systems could help reduce traffic problems in urban areas, specifically in Metro Manila. These systems could analyze traffic related incidents and consequently provide concrete inputs on how to minimize traffic. See **Box 2**.

Box 2. Application of Artificial Intelligence in Traffic Management

Vehicle traffic congestion is caused mainly by two reasons, vehicle volume and motorists' behavior. The CATCH-ALL Project: Contactless Apprehension of Traffic Violators on 24-Hours Basis and All-Vehicle Detection System addresses the latter. It aims to implement a machine vision system that can capture vehicle and license plate images, and traffic violations on the street intersection in real time. The system is comprised of a video capture system, which is a network of roadside cameras connected to a remote server location that analyzes video information in near real time. An artificial intelligence system is employed to analyze the violations of motorists captured in the video sequences. Further, the identities of the vehicles are drawn using recognition algorithms such as vehicle profile and plate number also through AI algorithms.

Currently, the government, chiefly the Metropolitan Manila Development Authority (MMDA), implements a manual vehicle contactless apprehension system. MMDA employees are stationed to watch video streams and record violations of vehicles. The use of CATCH-ALL can enable MMDA to reassign employees to perform other tasks. Further, with the use of this system and other similar systems, the demand for AI scientists and technical individuals for upgrades and maintenance of such systems will rise. New offices and agencies may be established in conjunction with the services that will be created together with CATCH-ALL.

Hitherto, the Philippines only has a few policy and programs on AI. According to DOST-PCIEERD Deputy Executive Director Raul C. Sabularse, the DOST is primarily looking to utilize AI for manufacturing industries for augmenting large scale production of goods in the country. The department is consulting with experts and stakeholders to form a development program on artificial intelligence (DOST, 2017).

3.3 Blockchain

3.3.1 Basic description

A blockchain simply is a digital ledger of transactions; this ledger is shared by a network of computers, making use of cryptography to secure the authenticity of the transactions. More technically, a blockchain refers to a non-terminating list of records called blocks. Every block is linked to other blocks with hash pointers that contains the information of the next block, timestamp and the data itself. Blockchains are designed to be resilient in data modification. Blockchain is commonly used as a public distributed ledger that holds transaction records between two parties with a function for verification (Iansiti and Lakhani 2017). In this configuration, a blockchain is overseen by a peer-to-peer network implementing rules and protocols for verification of blocks. All saved information are non-editable without the consensus of the whole network.

Characteristics of Blockchain:

- Uses the decentralized data storing technique.
- Uses ad-hoc message passing and distributed networking.
- Use of public-key cryptography.[1]
- Distributed ledger technology

3.3.2 Trends and applications

While the term blockchain hase generally been equated with the digital currency called bitcoin, the blockchain is much more. Currently, blockchain applications are not that widely used but the potential of the technology to affect several industries is very evident. The most likely industry to be affected is the banking and financial sector. Most of the leading banks in the world are in different stages of creation, design, and deployment of blockchain technologies in remittance management, smart contracts, identity management, and digitization of assets (Narayanan *et al*., 2016).

Cryptocurrencies, such as the bitcoin, is the most popular application of block chain technology. In different countries, blockchain is used for decentralized authentication in traditional banking transactions and clearing of transaction records (say for land titles). Block chain is also applied in the telecoms and computing industry. IoT could also use block chain for authentication and authorization of IoT connection and data transfer transactions. See **Box 3** for an application of blockchain in public service delivery.

[1] Public key (Random string of numbers) is a blockchain address

Box 3. Potential of Blockchain

Government services are always prone to criticism due to low responsiveness and the lack of coordination among agencies. For instance, individuals who would like to secure a passport are required to authenticate several documents (e.g., birth certificate) to validate their identities. Most of these requirements are also compulsory when acquiring other documents, such as a driver's license or professional licenses. Blockchain technology can offer distributed information storage without compromising security. If a government agency requests for information from individuals, the said information is stored in several storage facilities/nodes in the form of a blockchain. The information can then be deciphered when fragments of information from different locations are put together by the requesting agency. In this manner, government agencies would be able to access distributed information and utilize it to make services more efficient, especially as it starts to implement a national identification system.

Around 2014, blockchain penetrated the Philippines through the establishment of the company coins.ph by entrepreneurs Ron Hose and Runar Petursson from Silicon Valley, USA. The company handles trading and conversion of Philippine Peso to bitcoin as well as recently to another digital currency called etherium. Also, coins.ph is the leading mobile block chain platform in South East Asia.

Block chain in the Philippines is hitherto purely used in cryptocurrency trading and exchange. Most of the users of block chain in the Philippines, sees the technology for earning profits through exchanging pesos to bitcoins and converting back to the local currency when the value of bitcoin increase.

Several companies support coins.ph such as Quona Capital, wavemaker, Global Brain. Banks and financial companies such as Union Bank, Cebuana Lhuillier and Gcash (Globe Telecommunications) are supporting the transfer of funds in local currency to digital wallets available for the app of coins.ph, as well as the cashing out of the cryptocurrencies back into Philippine peso.

3.4 Big Data

3.4.1 Basic description

Although there is no universal consensus on what Big data means, most would refer to "Big Data" as the digital data sets that are so large (either in terms of scale, i.e. "volume", or streams across time, i.e. "velocity") or complex (in terms of variety). This data deluge is a by-product or "exhaust" from making use of electronic devices (smart phones, tablets, laptops, biomedical equipment), social media, search engines, as well as sensors and tracking devices (including climate sensors and GPS) (Albert, 2017; Sriramoju, 2017). Making use of "Big Data" involves descriptive analytics (e.g., getting customer profiles and behavior from social media and customer transaction databases), predictive analytics (i.e., forecasting future events) and even prescriptive analytics (using simulation and optimization methods) that extract value from digital data.

"There is little doubt that the quantities of data now available are indeed large, but that's not the most relevant characteristic of this new data ecosystem." (Sriramoju, 2017) Results of analytics using Big Data provide insights whether for business or development purposes.

Amazon, an electronic commerce and cloud computing company, makes use of its large customer database to inform their clients that "customers who bought Product A also bought Product B, and Product C …" Call center agents are now entering "what customers say" on their work stations and are subsequently provided instructions on workstations on "what to say" based on predictive analytics of customer databases. Businesses (and politicians) are also starting to conduct an examination of social media data, such as tweets on Twitter, in terms of "polarity" (i.e., positive, negative, or neutral) of sentiments on a product or service (or in the case of politicians, statements they say or current political issues).

Research has also been undertaken to address data gaps e.g., small area estimates of poverty rates, or various statistics important for gender analysis. Smith *et al*., (2013), for instance, reports on producing s the use of call detail records (CDRs) as well as information on mobile customer behavior to proxy poverty status of mobile users. Anonymized credit card and cell phone data have been examined to describe patterns of women's expenditure and mobility in a major Latin American metropolis (Data2X, 2017). Satellite imagery data has also been used to generate small area estimates of girls' stunting, women's literacy, and access to modern contraception in several developing countries, including Bangladesh, Haiti, Kenya, Nigeria and Tanzania (Data2X, 2017).

Big Data is typically high-dimensional, with a large amount of redundancy. Consequently, multidimensional Big Data can also be represented as tensors, i.e., arrays of numbers that transform according to certain rules under a change of coordinates, which can be efficiently handled by tensor-based computations, such as multilinear subspace learning. Technologies used in computations and analytics on Big Data also include massively parallel-processing (MPP) databases, search-based applications, data mining (i.e. statistical models including machine learning), distributed file systems, distributed databases, cloud and HPC-based infrastructure (applications, storage and computing resources) and the Internet (Sriramoju, 2017).

3.4.2 Trends and applications

While many insights have been gained from Big Data analytics, major challenges exist and persist in Big Data including (a) processing the data (given the large volume, high velocity, and complex variety of Big Data); (b) curating the quality of data (i.e., examination of reliability and accuracy of Big Data), (c) communicating results from Big Data analytics (effective visualization); and (d) addressing issues on data privacy.

Statistical methods and traditional computations that perform well for small data sets do not necessarily scale well to voluminous and complex data. Thus, a first issue pertains to data storage and access. Data selection, feature selection, and data reduction are essential task when dealing with large and varied datasets. The common practice in processing big data is to utilize a cluster of physical computers running a framework tool such as Hadoop or MapReduce that makes it possible to collect a rather large amount of semi-structured and unstructured data in a reasonable amount of time (Mitchell, 2014). This practice is, however, gradually shifting to making use of cloud processing technologies. Elimination of physical facilities for Big Data processing is seen to reduce cost in companies and industries. Furthermore, hiring the services of a data scientists (including statisticians, computer scientists) increases the efficiency and accuracy of data interpretation.

A standard process for Big Data analytics is to transform the semi-structured or unstructured data into structured data, and then apply statistical methods and data mining algorithms to extract knowledge (Mitchell, 2014). It is common to use “data lakes”, a repository of data wherein information is dumped in real time without any data set design. Then a (data mining) tool is used to draw analytics or interpretation from the data lake. It is usually processed by a data analytics provider and is uploaded to the cloud.

A major hurdle in Big Data analytics is the processing power required for extracting and examining big data. The bottleneck lies in the capabilities of the hardware used for accessing the database. Research undertakings have focused more on how to optimize the process and how the knowledge discovery tools deliver the analysis and interpretation in real time.

The process for knowledge discovery is another fundamental issue in Big Data analytics. Many statistical models or data mining tools, including machine learning tools, may be used for knowledge discovery but some of these methods may not be suitable or efficiently used for large datasets in a sequential computer. Researchers test the compatibility and the advantages of these analytical methods vis a vis other alternative tools. The basic objective is to minimize computational cost processing and complexities.

Another major issue in Big Data analytics is to handle inconsistencies and uncertainty present in the datasets and thus perform data quality curation. Big Data is burdened with challenges regarding veracity and reliability. In his book “The Signal and the Noise,” Silver (2015) points out that more (big) data need not mean better data: “If the quantity of information is increasing by 2.5 quintillion bytes per day, the amount of useful information almost certainly isn’t. Most of it is just noise, and the noise is increasing faster than the signal.” An article in Nature (Butler, 2013) reports on the discrepancy in the estimate of flu levels in the US for January 2013 between the Google Virus Trends (11%) i and the official estimate (6%) from the Center for Disease Control (CDC). Thinking Machines Data Science (2016) has conducted a case study of 116,071 tweets about the Philippine presidential candidates over the period between October 26 and November 25, 2015. The study reveals how the work of a bot artificially inflated the frequency of tweets of one candidate, thus suggesting that the frequency of internet conversations is still a long way from accurately measuring the popularity of presidential candidates.

Analytics also requires data to be presented in adequate visuals in order to facilitate proper interpretation. Consider the volumes of online transactions. Companies handling electronic commerce typically use a tool such as Tableau to transform large and complex data into intuitive portraits of latest customer feedback, and sentiment analysis. Several Big Data visualization tools however still have poor performances in functionalities, scalability, and response in time.

As regards data privacy, it should be noted that a lot of Big Data being generated from internet use includes personal information, involving precise, geo-location-based information that pushes the boundary of confidentiality and personal privacy. While some mechanisms are in place to protect privacy, including asking people to opt out of studying the information they give. Further, anonymization methods, such as differential privacy and “space time boxes”, may hide personal identity but these methods are not fool proof as there is potential to re-identify. Security of access to big data require authentication, authorization, and encryption techniques (Hongjun et al. 2014).

The current industry use of Big Data in the Philippines is relatively small compared to other countries, however a handful of companies and industry leaders are starting to embrace Big Data analytics. Thus, the Philippines is projected to be a big player in Big Data analytics especially with the increasing use of the internet and social media in the country.

Key informants in Philippine business and industry project that in the next 5 years, 10 million jobs will be created in data science and Big Data analytics. As of 2017, the Philippine Statistics Authority estimates that there are 40 million individuals employed in the country. If projections on future required employment on data science and Big Data analytics are realistic, this means that the Philippines is on the brink of transitioning from its beginnings as a call center provider and BPO hub to a processing hub of Big Data. Multinational companies in the country and startup companies are starting to thus make investments on Big Data analytics. Companies such as IBM Philippines, Accenture Philippines and TALAS are offering Big Data analytics services (IBM, n.d.). Further, the Asian Institute of Management has started in 2017 to offer a graduate program in Data Science, and other higher educational institutions known for their quality programs are likewise on the brink of offering similar degree programs.

3.5 Robotics

3.5.1 Basic description

Robotics is a multi-disciplinary area of engineering and science involving the fields of mechanical, electrical, computer science, and other engineering-based fields. Robotics refers to the science of design, construction, operation, and implementation of robots, as well as computer systems for control, feedback, and information processing.

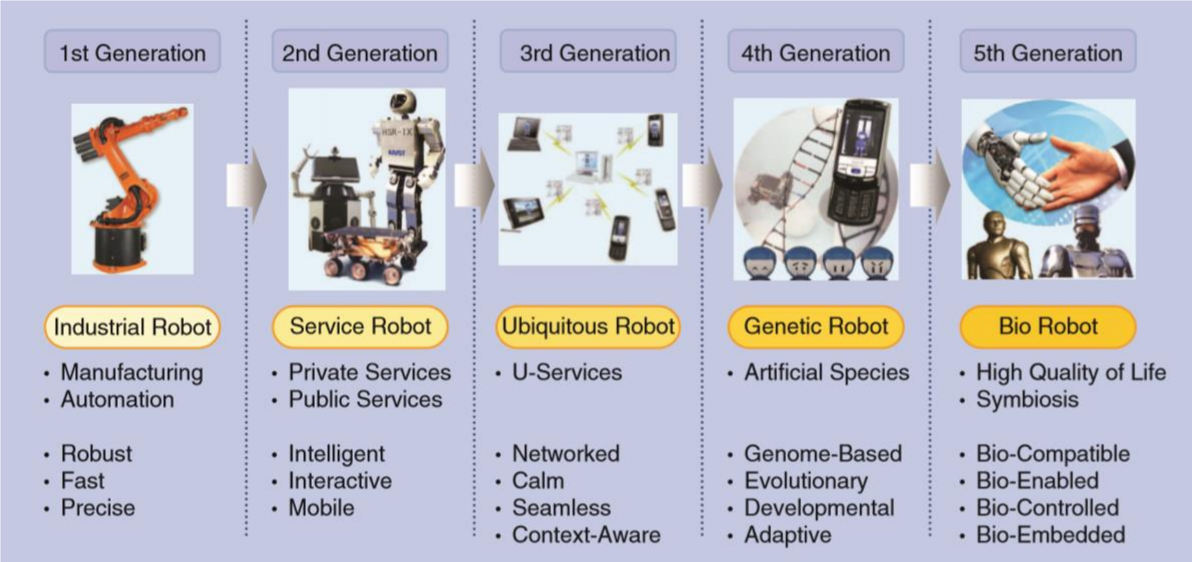
Robotics aims to replace humans in tedious and hazardous tasks. Robots can be deployed in any situation and for any purpose but are easily found in dangerous environments (including bomb detection and de-activation), manufacturing processes, or where human lives are at risk. Robots are can take many forms, but some are made to resemble a human's physique. Taking this form, robots are said to be more acceptable in human environment and performing repetitive human tasks. Humanoid robots are already replicating walking patterns of humans, lifting objects, speech, and cognitive skills. There are robots that mimic behavior and movements observed in nature especially animal movements. This is called bio inspired robotics.

Characteristics of Robotics:

- Fusion of mechanical, electrical and computer science principles
- Design of machine which can be controlled by computers.
- Machines that are capable of carrying a task of a human and saves them from strenuous activities.

Kim, *et. al* (2013) describe five generations of robots. The defining characteristics for each of these generations are their salient technical features, intelligence, and purpose or application. The trend from one generation to the next is an increase in autonomy, intelligence, modularity, versatility and ubiquity. On one end of the spectrum is the **industrial robot** which is an automatically controlled, reprogrammable, multipurpose manipulator. It is programmed to do repetitive actions in a robust, fast and precise manner and can be used for welding, painting, assembly, pick and place, etc. On the other end the **bio-robot** which is the use robots as assistants within the physical domain of biological species. Applications developed in bio robots include artificial heart, prosthetic limb, genetic engineering, in-body diagnosis and treatment (Kesner and Howe 2011 and Ueda, *et.al* 2010 as cited in Kim, *et. al* 2013). See **Figure 1**.

Figure 1. Five generations of robots



Source: Kim, *et. al* (2013), p. 71

3.5.2 Trends and applications

The number of robotics applications in businesses increased considerably in recent years primarily to enhance productivity. The International Federation of Robotics (IFR) reported that in 2016, the average global robot density is about 74 industrial robots installed per 10,000 employees across the manufacturing industry. The most automated countries in the world are the Republic of Korea, Singapore, Germany and Japan. The Philippines is among the lowest in the region for automation adoption with a robot density of three industrial robots installed per 10,000 employees in 2016. The country is behind Singapore, Thailand, and Malaysia which has a robot density of 488 units, 45 units, and 34 units, respectively (Reyes, 2018).

Using robots in repetitive tasks such in manufacturing plants fulfill the characteristics of automation, which greatly increase the yield and efficiency of the manufacturing processes. Commonly used robots in manufacturing processes are assembly robots, welding robots and heavy-duty robots. Examples of more recent military and agricultural applications in the Philippines are described in **Box 4** below.

Box 4. Local applications of robotics

Human security is a pressing issue in the country, especially with the persistent threats of terrorism. Recently, the country has dealt with violence in Marawi City brought by an ISIS-inspired terror group. Government forces though have had challenges in re-occupying the city because they have not been prepared to handle urban warfare. Terrorists in Marawi have hidden in strategic locations such as buildings and drainages. The military forces have, however, had the advantage of making use of drones as surveillance tools for assessing ground scenarios. Drones are robots which can be deployed and utilized in various environments. Employing military robots lead to higher chances of success in missions. Furthermore, increasing usage of robots may lead to the establishment of specialized units that can serve different branches of the military.

Apart from military applications, robots can also be applied to other sectors to increase productivity and quality of services. For example, the project called "Automation of Coconut Sugar Production" aims to automate the production of coconut sugar by using robotic systems, which utilize sensors to monitor the temperature and status of the cooking chamber. With this, the quality of coconut sugar is maintained while increasing the yield and minimizing the production time. The beneficiaries of the said project are now reaping the advantages of the system. The farmers have been trained to operate and maintain the machine.

3.6 Neurotech

3.6.1 Basic description

Neurotechnology refers to the technology that changes how people perceive and appreciate the brain and several characteristics of consciousness, thought, and complex activities in the brain. It also refers to the products that are made to augment and heal brain activities and allow researchers and clinicians to see, map and visualize the brain.

- Imaging – Magnetic fields produced by electrical currents that occur in the brain, are sensed and recorded conjunctively with brain activity. Magnetometers yield images that are used to detect and record brain activities. Applications of this technology includes research on brain processes connected with cognition, neurofeedback and determination of the function of various brain parts.

- Transcranial magnetic stimulation –Since the brain fires with electric currents, magnetic stimuli can induce electric currents in the brain because of the relationship between electric current and magnetic field. The magnetic field can be directed in a specific part of the brain. Transcranial magnetic stimulation involves the direct stimulation of the brain using magnetic stimuli.

- Transcranial direct current stimulation– Transcranial direct current stimulation (TDCS) is a procedure under neurostimulation that utilize electrodes attached to the scalp to deliver a constant current. Studies suggest that healthy adults improved their cognitive performance on several tasks under TDCS. In particular, study participants improved their language and mathematical ability, problem solving, coordination and attention span.

- Cranial surface measurements – The most popular procedure in measuring brain activity in non-invasive manner is the Electroencephalography (EEG). Electrodes are attached to the scalp that will receive electrical signals from the brain. A common application involves gathering information regarding the stages of sleep and the brain activity pattern while sleeping. In several occasions, EEG is used in experiments involving epilepsy, stroke and tumor presence in the brain.

- Implant technologies – Any device that is used to monitor or regulate brain performance is called a neurodevice. There are existing neurodevices used for treatment of Parkinson’s disease. The most popular neurodevices are the deep brain simulators (DBS)

Characteristics of Neurotechnology:

- Study of the brain and its function.
- Design of devices that will monitor the brain.
- Design of sensors for reading electrical signals produced by the brain.
- Deals with the design of devices for treating brain diseases.

3.6.2 Trends and applications

Around the world there are several applications of neurotechnology that have emerged and made significant impacts on society. From medical drugs to brain scanning, this new technology affects people, be it from assessment of mental states, neural implants, brain–computer interface (BCI) systems and many more.

Brain imaging allows doctors, researchers and technologists to monitor directly the brain's activities during experiments and provide a means to control to some degree activities of the brain. Controlling brain functions can help control depression, over-activation, sleep deprivation, and many other conditions. Furthermore, brain imaging can help improve motor related deficiencies brought by stroke.

Neural implants are considered as one of the most effective solutions for the treatment of nervous system dysfunction. For instance, one of the oldest and most established implant technologies, the cochlear implants (CIs) are commonly applied to restore the auditory senses in deaf people. At most, there are 200,000 patients with CIs worldwide, with low cases of failure.

Using cortically controlled brain–machine interfaces (BMIs), neurotechnology can also be used to help patients with Autism, Parkinson's disease, and Huntington's disease and other degenerative motor diseases. BMI with Brain computer interface (BCI) devices are used to extract motor commands and signal insertion in the brain to restore sensation. BCI technology is used primarily as measurement devices, allowing to assess and track mental states in real-time.

Neurotechnology is a disruptive technology getting more and more recognized as a key enabler for economic growth and social mobility. It is expected to improve the quality of life of people as part of the medium-term plan Philippine Development Plan 2017-2022 anchored on long term Vision for the Philippines AmbisyonNatin2040. However, neurotechnologies, in general, raise ethical, legal, and social questions due to the use of human subjects for experiments and trial.

In the Philippines, there is scant literature regarding neurotechnology due to availability and costs limitations of the technology. Most local studies do not describe actual implementations, but rather explain the development of components of the technology in Philippine universities and by the DOST through PCHRD. Further, these studies are mostly about neurometrics focused on EEG and BCI. For instance, one study involves the creation of a model of human academic emotions (namely: boredom, confusion, engagement and frustration) using EEG signals. Neural implants are not uncommon in the Philippines today, and mainly related to the treatment of various functional disorders such as in auditory senses, eye vision, and neuromotor diseases (Dimarco, 2003). See **Box 5**.

Box 5. Current Condition of Neurotechnology in the Philippines

Neurotechnology, a technology that is designed to measure, research, and visualize brain activity, allows medical practitioners to identify more efficiently and accurately certain health conditions. The most common and most frequently used measures are functional Magnetic Resonance Imaging (fMRI), magnetoencephalography (MEG) and electroencephalography (EEG). One of the most popular clinical applications of Neurotechnology is detecting neurologic ailments like Alzheimer's disease, head injuries and other mental disorders.

Beyond the health sector, neurotechnology is also being developed and merged with other fields to create more advanced applications. For example, the brain computer interface (BCI), which uses non-invasive devices, enables computers to detect and read brain activity of its users through electrodes. Through this, computer users are able to throw in inputs (e.g. opening applications) to the computer without having to click or type through a mouse or a keyboard. But scenarios like composing a 10-page document without having to press a single character button on the keyboard or playing video games by only imagining the motion of the characters are still far advanced. Electrodes in placed on our scalp can't read brain activities without the presence of much interference from our skull. Therefore, more research activities are still underway to advance the BCI.

In the Philippines, BCI activities are mostly research-related and are headed by universities offering electronics engineering and computer science. An example is a research project undertaken by students and faculty members of Ateneo de Manila University who used BCI and voice control in order to control a 3D-printed hand prosthetics (Oppus, 2016). Taking advantage of the rapid prototyping capability of 3D-printing, the researchers were able to successfully construct an upper-limb prosthetic. Further, they were able to manage the manufacturing costs by using this printer. Using EEG, the researchers were able to track and record electrical activity of the study volunteer's brain. Small electrodes are placed on the scalp and send signals to a computer to record results and thus help distinguish patterns.

3.7 Nanomaterials

3.7.1 Basic description

Nanomaterials refers to the materials of which a singular unit is in the size of 1 to 1000 nanometers and typically found in 1-100nm, the usual definition of nanoscale. Research activities in nanomaterials are focused in the field of materials science. With support of microfabrication research, researchers continuously develop and come up with advances in materials metrology and synthesis.

- Fullerenes - Fullerenes are classified as allotropes of carbon. They are made up of rolled graphene sheets and formed into tubes or spheres. Among the different forms of fullerenes, the most popular are carbon nanotubes or silicon nanotubes. Their popularity is due to the mechanical strength and electrical properties of carbon nanotubes.

- Graphene nanostructures – One type of 3D nanomaterial is box-shaped graphenes (BSG) formed after the mechanical cleavage of pyrolytic graphite. BSGs are multilayers of nanostructures constructed as parallel and hollow along the surface with quadrangular cross-section. The thickness of walls is measured to be around 1nm with average channel facets of 25nm.

- Nanoparticles – Nanoparticles, including quantum dots, nanowires and nanorods, are inorganic nanomaterials that contain remarkable optical and electrical characteristics often used in optoelectronics. These characteristics are dependent on the size, shape and organization of particles. This is capitalized by tuning and synthesizing different shapes and sizes and organizing their structure. There is also a possibility of merging this material with organic material to form optoelectronic devices such as organic solar cells or OLEDs. Electron transfer and energy transfer are examples of photo-induced processes that are utilized in such devices.

- Nanozymes – Nanozymes derived its name from its enzyme-like properties. This is one of the emerging type of artificial enzymes. It is typically used in biosensing and bioimaging and antibiofouling.

Characteristics of Nanomaterials:

- Materials are engineered in 1 to 1000nm.
- Uses graphene sheets rolled into tubes or spheres
- Uses silicon nanotubes
- Uses 2d and 3d nanostructures
- Uses quantum dots, nanowires and nanorods
- Uses nanozymes

3.7.2 Trends and applications

Nano technology found its way in making athletic equipment such as tennis rackets, baseball bats and racing bikes stronger and more durable. It has evolved into a vital component in different fields and areas such as aerospace, automobile, construction and manufacturing. This is due to the integration of carbon nanotubes in several base ingredients to create a better meshed material (Giges 2013).

The challenge that designers and researchers in nanotechnology face is the technology to mass produce and lower the cost of manufacturing nanomaterials. This technology requires scarce materials which are very expensive and require complex manufacturing processes.

Nanotechnology is involved in energy storage, lighting, and photovoltaics which are required in the popularly growing applications such as smart cities, electric cars and smart vehicles. Nanotechnology is also seen to grow in medical fields such as diagnostics and treatment of cancer, as well as early detection of body contaminants and biological substances that may lead to illnesses.

The Philippine government is supporting several nanotechnology R&D projects. Most of these projects are synthesis of nanomaterials and closely follow the development of nanomaterial applications. Applications development of nanomaterials is focused on ICT and semiconductors products, health and biomedical products and environmental applications.

Locally developed commercial products have found their way in the consumer domain. Nanoclay (organoclay or organo-montmorillonite) is used as a filler in polymer nanocomposites. Atovi is a feed premix for livestock. It is based on molecular alteration, nuclear reaction and nanotechnology. It is proven to improve the immune system of livestock (Basilia n.d.). See **Box 6**.

Box 6. Nanotechnology's role in the country

Nanotechnology materials will play a very big role in developing stronger materials for the needs of several industries in the Philippines. These products, especially construction materials, will improve tremendously by applying carbon nano tubes. This can be used to improve the quality of materials being used in the current administration's "Build, Build, Build" program which aims to boost the country's infrastructure for improved connectivity and efficient transport of goods. Nanotechnology can provide optimized materials by altering the properties of known materials, making it stronger, lighter and more flexible.

In the health sector, nanotechnology has also been advancing. Pharmaceutical companies are conducting research activities that allow nano-sized particles or organisms to enter our bodies and perform functions like cancer detection and treatment, isolated or targeted therapy, monitoring of vital functions and bio parameters, immunizations, among others.

3.8 Additive Manufacturing

3.8.1 Basic description

Additive manufacturing (AM) also known as 3D-printing, refers to processes used to create a three-dimensional product in which a computer control assembles materials into layers. Products can be in any form or size and geometry from a 3D model. Several other electronic data sources such as an Additive Manufacturing File (AMF) file can be used. Unlike material carved and removed from a series of conventional machining process, 3D-printing or AM creates a three-dimensional object from a computer-aided design (CAD) file by sequence adding material layer by layer.

Characteristics of Additive Manufacturing:

- Creation of 3D objects by stacking 2D objects
- Geometry or shapes are produced in digital model data.
- Successive addition of material layer by layer

3.8.2 Trends and applications

Additive manufacturing has the potential to disrupt the global balance as the new economics of manufacturing favors cheap labor, National Journal's Ben Schreckinger (2013) wrote recently. Improvements in 3D-printing has developed for over 30 years and now equips consumers and businesses to do rapid prototyping and produce individual items. Commercial 3D-printers are also on the verge of becoming more portable (Wile R., 2014); consequently, the growth of 3D manufacturing may end up echoing through different global labor markets. The unique feature of AM is their layer-wise fabrication approach. This allows the printing of many complex geometric shapes. In contrast, subtractive processes hinder this approach due to the need for fixtures, diverse tooling, and the possibility of collisions and difficulty of the cutter in reaching deeper zones when fabricating complex geometries (Bernard *et al*., 2012).

AM can alter the assembly line and eliminate the need for making molds where a lot of stations can be eliminated by the use of AM. Some pieces can be produced at a single station and it can eliminate the need for assembling these products at different stations. The current production process can be time-consuming as different parts have to be produced in different factories. Afterwards, the parts are brought to another factory for the final assembly. With AM, the manufacturing process could go smoothly by producing custom parts close to the final product assembly station (IAEResearch, 2013). See **Box 7**.

Box 7. Benefits of Additive Manufacturing

Traditional manufacturing technologies have been used in industrial processes such as casting and machining. While they are known to be of high quality in terms of surface finish and accuracy, as well as mechanically, but advances known as additive manufacturing have started to become used in the production line. 3D-printing is one of the mainstream examples. Due to the advancement of technologies in 3D-printing, even the most cutting-edge companies like aerospace, automotive, and medicine are either using it or considering its use.

Since additive manufacturing has the ability to integrate components regardless of design complexity, redesigning will never affect reproduction cost. Further, additive manufacturing enables rapid product development, with minimal cost for low volume manufacturing. The potential of providing high quality products will undoubtedly make additive manufacturing the choice of many firms in the near and foreseeable future.

Despite the great opportunities for this technology, uncertainties and speculations about its future developments remain. Changes in the localization of production, development of consumer demand, and the emergence of new competitors are just a few of the factors that may lead to turbulence in many industries. Despite the vast potential of additive manufacturing and the hype about this technology, there are hitherto no scientific studies available on developing scenarios about the future of additive manufacturing from an economic and policy perspective, including predictions regarding the economic impact of this technology (Baumers *et al*., 2016).

Additive manufacturing technology is still new in the Philippines. Manufacturing industries use the conventional subtractive manufacturing.

3.9 Cloud computing

3.9.1 Basic description

As with other emerging terminologies such as digital trade, various definitions exist to explain cloud computing. Citing Schubert *et al.* (2010), OECD (2014) explains that, partly, cloud computing has multiple definitions because it does not refer to a single specific technology but rather a concept composed of different technologies (OECD 2014). The core aspects of cloud computing, however, are covered in the two definitions developed by the US National Institute of Standards and Technology (2011) and the Berkley RAD lab (2009). NIST's definition focuses on cloud computing's function while Berkely RAD Lab's describes the components and the different ways cloud computing is delivered (Armbrust et al. 2009; Mell and Grance 2011).

US National Institute of Standards and Technology (NIST) – "Cloud computing is a model for enabling ubiquitous, convenient on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell and Grance 2011, p. 2)".

Berkeley RAD Lab – "Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The services themselves have long been referred to as Software as a service (SaaS), so we use that term. The datacenter hardware and software is what we will call the cloud (Armbrust et al. 2009)".

There are also certain characteristics and important aspects that are generally found in cloud computing, but not necessarily a feature of every cloud computing application. See **Table 4** based on Mell and Grance (2011), Armbrust et al. (2009), and Schubert et al. (2010).

Table 4. Characteristics of Cloud Computing

Characteristic/Aspect	Description
On-demand self service	Users of clouds can "unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider (NIST 2011, p.3)".
Availability of "infinite" computing resources	Cloud users do not have to plan the provision of their computing resources in advance as they have the potential to access computing resources on demand
Rapid elasticity and adaptability	Elasticity is one of the key features of cloud computing. Computing resources can be provisioned in an elastic and rapid way that allows adaptation to changing requirements such as the amount of data supported by a service or the number of parallel users. Users can buy computing services at any time at various granularities. They are able to up- and downscale those services according to their needs.
Elimination of up-front commitment	Users of cloud services do not have to make heavy, upfront IT investments allowing companies to start small and to successively increase hardware and software resources only when needed. In addition, small and

	medium enterprises have a much easier and more affordable access to state-of-the-art applications and platforms which were only available for larger companies before.
Short-term pay for use	Users are able to pay for their use of cloud services on a short-time basis thereby only paying for the time they use the computing resources and release them when they do not need them anymore. Companies are thus able to reduce capital expenses and convert them into operating expenses.
Network access	Computer services are accessed over the network and through standard mechanisms which allow users to connect several devices to the cloud (e.g. laptops, mobile phones).
Pooling of resources	Providers' cloud services "are pooled to serve multiple customers using a multitenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand (NIST 2011, p. 2)". As a consequence, users of cloud computing usually do not know and are unable to control where the provided cloud computing resources are exactly located. It is, however, in certain cases possible to specify the location at a more abstract level (e.g. continent, country).
Measured service and adaptability	Cloud computing systems are able to react on-time to changes in the amount of computing resources requested and thus automatically control and leverage resources.

Source: OECD, 2014.

3.9.2 Trends and Applications

Cloud computing covers a wide range of services, categorized into three cloud service models, namely: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). The SaaS model allows cloud users to directly access applications of the cloud provider from the user's device (e.g. smartphone) through a client interface or a program interface (e.g. Microsoft Office). The PaaS model provides users access and control over programmed applications by the supplier. For example, Google applications allow customized professional e-mail and cloud-based document storage solutions. Both PaaS and the SaaS provide convenience to cloud users by not having to manage the underlying infrastructure and operating systems that allow programmed applications to work. The IaaS, as its name suggests, provides its users access to computing infrastructure resources – both physical and virtual - such as processing, storage, and networks to the users of clouds (OECD 2014). Popular examples of such are the Microsoft Azure and Amazon Web Services which allows users to manage applications, data, and operating systems. For online storage, Dropbox and RackSpace are also known examples of IaaS model to provide cloud services.

There are also various ways to deploy cloud services, depending on the end-users' needs. The four main deployment models, which are categorized on the basis of size, access, and security, are *public clouds*, *private clouds*, *community clouds*, and *hybrid clouds,* detailed as follows:

- *Public cloud* model involves provisioning of the cloud infrastructure for the use of a large group or the general public. In this model, while the end-user (e.g. business, academic, government institution) is given access to operate the cloud infrastructure, it exists on the premises of the service provider.
- *Private clouds* are data centers owned and operated by a particular organization or enterprise. This model offers better security, and thus is usually used by organizations that provide data management service. Cloud infrastructure in private cloud models may be located on- or off-site.
- *Community clouds* are like public clouds, except that it is only accessible to a specific group of cloud users. This makes community clouds cost-reducing as it is a shared amongst a group of institutions with common access, security, and compliance considerations. This model allows ownership, management, and operation of the cloud infrastructure by one or more of the organizations in the community. The infrastructure may exist on- or off-site.
- *Hybrid cloud* is a combination of both private and public clouds. In this model, a section of the data center is reserved for a single user and the rest are made available to the general public. Usually, a private cloud is used to limit accessibility to sensitive data while allowing other data to be used publicly.

Numerous benefits come with the utilization of cloud computing. For one, organizations are able to store and manage more data without having to build new data centers to increase capacity. Cloud computing allows greater flexibility, and thus also allows organizations to expand fast enough to meet growing demands. Secondly, and related to its flexibility, cloud computing also significantly reduces costs on Information Technology given that cloud users do not have to build their own server infrastructure. This translates to another significant benefit of cloud computing which is the transfer of IT expenses from capital expenditures to operating expenditures, providing organizations with more investment capacity (Kushida et al. 2011). Since the upfront capital investments will become less important in the medium run, cloud computing also has the potential to become a platform for innovation given that organizations will be more focused on their core product or service (OECD 2014). The case of cloud computing in the Philippines is described in **Box 8**.

Box 8. Philippine Government Cloud

It is uncommon to find entrepreneurs and ordinary citizens who are frustrated in dealing with frontline government agencies because of slow delivery of services. This stems from the cumbersome bureaucratic processes which greatly slows down the provision of public services such business registrations and acquisition of basic documents.

In 2013, in accordance with Executive Order No. 47 s. 2011, the Department of Science and Technology (DOST) spearheaded the Integrated Government Philippine (iGovPhil) Project which aims to provide ICT infrastructure in aims of making the government more efficient, transparent, and accountable. Part of this project is the establishment of the government cloud (GovCloud) infrastructure to enable efficient government operations and improve delivery of public services to the people (iGovPhil 2013). The GovCloud is seen to reap the benefits of cloud computing through cost reductions brought about by shared cloud services that will also facilitate easier exchange of resources between government offices. For instance, if the DTI and LGUs are connected to the same cloud, duplication of documentary requirements will be avoided. Costs are reduced for both the government and the citizen or client as hardware acquisition and volume of documents would be reduced, respectively.

Currently, the GovCloud offers Government-wide Email System (GovMail) which gives government employees “@agency.gov.ph” email addresses. This adds credibility to government employees and increased confidence and peace of mind for citizens dealing with them. The GovCloud also offers PhPay, a government online system that allows citizens and businesses to electronically issue payments to government agencies. Aside from the reduced time for making physical payments, opportunities for fixers, graft and corruption are also eliminated as face-to-face transactions are avoided. Thirdly, the GovCloud also offers the National Archives and Records Management Information System (NARMIS), a program that provides digital management of records, documents, and archives of national government agencies.

3.10 Energy Storage

3.10.1 Basic description

Energy Storage is the technology which stores generated energy for later use. Devices used for storage are sometimes referred to as accumulators or batteries. Sources of energy include gravitational, solar, electrical potential, temperature, kinetic, and many others. Different forms of energy are converted to electric energy which is more convenient to store and has available storage mediums.

Storage forms range from short term storage to those that can last for long period of time. For instance, a wind-up coil stores potential energy into mechanical form, while a battery stores chemical energy to be available for discharging as electrical energy. Furthermore, hydroelectric dams store potential energy in a reservoir. Coal and gasoline are fossil fuels which store energy from organism buried over time. Food is a form of energy stored in chemical form. These are some of the widely used forms of energy storage.

Listed below in **Table 5** are the types of energy storage, both natural and non-commercial. This excludes the propriety designs of private industries and companies.

Table 5. Types of Energy Storages

Types of energy storage	Example
Storage of Fossil Fuels	natural gas storage (coal and gas)
Mechanical/Machines	compressed air energy storage (CAES), fireless locomotive, flywheel energy storage, gravitational potential energy, hydraulic accumulator, pumped-storage hydroelectricity (pumped hydroelectric storage (PHS) or pumped storage hydropower (PSH))
Electrical/Electro-magnetic	capacitor, supercapacitor, superconducting magnetic energy storage (SMES), superconducting storage coil
Biological	glycogen, starch
Electro-chemical	battery energy storage system (BESS), flow battery, rechargeable battery, ultrabattery
Thermal	brick storage heater, cryogenic energy storage, liquid nitrogen engine, eutectic system, ice storage air conditioning, molten salt storage, phase changing material, seasonal thermal energy storage, solar pond, steam accumulator, thermal energy storage (general)
Chemical	biofuels, hydrated salts, hydrogen storage, hydrogen peroxide, power to gas, vanadium pentoxide

Source: Authors' compilation

Characteristics of energy storage:

- Captures energy for future use.
- Uses several devices to harness the energy in various form

3.10.2 Trends and applications

Consumers and prosumers will have the freedom to choose alternative energy that are renewable and efficient. The main goal is addressing increasing demand while reducing emissions. Renewable Energy is high on the public policy agenda following the Conference of the Parties (COP 21) in Paris in December 2015 and the International Renewable Energy Agency's (IRENA) annual assembly to give substance to the Paris outcomes. This revolution provides a personalized energy experience for the consumers, prosumers and utility companies. Three important changes may arise. First, consumers are aware of making responsible decisions and use electricity from renewable energy. Second, consumers and prosumers alike demand real-time information about their electricity consumption that will in effect influence consumption behavior. Third, local and regional policies, such as the Energy Union, are pushing to increase renewable and affordable electricity. Energy storage applications can be divided into four categories, namely: (1) bulk energy applications, (2) ancillary applications, (3) end-use energy applications, and (4) renewable energy integration applications.

Another important application of energy storage technologies is in transportation. Energy storage technologies can be divided into three groups based on discharge duration: Short term (seconds to minutes), medium term (minutes to hours) and long term (hours to days). The storage technologies with discharge duration of short and medium term are suitable for end use energy applications and ancillary services in grids. Long term (hours to days) is more suitable for bulk energy applications and renewable energy integration applications. Bulk energy plays a significant role in integrating a large amount of energy in modern grids whereas ancillary services application has an important part in modern grids for its smooth and stable operation. It provides support to the system from generation, transmission to customer end energy use.

As far as energy storage technology in the Philippines, there is a dearth of literatures regarding the adoption of such technologies on existing renewable energy sources. The ones available pertain to renewable energy projects aligned for energy technology adoption.

Some of the renewable energy projects have been sponsored by some donors. They cluster around two specific fields of activity: solar power for rural electrification (local level) and advice for renewable energy policy (national level). There are also some other projects on renewable energy financed by corporations from the international and local groups.

To provide the appropriate policy support in energy conservation programs, the Department of Energy (DOE_ has put forth the Energy Efficiency and Conservation Roadmap, which specifies the direction toward an energy-efficient Philippines by 2030. To implement the roadmap, the National Energy Efficiency and Conservation Action Plans for 2016 to 2020 were developed across energy-using sectors (NEDA, 2017).

Box 9. Footprints of Energy Storage

Solar power harvesting systems are now in the local market. Households are recognizing the promise of potential savings and environmental benefits of these systems. On a bigger scale, communities are also utilizing energy storage systems to take advantage of strategic locations. For instance, windmills have been established in Ilocos Norte and Rizal to take advantage of strong winds in these provinces.

Energy sources are also now available in very small form factors. This could be seen in the prominence of commercial products like smartphones, laptop computers, and power banks. Batteries are now more affordable and can charge more energy. Even more affordable systems and environment-friendlier devices are expected in the future because of the continuous development of more advance energy storage devices.

Many of the problems being experienced by many Filipinos have something to do with the use of energy on various times of the day. Energy Storage (ES) technologies would simply address this problem by allowing absorption and storage of energy for a period. These technologies transform conventional electrical energy to a storable form and will be used after converting it back when needed. ES technologies provide opportunities either to produce electricity at peak hours or use it for improving system energy efficiency, integrate higher levels of renewable energy resources as well as improving electricity grid stability, flexibility, reliability and resilience.

3.11 Synthetic Biology

3.11.1 Basic description

Synthetic biology is the union of biology and engineering disciplines. It includes the areas of bio-physics, biology, electrical engineering, evolutionary biology and molecular biology. For the applications of research engineering and medical applications, synthetic biology harmonizes all the said areas.

The goal of synthetic biology is described as the creation of unique artificial biological pathways, devices or organisms, and or mimicking the existing natural biological systems. Specific examples are listed as follows:

- Biological Computers
- Biosensors
- Cell transformation
- Designed proteins
- Industrial enzymes
- Information storage
- Materials production
- Reduced amino-acid libraries
- Space survey and exploration
- Synthetic genetic pathways
- Synthetic biological life
- Manmade amino acids
- Unnatural nucleotides

Characteristics of synthetic biology:

- Study of artificial biological systems
- Recreation of natural biological systems
- Transformation of cells

3.11.2 Trends and application

Synthetic biology is emerging as a lucrative technology. The healthcare industry is one of the main beneficiaries of synthetic biology. Most of the problems faced in the said industry is centered upon raw materials supply, production costs and the effectiveness of processed materials. The main contributors of the price markups of products are costs of manufacturing and raw materials. Available materials are limited in their functions and properties. Materials that are biological in nature are usually cheap, abundant and have unique functions, such as self-healing/repair, with energy-efficiency and clean manufacturing.

The greatest potential of synthetic biology is in the field of energy which is possibly a replacement for fossil fuels, improving efficiency, and a solution to pollution. A fuel which is being developed is formed by optimizing metabolic processes in bacteria through deliberately increasing their alcohol content.

The biggest technical hurdle for synthetic biology is to sustain and produce predictable and repeatable outcomes from the designs and experiments. Knowing DNA sequences and controlling different elements does not guarantee a preferred outcome. Cells with similar genetic circuits are found to work differently, with causes varying from different growth conditions and sometimes varies due to genetic mutation. There is still a lot of potential in this technology for discoveries and breakthroughs, learnings and inventions.

The potential and availability of inventions and new technologies is hindered by safety apprehensions or their misuse. Genetically modified (GM) crops are one of the areas that is closely observed. While GM crops has great potential to solve food security, some stakeholders in agriculture have, however, expressed great concern regarding the safety of GM crops.

Synthetic biology (SB) is the engineering of biology to carry out the various functions that we need. Outputs of SB can range from producing new food ingredients to creating molecules for cancer treatment. SB enables us to engineer biology in the same way that we create computers using electronic components. This technology is possible today because of the advances made in reading and writing DNA and computing power. Many people think though that while SB is an exciting prospect, it is difficult to predict its future applications from today's knowledge.

See **Box 10** for the prospects of synthetic biology in the Philippines.

Box 10. Potential of Synthetic Biology

Currently, synthetic biology (SB) has no strict definition as the field is still evolving. But according to the High-Level Expert Group of the European Commission (Serrano, et al. 2005), SB is described as the engineering of biologically-based systems. It can be applied to any level of the biology like organisms, cells, tissues, organs, and many others. The field is interdisciplinary; it integrates engineering, computer science, biology, chemistry and other related disciplines.

The field is relatively new but has many potential applications. One significant example is the production of synthetic organisms with the capability to produce a medicinal compound. Another is engineering a synthetic micro-organism that when induced by a person is harmless but acts as a sensor for specific dangerous substances that might be present in the person's body.

In the Philippines, the National Institute of Molecular Biology and Biotechnology under the University of the Philippines Los Baños make use of biofertilizers, vaccines, antibiotics and biopesticides with SB.

4. Impacts and implications of the Fourth Industrial Revolution

4.1 Labor market

The impact of technology on the labor market is complex, evolving and perhaps unpredictable but there are illuminating conceptual and empirical patterns emerging. Conceptually three impacts can be thought of: (a) it substitutes for labor; (b) it complements labor; or (c) it creates new jobs. It therefore can have mixed net effects on the labor market depending on which effect is dominant. The empirical estimates are facilitated by characterizing labor markets in specific ways to explain emerging trends depicted by data. One such characterization is dividing jobs into routine or codifiable and non-routine or non-codifiable. Computers or robots are expected to replace routine jobs and complement non-routine ones. With the advance in artificial intelligence (AI) this classification is dynamic, i.e., what is non-codifiable today maybe in the future become codifiable (Autor, Levy, and Murnane, 2003; Autor and Dorn, 2009; Acemoglu and Autor, 2011; Autor, 2015; Acemoglu and Restrepo, 2018). In terms of prognosis, some are more optimistic than others. Autor (2015) and Acemoglu and Restrepo (2017) for instance emphasizes the job creation aspect of technology. Although there appears more unanimity in the prognosis that technology will replace routine or codifiable jobs, what remains uncertain is the timing. There are also those who emphasize the point that technological feasibility does not mean outright adoption. They argued that there are many filters before technology is deployed in production (Meyer, (n.d.); ADB, 2018). Some (e.g. Stiglitz, 2017) are more pessimistic that markets can adjust fast enough to reallocate resources and restore full employment without massive displacements.

Two tracks of empirical research relating technology and labor market outcomes have emerged. One tract measures the susceptibility of jobs to automation. Another track follows two but intertwined strands. One measures the impact of ICT investments and more recently, as data on robotization became available, the impacts of using robots in production.

Frey and Osborne (2013) estimated the probability of computerization of 702 detailed occupations using labor data from O*NET, an online service developed for the US Department of Labor. They measured the susceptibility of occupations to automation by using three criteria, namely: perception and manipulation, creative intelligence, and social intelligence. According to their estimates, nearly half (47%) of total US employment are at high risk of job automation over some unspecified number of years, perhaps in a decade or two. Citing previous work by Autor *et al*. (2003), they explain that historically, job automation has been confined to routine tasks bounded by explicit rules. However, recent technological advancements in storage, usage, analysis, and transfer of data now cover even non-routine cognitive tasks. Additionally, robots are gaining enhanced senses and dexterity which enables them to undertake a broader scope of manual tasks. Their model predicts that most workers in transportation and logistics occupations, as well as the bulk of office and administrative support workers, and labor in production occupations, are highly susceptible to computerization. Furthermore, a substantial share of employment in service occupations are at risk, which is consistent with the rise in the market for service robots. The study also presents evidence of the strong negative relationship between wages and educational attainment with an occupation's probability of computerization. The findings imply that as technologies continue to advance, low-skill workers will reallocate to tasks that are non-susceptible to computerization. They conclude that for workers to survive, they will have to acquire creative and social skills.

Applying the methodology of Frey and Osborne (2013), Chang and Huynh (2015) estimate that over the next decade or two around 56% of all employment in the ASEAN-5 (Cambodia, Indonesia, Philippines, Thailand, Viet Nam) is at high risk of displacement due to technology. The industries with high capacity for automation are hotels and restaurants; wholesale and retail trade; and construction and manufacturing while industries with low automation risk across include education and training, as well as human health and social work. The high-risk occupations in each country are as follows: Cambodia – 447K sewing machine operators; Vietnam – 769K sewing machine operators; Philippines – 2.2m shop and sales persons and demonstrators; Indonesia – 1.7m other office clerks; and Thailand – 634K food service counter attendants. Jobs resistant to computerization involve extensive non-routine, abstract tasks that require judgment, problem-solving, intuition, persuasion, and creativity. In each of the ASEAN-5, women are more likely than men to be employed in an occupation at high risk of automation. Moreover, less educated workers and employees earning lower wages face higher automation risk.

A study by Arntz *et al*. (2016) on job automation estimated the risk of job automation for 21 OECD countries using a task-based approach, which is based on the idea that the automatibility of jobs ultimately depends on the tasks which workers perform for these jobs, and how easily these tasks can be automated. Moreover, the task-based approach recognizes that task structure differs within occupations (i.e. workers are very differently exposed to automation depending on the tasks they perform). This is in contrast with the methodology of Frey and Osborne (2013) which is referred to as occupation-based approach**.**

Using the task-based approach and the Programme for the International Assessment of Adult Competencies (PIACC) database, Arntz *et al*. (2016) found that in the case of the US, 9% of jobs face high risk of automation rather than the 47% estimated by Frey and Osborne (2013) using the occupation-based approach. Susceptibility of job automation is similarly found to be lower in jobs that require high educational attainment or jobs that necessitates cooperating with other people. On the other hand, tasks that are related to exchanging information, sales, physical labor (e.g. use of fingers and hands) are more susceptible to job automation. As the authors note, the study demonstrates the necessity to view technological change as substituting or complementing certain tasks instead of occupations. The danger in ignoring the differences in tasks of comparable jobs is the overestimation of job automatability. Additionally, they found heterogeneities across OECD countries (e.g. the share of automatable jobs in Korea and Austria is 6 % and 12 %, respectively) which reflects general differences in workplace organization, differences in previous investments into automation technologies as well as differences in the education of workers across countries. Furthermore, even if there is an increase in the use of advanced technologies, its impact on employment varies depending on whether countries or workplaces adjust existing jobs to perform tasks that are complementary to new technologies. New technologies are also likely to increase demand for labor. More efficient production using advanced technologies could improve competitiveness of markets and, in turn, increase product demand.

The research on the impact of ICT investments on labor market outcomes highlights the polarization effects as computers replace the middle-skilled, complements the higher skilled and does not affect the low skilled (Auto and Dorn, 2009; Autor, Levy and Murnane (2003), Acemoglu and Autor, 2011). Goos, Manning and Salmons (2014) highlights the role of the offshoring of jobs in developed countries but argues that routine-biased technological change is more important.

US data relating use of industrial robots and employment show a decline of employment to population ratio by as much as -0.34 percentage points and wages by as much as -0.5 percent per one robot per thousand workers (Acemoglu and Restrepo, 2017).

Using a panel data of 17 developed countries from 1993-2007, Graetz and Michaelz (2018) finds that an increase in robot use contributed to 0.36 percentage points increase in annual labor productivity (or 15 percent given a mean growth of 2.4 percent). It also showed no impact on aggregate hours worked. However, there appears to be a reduction in the share of hours worked by low-skilled relative to middle-skilled and high-skilled workers. It is important to point out that, unlike investments in ICT, robots do hurt the relative position of low-skilled workers compared to middle-skilled ones. It was also shows that increased density of robots reduces output prices which benefits both consumers and downstream producers.

ADB (2018) provides detail on the likely effect at different levels of aggregation, namely, within-in firm or within-industry effects, cross-industry effects, and aggregate macroeconomy effects. It also empirically demonstrated how employment structure is changing toward jobs intensive in nonroutine cognitive, social interaction, and ICT tasks in Asia.

In his essay, Autor (2015) argues that the extent of machine substitution for human labor tend to be overstated by ignoring the strong complementarities which increase productivity, raise earnings and augment the demand for labor. Although computers substitute for workers in performing routine, codifiable tasks, they also amplify the comparative advantage of workers in supplying problem-solving skills, adaptability, and creativity. He adds, however, that even if automation does not reduce the quantity of jobs, it may affect the qualities of jobs that are available. The implication for policy in his view is that human capital investment must be at the heart of any long-term strategy for producing skills that are complemented by rather than substituted for by technological change. Also, if human labor is indeed rendered superfluous by automation, then he believes the chief economic problem will be one of distribution, not of scarcity.

4.2 Education and Human Capital

The fourth industrial revolution is characterized by rapidly changing production and consequently labor markets. To be responsive to this rapidly changing environment, the education system that accompanies the fourth industrial revolution should encourage as well as enable flexibility and modularity. Flexibility and modularity is critical to cater to the changing needs, diverse talents, passions and interests of students. The continuing challenge will be in mixing and matching changing needs and interests of the students who will be facing a constantly changing work environment. An appropriate description for building education qualifications of the future are those of LEGO blocks which can used to create different figures using the same building blocks. Necessarily there should be continuous improvement in the learning environment. The system should produce learners that can work alongside machines rather than compete with them (Brown-Martin, 2017). In addition, measurability and transparency in the types and extent of learning outcomes should be promoted to facilitate matching between learners and providers and minimize asymmetric information that hinders the allocation function of education markets from generating desired outcomes (Worldbank, 2003).

Learning is expected to be generated from various environments including formal, non-formal and informal education systems. Given the expected diverse ways of generating competencies and skills, the quality assurance and certification systems should not be limited within systems but should facilitate movement across formal, non-formal and informal education systems.

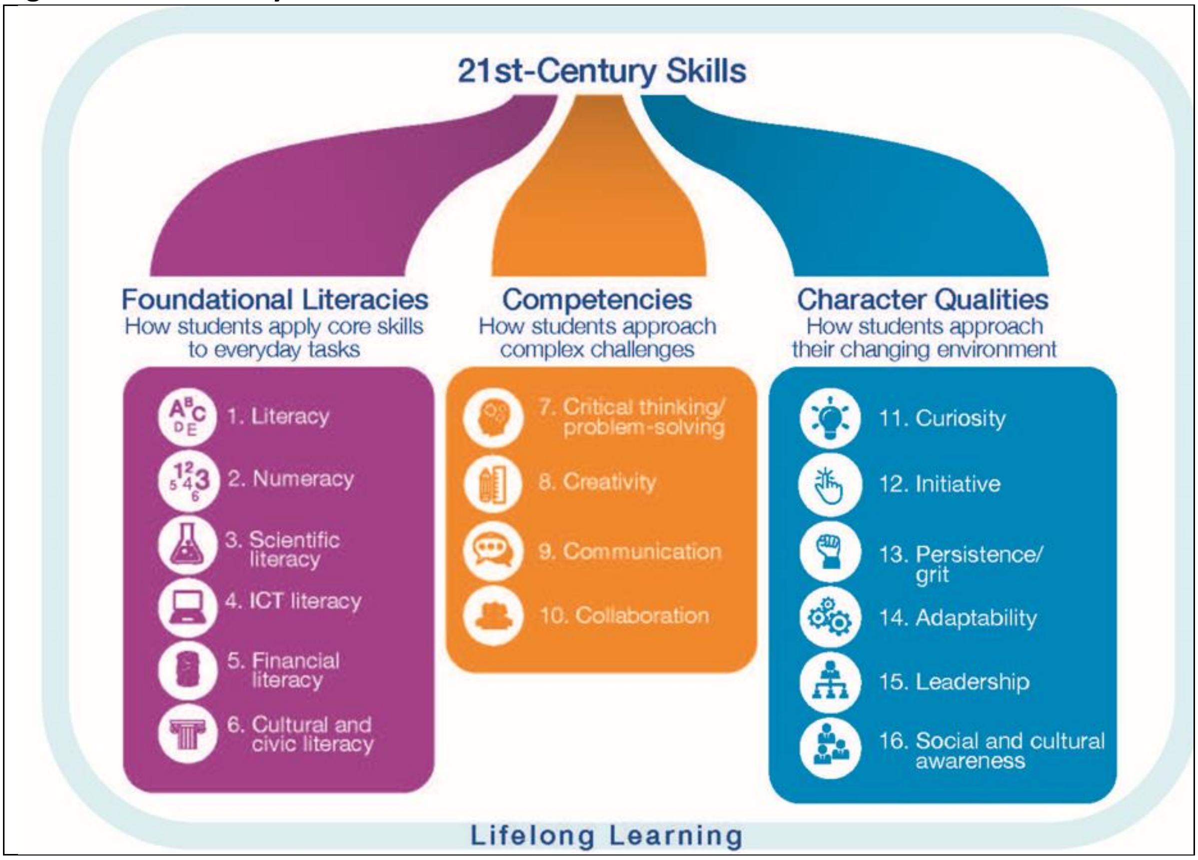
The assessment and certification of knowledge learned outside the classroom will be an importance source of building qualifications. In addition, it should also facilitate movements of learners across different levels (Worldbank, 2003; Brown-Martin, 2017).

Given that production systems are evolving with technologies, a key characteristic of education and human capital development in the future is continuous learning. With rapidly changing technologies, rapidly changing learning and work environments, the only way to keep up is to continuously learn, unlearn, and re-learn. Toffler (1970) defines illiteracy in the 21st century as no longer those who cannot read and write but those “who cannot learn, unlearn and relearn.” A key skill that needs to be developed among learners is “learning how to learn.” The system should produce students that embraces lifelong learning, continuous training and retraining (Brown-Martin, 2017).

The pedagogy should not merely be instructionist or transmitting knowledge but constructivist encouraging reconstruction of knowledge making learning experiential and promote learning by doing (Brown-Martin, 2017; Sawyer, 2008). The objective is to develop higher order and critical thinking skills needed to solve complex and abstract problems. It should embrace technologies in both instruction and assessment. There should be continuous improvement in teaching and learning environments. The teachers should embody this philosophy by being continuous and lifelong learners and collaborative workers themselves (Brown-Martin, 2017; Worldbank, 2003).

WEF (2015) lists and describes 21st century skills and clusters them into three groups, namely, (a) foundational literacies, (b) competencies, and (c) character qualities. This is depicted in **Figure 2**. The foundational literacies are the basis on which students will build the competencies and character qualities. The competencies are what is needed to face complex challenges. Finally, the character qualities are what students need to navigate changing environments.

Figure 2. 21st Century Skills



Source: WEF (2015)

4.3 Implications for Social Protection

The social protection (SP) system of the future must recognize two challenges that the fourth industrial revolution brings, namely, (a) the various forms of existing and emerging work engagements – regular employment, gig economy and independent consulting – as well as the more frequent turnovers, and (b) the threat of a widening inequality. These require finding smart solutions to address current needs and prepare for tomorrow's challenges. These also require finding new better ways of distributing income more equally.

Recognizing these diverse work engagements, SP coverage of the future should be detached from the firm or a job and follow the worker recognizing that workers will move from one work engagement to the next more often than previously observed (Auer, 2006). Addressing the challenges requires SP systems to (a) reexamine eligibility criteria such as minimum earnings thresholds and duration of employment, (b) be flexible with interrupted contribution periods, and (c) enhance portability of benefits across employment engagements (Behrendt and Nguyen, 2018). An important aim should be to ease the transition costs from one work engagement to the next (Ortiz, 2018).

Beyond tweaking existing systems, WEF (2017) calls for a whole-of-life approach to social protection. The system should be able to cover typical life cycle events including education, raising families, work, career gaps, and elderly care. Health and income protection should be tied to the person not specific employment engagement. Worker need help in moving from one work engagement to the next. This calls for increased public spending on active labor market programs (ALMPs) that are proven to lower the cost of movement of workers across work engagements. If income distribution is expected to worsen, then new ways of lessening income inequality needs to be found. This may involve welfare benefits that are not tied to being out of work, such as negative income tax, and wage supplements for those earning below some threshold. There a need to recognize that pension systems are facing diminishing fund values because of low interest rates, increasing life expectancy and regulatory complexity. Finally, we should recognize retirement as a process rather than an event. Toward this end, part-time or self-employment for older workers can be considered integral part of the labor market. This may mean changing existing laws on working ages. This issue is expected to be more pronounced among women compared to men who have career breaks and lower pay and at the same time have longer life expectancies. They will need re-skilling and lifelong learning opportunities.

WB (2018) argues for "progressive universalism" as a guiding principle. Once everyone is covered with basic minimum protection, putting in place more flexible labor market regulations that facilitate work transitions will be the next challenge. Over and above these, it also highlights the importance of human capital investments in increasing opportunities for workers finding better jobs.

In the face of the impact of rapid technological changes on the labor market, some specific proposals have been identified, namely, (a) universal basic income (UBI), (b) wage subsidies, and (c) guaranteed employment (Furman and Seamans, 2018). It is notable that these proposals are not new but have been tried in many situations.

Sharing the gains more broadly is the continuing challenge. If technology leads to less equitable income distribution then ways should be found to redistribute income more equally (UN, 2017).

Stiglitz (2017) warns that the great divide currently existing in society will become even larger. He argues that transitions toward full employment may not happen in time and government intervention is required to prevent "excessive immiseration". Finally, he believes that creating meaning full work with decent pay for as many people as possible is the better solution compared to universal basic income.

Of course, raising pays that are not related to productivity always carries with it unintended consequences. For instance, Lordan and Neumark (2018) finds evidence using CPS data from 1980-2015 that increases in minimum wage resulted in a decline in the share of automatable employment held by low-skilled workers and increases the likelihood that low-skilled workers in automatable jobs become unemployed or slide to employment in worse jobs. They also find that there are larger effects on older workers and lower skilled workers in manufacturing.

The draft World Development Report 2019 (World Bank, 2018) argues for combined labor market flexibility accompanied by strong social security and active labor market programs. It also highlights the importance of human capital investments in increasing opportunities for workers finding better jobs.

4.4 Trade and investment

According to Baldwin (2006, p. 40), globalization can be characterized as an "unbundling of things". The **first unbundling** was brought about by the reduction in transportation costs making it economical to locate factories away from consumers. The **second unbundling** was triggered by the reduction in communication and coordination costs facilitating the relocation of various production stages in different parts of the world. Also called vertical specialization, slicing up the value-added chain, and fragmentation, the second unbundling shaped the configuration of both factories and offices. To illustrate, in the mid-1980s Japanese manufacturers responded to the erosion in the country's comparative advantage in manufacturing by offshoring labor-intensive production stages in other East Asian nations which is reflected in the increase in exports of intermediate goods. In the case of the office, tasks that were previously considered as non-traded became freely traded when telecommunication costs dropped to almost zero (e.g. the offshoring of US call centers to India). Fears of massive job losses from the tradability of tasks particularly in developed countries tend to be exaggerated when transactions costs and economies of scope are taken into consideration. While various tasks could be technically offshorable, Lanz *et al*. (2011) argue that doing so will not always make sense from a business perspective. They add that trade in tasks has a similar impact as trade in other intermediate inputs since it improves productivity and induces shifts within firms and sectors in a similar way as technical change does.

Further reductions in transport and coordination costs, coupled with a considerable fall in the costs of sharing ideas through the transfer of data or information has ushered in the **third unbundling** or the *age of digitally enabled trade* (López González and Jouanjean 2017). Notice the use of the term "enabled". As the authors stress, this new era of hyperconnectivity is not just about digitally delivered trade. It also covers more physical, traditional or Global Value Chain (GVC), trade enabled by growing digital connectivity. In turn, this increases access to foreign markets for firms in a way that would previously have been unimaginable. MGI (2016) also notes that globalization is no longer just the purview of the world's largest multinational corporations as small and medium-sized enterprises (SMEs), entrepreneurs, and ordinary citizens now are at much ease in making cross-border connections. Companies and individuals from developing countries can use digital platforms to overcome constraints in their local markets and tap into global customers, suppliers, financing, and talent. Instead of waiting for the benefits of globalization to trickle down from large firms, "SMEs can become micromultinationals in their own right, and startups can be 'born global'" (*Ibid*., p. 7).

López González and Jouanjean (2017) explain that digitalisation not only changed how we trade but also what we trade. Today, trade includes a larger number of smaller and low-value packages of physical goods, as well as digital services that are crossing borders; goods that are increasingly bundled with services; and new, and previously non-tradable services being traded across borders (e.g., transport services). New technologies and digitalisation are also giving rise to new 'information industries' such as 'big data' analytics, cybersecurity solutions or at-a-distance quantum computing services across borders. What underpins the digital trade environment is the movement of data, or information, across borders. This movement is at the core of new and rapidly growing service supply models such as cloud computing, the IoT and additive manufacturing. The authors add that data flows affect trade less directly by enabling control and coordination along international production networks or by enabling the implementation of trade facilitation measures. Data help organize flows of goods and services; links between contractors and suppliers; enables electronic payments (such as online banking or mobile payments) and facilitates in-plant production which increasingly involves employees working alongside robots (so called, 'cobot'). Thus, data flows are "a means of production, an asset that can themselves be traded, the means through which some services are traded, and the means through which GVCs are organized and some trade facilitation measures implemented" (*Ibid*., p. 10).

As a result of the application of new technologies to production and distribution methods, the FIRe is resulting in selective reshoring, nearshoring and other structural changes to global value chains (WEF 2018, ILO 2016). For example, rapid improvements in automation in developed economies has led to a reversal in offshoring practices. There has been an increase in *reshoring* or the transfer of production activities back to the home country in labor-intensive manufacturing such as garment and footwear, electronics, and automotive, production (Chang and Huynh 2016). Although other factors could be at play, e.g., colocation of research and development (R&D), innovation, and production; rising wages in emerging economies; and threats to intellectual property, one of the reasons for this phenomenon is the growing digitalization of manufacturing (De Backer *et al*., 2016). Emerging digital technologies such as sensors, machine-to-machine communication (M2M), data analytics and artificial intelligence are gradually transforming production, which some argue make labor costs relatively less important for competitive advantage in manufacturing industries. This phenomenon is not only happening in manufacturing however. Previously outsourced services jobs are also returning to developed economies (or perhaps more accurately, the need to offshore some tasks has diminished) partly due to emerging technologies. For example, artificial intelligence can now do most of the routine information-technology and business-process tasks performed by workers in offshore locations (See The Economist Special Report on the Rise of Software Machines, January 19, 2013).

4.5 Sustainable development

Special attention is being given to the role of technology in achieving the Sustainable Development Goals (SDGs) that 193 UN member states, including the Philippines committed to attaining by 2030 (UN 2015). It is recognized that the Fourth Industrial Revolution is fundamentally different from the three previous revolutions in that it fuses the fields of physics, biology, computer science and many more, impacting all disciplines, industries and the world’s economy. New technologies are developing at an exponential pace and it is expected that by 2030, the end year of the SDGs, many new technologies will emerge, while current nascent or immature technologies will reach the commercialization stage which could help achieve some of the SDGs.

Table 6 presents the important technologies that, according to international experts surveyed, will be most crucial until 2030. It also presents specific opportunities and threats related to the identified technologies. Experts also identified the two most crucial technology clusters for the SDGs namely: energy technologies and information, communication, and computer technologies. Other areas with great potential for disrupting many sectors include advances in biotechnology, nanotechnology and neurotechnology.

Table 6. Crucial emerging technologies for the SDGs until 2030*

Technology cluster	Crucial emerging technology for the SDGs until 2030	Opportunities in all SDG areas, including:	Potential threats, including:
Bio-tech	Biotechnology, genomics, and proteomics; gene-editing technologies and custom-designed DNA sequence; genetically modified organisms (GMO); stem cells and human engineering; bio-catalysis; synthetic biology; sustainable agriculture tech;	Food crops, human health, pharmaceuticals, materials, environment, fuels.	Military use; irreversible changes to health and environment.
Digital tech	Big Data technologies; IoT; 5G mobile phones; 3-D printing and manufacturing; Cloud computing platforms; open data	Development, employment, manufacturing,	Unequal benefits, job losses, skills gaps, social impacts, poor

	technology; free and opensource; Massive open online courses; micro-simulation; E-distribution; systems combining radio, mobile phone, satellite, GIS, and remote sensing data; data sharing technologies, including citizen science-enabling technologies; social media technologies; mobile apps to promote public engagement and behavioural change; pre-paid system of electricity use and automatic meter reading; digital monitoring technologies; digital security technology.	agriculture, health, cities, finance, absolute "decoupling", governance, participation, education, citizen science, environmental monitoring, resource efficiency, global data sharing, social networking and collaboration.	people priced out; global value chain disruption; concerns about privacy, freedom and development; data fraud, theft, cyber-attacks
Nano-tech	Nano-imprint lithography; nano technology applications for decentralized water and wastewater treatment, desalination, and solar energy (nanomaterial solar cells); promising organic and inorganic nanomaterials, e.g., graphene, carbon nanotubes, carbon nano-dots and conducting polymers graphene, perovskites, Iron, cobalt, and nickel nanoparticles, and many others;	Energy, water, chemical, electronics, medical and pharmaceutical industries; high efficiencies; resources saving; CO2 mitigation.	Human health (toxicity), environmental impact (nanowaste)
Neuro-tech	Digital automation, including autonomous vehicles (driverless cars and drones), IBM Watson, e-discovery platforms for legal practice, personalization algorithms, artificial intelligence, speech recognition, robotics; smart technologies; cognitive computing; computational models of the human brain; meso-science powered virtual reality.	Health, safety, security (e.g., electricity theft), higher efficiency, resource saving, new types of jobs, manufacturing, education.	Unequal benefits, de-skilling, job losses and polarization, widening technology gaps, military use, conflicts.
Green-tech	**Circular economy**: technologies for remanufacturing, technologies for product lifecycle extension such as re-use and refurbishment, and technologies for recycling; multifunctional infrastructures; technologies for integration of centralized systems and decentralized systems for services provision; CO2 mitigation technologies; low energy and emission technology. **Energy**: modern cookstoves with emissions comparable to those of LPG stove; Deployment of off-grid electricity systems (and perhaps direct current); mini-grids based on intermittent renewables with storage; advances in battery technology; heat pumps for space heating, heat and power storage and electric mobility (in interaction with off-grid electricity; smart grids; natural gas technologies; new ways of electrification; desalination (reverse osmosis); small and medium sized nuclear reactors; biofuel	Environment, climate, biodiversity, sustainable production and consumption, renewable energy, materials and resources; clean air and water; energy, water and food security; development, employment; health; equality.	New inequalities, job losses; concerns about privacy, freedom and development

	supply chains; solar photovoltaic, wind and micro-hydro technologies; salinity gradient power technology; water saving cooling technology; LED lamps; advanced metering. **Transport**: integrated public transport infrastructure, electric vehicles (e-car and e-bike), hydrogen-fueled vehicles and supply infrastructures. **Water**: mobile water treatment technology, waste water technology, advanced metering infrastructure. **Buildings**: sustainable building technology, passive housing. **Agriculture**: Sustainable agriculture technology; Innovations of bio-based products and processing, low input processing and storage technologies; horticulture techniques; irrigation technologies; bio-organometallics which increase the efficiency of biomimetic analogs of nitrogenase. **Other**: Marine Vibroseis, artificial photosynthesis		
Others	Assistive technologies for people with disabilities; alternative social technologies; fabrication laboratories; radical medical innovation; geo-engineering technologies (e.g. for iron fertilization of oceans); new mining/extraction technologies (e.g., shale gas, in oceans, polar, glacier zones); deep sea mining technologies;	Inclusion, development, health, environment, climate change mitigation, resource availability.	Pollution, inequalities, conflict

* as identified through outreach of the GSDR team to scientific communities around the world

Source: Table 3.3 UN (2016, page 53)

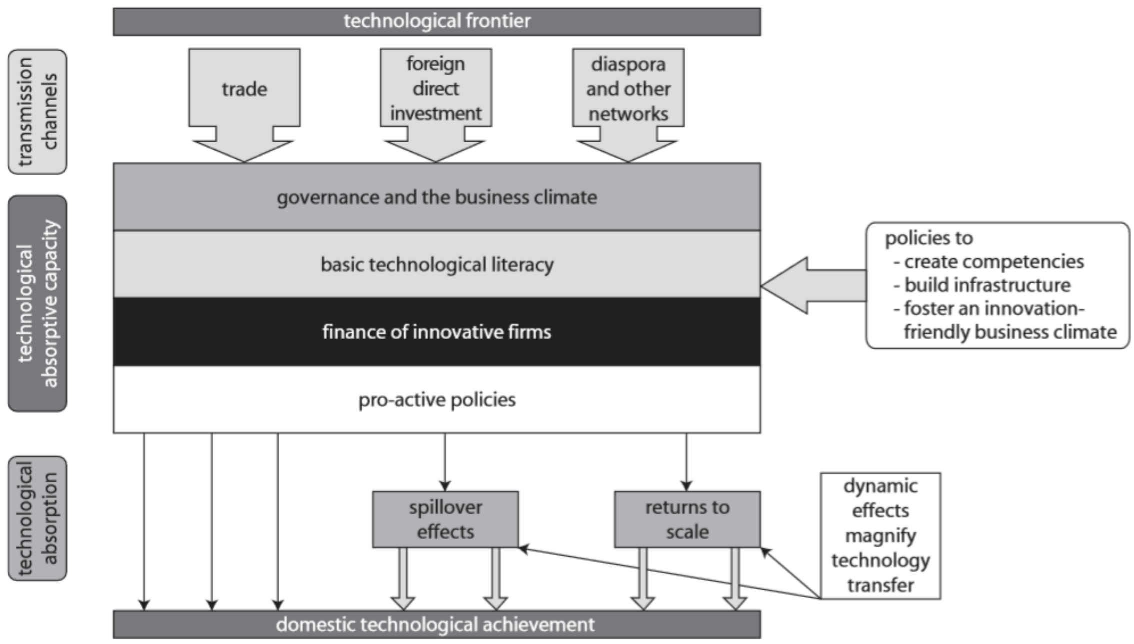
As the Table above shows, there are also potential threats associated with each technology. For example, the use of ICTs has led to security and privacy issues. Moreover, technological change itself is often not neutral as it is often biased toward capital and skilled labor which could have significant distributional effects leading to increased inequality. Technologies therefore could be a double-edged tool that is both a solution and a problem. Experts warn that while these technologies have great potential, they are not without risks and that even the most sustainable technologies have had unintended and known adverse impacts. Thus, we should make efforts to identify and minimize risks, as well as work out strategies to mitigate potential problems or dangers that may arise from the use of new technologies.

5. Drivers and constraints to technology adoption and innovation

How prepared is the Philippines for the Fourth Industrial Revolution? According to WEF's Readiness for the Future of Production Report 2018 (2018), the Philippines is the archetype of a ***legacy country***. This means that the country has a strong production base today, but it is at risk for the future due to weaker performance across drivers of production, which include technology and innovation, human capital, global trade and investment, institutional framework, sustainable resources, and the demand environment. In WEF's assessment, to be FIRe-ready a country must have the ability to capitalize on future production opportunities, mitigate risks and challenges, and be resilient and agile in responding to unknown future shocks. As such, it adds that "the best case for Legacy countries is to improve performance across the Drivers of Production so that they have the right factors in place to transform current production systems and maintain and grow their Structure of Production. The worst case for Legacy countries is to underinvest across key drivers and have this result in a shrinking production base (Ibid, page 13).

For a developing country such as the Philippines, the diffusion of technology depends both on access to foreign technology and on the ability to absorb technology (World Bank 2008). Trade, FDI, international migration, and other networks (including information networks such as the academe and media) act as important transmission channels while factors such as the quality of government policy and institutions, the stock of human capital, R&D efforts, and the financial system, among others, determine a country's absorptive capacity for new technologies. The extent of technology upgrading then depends on the interaction of these factors (**Figure 3**). Thus, no matter how compellingly useful a technology may be, the speed of absorption and adoption depends on a variety of complementary factors which include for example, the availability of a technologically literate workforce; a business climate conducive to investment and the creation and expansion of firms using higher-technology processes; access to capital; management appetite for innovation in both public and private sectors; regulatory frameworks supportive of innovation; as well as public sector institutions that promote the diffusion of critical technologies where private demand or market forces are inadequate (World Bank 2008).

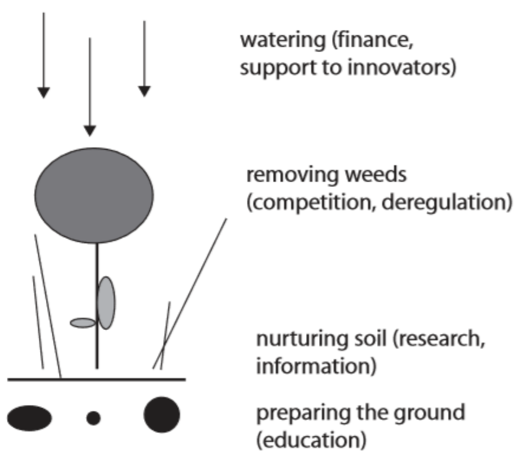
Figure 3. Determinants of technology upgrading in developing countries: Domestic absorptive capacity both conditions and attracts external flows



Source: World Bank (2010, 2008)

The factors identified above influence a country's innovation capabilities (World Bank 2010). Although innovations are largely implemented by entrepreneurs who exploit available knowledge and technology to introduce new products or adopt new processes, success at the firm level requires government support. A simple analogy for the role of government in nurturing innovation is depicted in **Figure 4**. Like a good gardener, the government "prepares the ground" (i.e. building up the human resources needed to drive innovation forward); "fertilizes the soil" (i.e. boosting Research and Development and access to most up-to-date-information); "waters the plant" (i.e., assists innovators by providing financial support and other measures to incentivize innovation); and "removes weeds and pests" (i.e., removes regulatory, institutional, or competitive obstacles to innovation).

Figure 4. Gardening innovation



Source: World Bank (2010)

As suggested in the figure above, various institutions of government are needed for innovation to flourish. With the advent of the Fourth Industrial Revolution, ASEAN Member States have implemented various initiatives (ASEAN Secretariat 2018):

- Indonesia: Launch of 'Making Indonesia 4.0' Roadmap (2017); Indonesia Broadband Plan 2014-2019

- Malaysia: Development of the National Industry 4.0 Policy Framework (2018); Establishment of Industry 4.0 High Level Task Force (2017); Launch of the Centre of Excellence on Industry 4.0 (2017);); Launch of the Digital Free Trade Zone (DFTZ) Initiative and Pilot Project(2017); The Malaysian ICT Strategic Plan 2016-2020 (2016); Launch of the National e-Commerce Strategic Roadmap (2016); 11th Malaysia Plan 2016-2020 (2015); National IoT Roadmap (2015); National Broadband Initiative (2006)

- Singapore: AI.SG Initiative (2017); Research Innovation Enterprise 2020 Plan (2016); Industry Transformation Programme (2016); Intelligent Nation 2015 (2015); National Robotics Program (2015); Smart Nation (2014)

- Thailand: Digital Government 2017-2021 (2017); Thailand 4.0 (2016); National Digital Economy Master Plan (2016-2020); Digital Economy Master Plan (2015)

- Viet Nam: Prime Minister's Directive 16/CT-TTg on Strengthening Access to the Fourth Industrial Revolution (2017); 2020 Broadband Plan (2016)

In this chapter, we present relevant initiatives in the Philippines and examine the policy and regulatory landscape to determine how the government is either driving or impeding innovation and harnessing the FIRe.

5.1 Science and technology policies

With the Philippines participating more and more in a number of regional and global value chains, including some in relatively high-tech sectors, the nation's economy has been evolving, with nearly half (43%) of firms in business and industry engaged in innovation activities, according to results of the 2015 Survey of Innovation Activities (Albert *et al.*, 2017). Since 2011, the Philippine economy has been posting outstanding robust and broad based economic growth consistently having GDP growth rates of over 6% since 2011. This performance puts the country among the fastest growing economies in Asia, a big turnaround from its poor performance in past decades. The country still faces challenges in advancing science, technology and innovation (STI) with the country ranking 73rd out of 127 economies in an overall measure of the innovation climate, according to the 2017 Global Innovation Index (GII) Report (Cornell University, INSEAD, and WIPO, 2017). Out of seven Association of Southeast Asian Nations (ASEAN) member states, the Philippines is 5th in the GII for 2017, behind Singapore (7th), Malaysia (37th), Vietnam (47th), and Thailand (51st), but ahead of Indonesia (87th) and Cambodia (101st). Further examination of the components of the GII show that although the Philippines tops ICT services exports in ASEAN, it has limited human capital in science and technology, rather low levels of research and development (R&D) expenditures and weak linkages of actors in the innovation ecosystem.

In the Philippines, R&D has been focused toward improving productivity in some sectors of the economy, notably in agriculture (for the development of new variety of crops that can withstand undesirable weather conditions), health (to improve nutrition and combat various diseases), and industry (to develop new products and services). In the private sector, R&D activities are typically geared toward directly developing new products, or into applied research in scientific or technological fields that may facilitate future product development.

The 1987 Philippine Constitution articulated the vital role of R&D in economic development and even stipulated the provision of incentives to further encourage participation in R&D activities. Government has provided various incentives, including financial ones to the private sector. It has also formulated and implemented various policies, plans and programs for boosting STI. The extent of support by government in STI, however, has been viewed to be limited by firms (Albert *et al*., 2017). The bulk (60%) of R&D spending across sectors is actually supported by government (Albert *et al*., 2015). While the Philippines has had a slight increase in R&D expenditure to GDP in recent years, this spending is still at less than a fifth of one percent of GDP, which is below the one percent benchmark recommended by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). The country's share of spending in GDP also falls below spending of several ASEAN member states, especially Singapore (2.4 %) and Malaysia (1.3 %), and even including Thailand (0.5 %) and Viet Nam (0.2 %). In the past, spending for R&D has been limited owing to many competing priorities, but the current fiscal space provides opportunities for investments in STI.

Advancing R&D

The Department of Science and Technology (DOST), the national government agency responsible for the coordination of science and technology-related projects in the country and for the formulation of policies and projects in science and technology in support of national development, has been undertaking or supporting a considerable share of R&D activities in the country, even with the rather limited resources available for STI. In the Harmonized National R&D Agenda (HNRDA) 2017-2022 prepared by DOST, thrusts for R&D have been identified across five domains (Guevara, 2017). These domains include (i) Basic Research; (ii) Agriculture Aquatic and Natural Resources; (iii) Health; (iv) Industry, Energy and Emerging Technology; and (v) Disaster Risk Reduction and Climate Change Adaptation. The HNRDA, formulated by DOST's Sectoral Councils in cooperation with R&D stakeholders, is aligned with the country's long-term development plan articulated in *AmBisyon Natin* 2040 (NEDA, 2016; which are built around three pillars: that of enhancing the social fabric (*Malasakit*), reducing inequality (*Pagbabago*) and increasing potential growth (Kaunlaran). Unfortunately, the HNRDA still needs to improve its focus and has yet to articulate how the country will harness AI, IOT and Data Analytics.

As regards basic research, a component of the HRNDA is the National Integrated Basic Research Agenda (NIBRA) which prioritizes six programs for 2017-2022, viz., (a) water security, (b) food and nutrition security, (c) health sufficiency, (d) clean energy, (e) sustainable community and (f) inclusive nation-building. Among these six, the top three priority areas for 2017-2019 are sustainable community, inclusive nation-building, and health sufficiency. The NIBRA, coordinated by the National Research Council of the Philippines (NRCP), is a product of a series of consultations and forums which was initiated in 2016 by the NRCP, a collegial body of researchers, scientists, and experts, functionally attached to the DOST.

Building pool of researchers and innovators

Republic Act No. 7687, also known as the "Science and Technology Scholarship Act of 1994", has been the basis for the provision of scholarships in science, technology, engineering and mathematics (including science and mathematics teaching). Unfortunately, this legislation, together with other efforts to promote STEM have not still yielded a sufficient pool of researchers in the country. While the number of RSEs in the Philippines has increased from 180 in 2009 to 270 in 2013, this is still below the UNESCO benchmark (380) for developing countries and this level is still far from those of several ASEAN member states, such as Singapore (6,618), Malaysia (2,826), and Thailand (974). The low number of researchers in the country reflects the tendency of the educational system to produce graduates outside of STEM, and this condition has hardly changed since one and a half decades ago (Cororaton, 1999), when a high percentage of doctoral degree holders were concentrated in social sciences, and not in the STEM, which tend to be the disciplines where R&D flourishes.

To significantly accelerate STI towards social progress, and global competitiveness, the DOST has formulated its Science for Change Program (S4CP) of DOST which entails massive investments in science and technology education, training, and services. The S4CP also supports indigenous, appropriate, and self-reliant scientific and technological capabilities, and their application to the country's productive systems and national life, by way of its four components: (a) Program Expansion in ten areas[2], (b) New Programs in five areas[3], (c) Grand Plan for S&T Human Resource Development (HRD), and (iv) Accelerated R&D Program for Capacity Building of Research and Development Institutions and Industrial Competitiveness. Legislation is being currently proposed at both the House of Representatives and the Senate to support the S4CP that will involve considerably increasing funds at DOST for innovation, with R&D budgets more or less doubling yearly over the next five-year period to reach PHP672 billion by 2022.

Even if the Philippines spends more on R&D and innovation, this is no guarantee for returns on these investments. When countries are far from the technological frontier, the potential gains from catch-up increases but if the stock of human capital, firm and management capabilities, financial markets are lacking, then returns will be low, and possibly even negative (Cirera and Maloney, 2017). The Philippines should be building massively a pool of research scientists and engineers, learning from experiences of other countries. In the late 1970s to early 1980s, China made massive investments in human capital sending thousands of scholars in science and engineering to the best universities in the US, partly with support of the US government, and these has subsequent reaped returns on these investments.

Under S4CP, DOST essentially proposes a doubling of the current number of scholarship slots across bachelors, masters and doctoral programs. If the proposed number of scholarship slots in STEM under S4CP are followed, the DOST expects the gap in the UNESCO benchmark (of 110 RSEs per million population) to be addressed by 2021 (assuming that all available slots are subscribed and that only 30% of the DOST scholar-graduates go into R&D, as has been roughly the past behavior). At the current number of slots being offered by DOST, the UNESCO benchmark is expected to be met in 2025.

The S4CP's plans for Capacity Building of RDIs and support for Industrial Competitiveness consist of four components (Guevara, 2018). These components are respectively focused on

[2] The ten S4CP areas for program expansion include: (1) health self-sufficiency; (2) renewable energy; (3) nuclear science for energy, health and agriculture; (4) climate and environmental sciences; (5) climate and environmental sciences; (5) food and nutrition; (6) agricultural and aquatic productivity; (7) biotechnology for industry, agriculture, health and environment; (8) technology business incubation; (9) foreign scholarships for STI; (10) promotion of culture of science.

[3] The five S4CP areas for new programs include: (1) human security R&D; (2) strengthening of R&D and S&T services in the regions through infrastructure; (3) space technology and ICT development; (4) S&T for creative industries, tourism industry and service industry; (5) artificial intelligence: from HRD to R&D industry

(1) capacitating higher education institutions (HEIs) in the Regions to undertake quality research through the establishment and maintenance of Niche Centers in the Regions for R&D (NICER) (2) employing experts with strong leadership, management and innovative policy-making proficiencies to take charge of strengthening the research capabilities of the HEIs under the R&D Leadership (RDLead) program; (3) creating synergy between academe (as producer of knowledge and human resources) and the industry (as the translator of R&D technologies to real world applications) under the Collaborative R&D to Leverage Philippine Economy (CRADLE) program for RDIs and Industry; (4) leveling-up the Philippine Industrial Sector through acquisition of strategic and relevant technologies (including equipment) to enhance their technology level and production processes under the Business Innovation through S&T (BIST) Program for Industry. The DOST has recently released operation guidelines for this component of S4CP through its Administrative Order 002, series of 2018.

According to OECD (2011), while it is clear that talent is a key to knowledge creation and value-generating R&D activities, and that higher levels of human capital and skills are a foundation of improved innovation performance, designing appropriate policies and programs is less straightforward. Simple "more-is-better" policy prescriptions may not achieve the desired outcomes given that innovation is a multifaceted and complex undertaking. It will be important that for human resources investments in STEM to match actual industry demands. A better understanding of the linkages between skills and innovation is also needed so that government can develop the appropriate interventions to build capacities for innovation, and to decide the specific distribution of support to be provided to the various STEM disciplines. There has yet to be, for instance, a realization of focusing investments in analytics and data science that can become a knowledge niche for the country, especially as data science programs are only even in their infancy in HEIs.

An assessment of the country's innovation system conducted by the United States Agency for International Development-Science, Technology, Research and Innovation for Development (USAID-STRIDE) Program revealed that the supply of STEM graduates considerably exceeds local demand. Further, many skilled, locally-trained scientists and engineers resort to outmigration. The DOST has been implementing a *Balik* Scientist program since 1975 to encourage Filipino scientists, engineers, and innovators of Filipino descent residing overseas to encourage them to return to the country and work for national development Current priority areas of the program are Agriculture and Food, Biotechnology, Disaster Mitigation and Management, Environment and Natural Resources, Electronics, Energy, Genomics, Health, ICT, Manufacturing, Nanotechnology, and Semiconductors.

In June 2018, Republic Act No. 11035, also known as an "Act Institutionalizing the Balik Scientist Program," was signed into law which gives more incentives to returning Filipino experts, scientists, inventors, and engineers who would share their expertise in the country. Among the benefits, incentives and privileges to be made available for *Balik* scientists include tax and duty exemptions for importation of professional equipment and materials, exemption from licensing or permitting requirements, free medical and accident insurance covering the duration of the engagement awarded by the DOST, reimbursement of expenses for baggage related to scientific projects, and even exemption from renouncing their oath of allegiance to the country where they took the oath. *Balik* scientists can participate in Grants-in-Aid R&D projects of the DOST with an initial lump sum research subsidy of P500,000 for short-term program, P500,000 to P2,000,000 for the medium-term program, and P2,000,000 for the long-term program. The benefits also include special working and non-working visas, a round-trip business class airfare from a foreign country to the Philippines exempt from local travel tax, and DOST-subsidized visa applications.

Technology application, transfer and promotion

Government has recognized the importance of having in place the proper mechanisms for the diffusion of innovation; it has thus worked toward formulating policies on technology application and promotion. Republic Act 10055, also known as the Technology Transfer Act of 2009, defines ownership of technologies, as well as provide means of managing and commercializing the results of government-funded research. Inspired by the 1980 Bayh-Dole Act of 1980, the Technology Transfer Act makes R&D institutions the owner of intellectual property rights (IPR) arising from the outputs of government-funded research. The legislation also allows scientists to create, manage or serve as consultants to companies that can commercially exploit technology arising from their government-funded research. Thus, it provides a financially rewarding environment for research institutions and scientists. To safeguard against possibilities of having innovations not made accessible to the poor, the law provides government the right to take control of technologies or IPRs if national interest is at stake, thus ensuring inclusive innovation.

The DOST has also spearheaded several programmes geared toward technology transfer, including the Small Enterprise Technology and Upgrading Program (SETUP), which has aimed to improve productivity and efficiency of MSMEs by addressing the firms' technological needs and constraints. The program's innovation support system allowed MSMEs to acquire industry-standard equipment, thereby, upgrading their facility and production efficiency. The DOST's regional offices implement SETUP and are primarily responsible for selecting client MSMEs. They also manage the interventions for the clients, including innovation system support, technology needs assessment, technology and equipment acquisition, technical training of the MSME workforce, technical consultancy services, product improvement and development, packaging and labelling, database information systems development, and support in the establishment of product standards, including testing and calibration of equipment (Quimba *et al*., 2017).

Policies have also been articulated by DOST on IP (Administrative Order No. 004, Series of 2015), and IP Management Protocols (Administrative Order No. 004, Series of 2016). Further, DOST has policies regarding Technology Transfer Protocols for its R&D Institutions (Administrative Order No. 009, Series of 2015, 14 Sept 2015), data sharing (Administrative Order No. 003, Series of 2015), as well as Fairness Opinion Board and the issuances of Fairness Opinion Reports (Memorandum Circular No. 003, Series of 2015) for mainstreaming innovation.

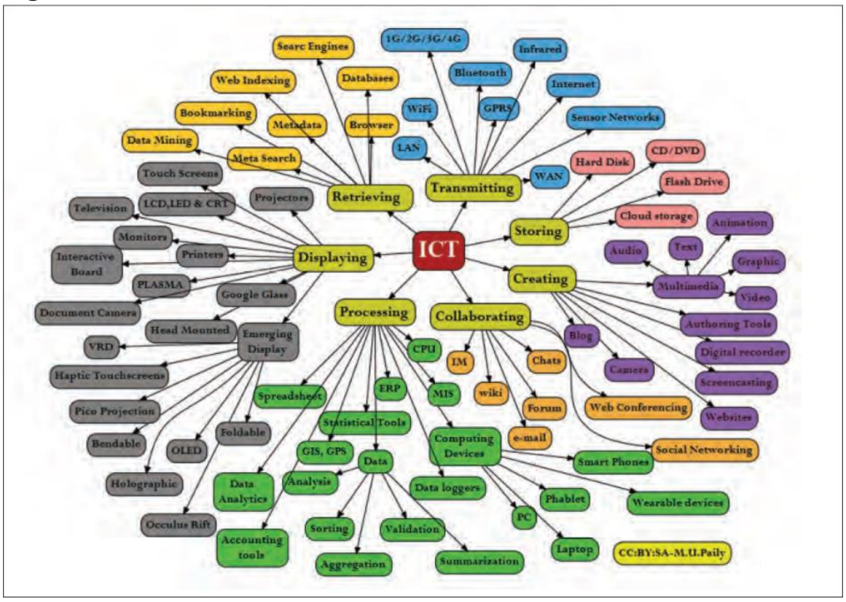
More financial resources will certainly be required for supporting STI but where these resources go will also be important to examine. With FIRe underway, government needs to get a better handle on its role in leveraging STI for further boosting economic activity and productivity.

5.2 Information and communications technology policies

Information and Communications Technology (ICT) have been a game changer in our ways of doing things, especially in doing business and providing services, in connecting with one another, as well as in accessing and sharing information. The deluge of available data is a result of increased access and use of the internet globally, and even in the Philippines where (according to We Are Social) internet penetration rate has reached 63% of the total population in 2018 (equivalent to 67 million internet users). Despite improved internet access in the country over the years, a digital divide persists, and ICT has not been fully maximized. In its 2016 World Development Report, the World Bank (2016) points out that digital dividends have not spread fast across the world and identifies two major reasons for this: a considerable proportion of the population especially in the developing world continue to be left out, and inequalities have concentrated digital dividends in the hands of a few: those with better educated, better connectivity, and more capabilities. However, it is widely believed that the collection, storage, editing, and communication of information in various forms has potentials to accelerate human progress. Thus, UN member states have committed to harnessing the potential of ICT to achieve the 2030 Agenda for Sustainable Development. To develop knowledge societies where everyone has opportunities to learn and engage with others, the Sustainable Development Goals (SDGs) includes specific targets for the use of ICT in education (SDG4), gender equality (SDG5), infrastructure (SDG9) and partnerships and means of implementation (SDG17).

The ICT sector has become an integral part of business processes of various industries through the application of new technologies. These advanced technologies, which includes automation, IoT, and big data analytics, are believed to have ushered in to the innovation-driven industrial revolution more commonly known as the FIRe. Through merging these technologies with existing production methods, the ICT sector has not only optimized business processes but also enabled machines to perform complex tasks even with minimal human interaction and supervision (WFEO 2017). The myriad of things the ICT sector can do is presented in **Figure 5**. New applications and functions of ICT are being discovered by the minute. Given the comparative advantage of the Philippines in ICT-related services and the growth performance of its Information Technology-related services, the FIRe presents a huge opportunity for the country to improve its standing in this time of digitization. Fortunately, the Philippine government has formulated and implemented several policies, plans, and initiatives to prepare and encourage the development of the ICT sector as well as other industries connected to it.

Figure 5. Collection of ICT-related functions



Source: World Federation of Engineering Organizations, 2017.

In 2016, Republic Act No. 10844, also known as the Department of Information and Communication Technology (DICT) Act of 2015, was passed into law. This Republic Act established the DICT to plan, implement, and promote the country's ICT development agenda. The establishment of this new department is very timely in light of the FIRe as digital transformation may disrupt business processes across different sectors of the economy. While previously, a Commission on ICT took charge of ICT development in the country, its elevation into an executive department provides a strong signal of the importance of ICT in nation-building. Further, this strengthens the enabling environment for private investment, for coordinating policy dialogue, as well as for enforcing regulations for ICT development (WEF 2013). Currently, three agencies, viz., the National Telecommunications Commission (NTC) National Privacy Commission Cybercrime Investigation and Coordination Center (CICC), are attached to the DICT for purposes of policy and program coordination.

ICT for Businesses

The establishment of the DICT was a big step forward not only for the growth of ICT-related services and operations but also for ensuring that consumers are well-protected from abusive practices (e.g. overpricing, poor quality of service, personal privacy violations) and anti-competitive behavior of service providers. The DICT could do this by partnering up with other government agencies such as the Philippine Competitive Commission (PCC) for the elimination of anti-competitive practices and the Department of Trade and Industry (DTI) for consumer protection. The role of the DICT in fostering a fair and competitive market environment is more important now than ever given that the presence of digital trade or e-commerce is growing.

In 2008, the DTI, in collaboration with the Department of Health (DOH) and Department of Agriculture (DA) released a joint administrative order which issues the rules and regulations for consumer protection in electronic transactions covered by the E-Commerce Act (Administrative Order No. 01, series of 2008). The DICT's support could increase the effectiveness and enforcement of these rules and regulations through the establishment of an online process for handling merchant and consumer complaints.

More importantly, since data privacy is a key concern when it comes to online or electronic transactions, the DICT must be included as regulatory and enforcement agency in policies related to e-commerce given that ensuring security and privacy of data is the mandate of the department.

In many ways, the Philippine government has continuously shown its support for Micro-, Small-, and Medium-enterprises (MSMEs) through different MSME development strategies and support programs. It also recognizes the growing number and importance of integrating ICT with these enterprises. This is revealed through the Department of Science and Technology's release of The Philippine Roadmap for Digital Startups which aims to boost and encourage the growth of businesses that are ICT-intensive. Common classifications technology start-ups include but are not limited to popular emerging technologies such as rapid prototyping (e.g. 3D printing), sharing economy (e.g. Uber, Airbnb), cryptocurrencies (e.g. Bitcoin), add e-Commerce (e.g. e-bay, Amazon) as well as uncommon ones such as enterprise security (e.g. Palo Alto Networks) (DOST 2015). As may be seen, these startups specialize in providing products and services through the mix of existing business activities with new ICT tools, resulting to reduced costs and greater efficiency.

By reviewing good practices from other countries and the Philippines' current standing in terms of technology startups, the roadmap was able to recommend a set of action plans in order to promote the development the sector. For one, intellectual property rights (IPR) must be further strengthened in order to spur innovation and competition amongst "technopreneurs". Secondly, it is imperative that internet speed is fast and stable in the country since business operations of technology startups rely on connectivity. With the pace of traffic in urban areas, it is likely for many businesses to adopt work-from-home strategies for its work force as a way of coping with traffic conditions, but this assumes better connectivity. Another recommended action plan for fostering development of technology startups is to establish science parks and innovation hubs where strong networks, accessible infrastructure and facilities, and other incentives are available. Support to grassroots activities such as holding innovation competitions and campaigns and promotions could also be an effective marketing tool to entice Filipinos to showcase their talents and skills in ICT-related activities. Fiscal support from the government and encouraging investors to invest in Filipino technology startups is another initiative suggested by the roadmap (DOST 2015). By developing the MSME sector of the country, particularly those with ICT-related business activities, the Philippines would be able to capitalize and further improve its comparative advantages in various ICT-related services.

E-Government for Inclusive Growth

Aside from this, the DICT is also in charge of ensuring universal access to ICT services through expansion of operations in both unserved and underserved areas of the country. In 2017, the DICT launched the **National Broadband Plan** (NBP) which aims to provide "strategic, reliable, cost-efficient, and citizen-centric infostructure (DICT 2017, p. iv)." The DICT plans to achieve this goal through three major strategic actions, specifically enacting policy and regulatory reforms, providing investment on broadband infostructure, and stimulating broadband demand through government support (DICT 2017). The successor to the Philippine Digital Strategy 2011-2015 is still being developed.

With the help of the Department of Science and Technology (DOST), great progress has been made in different parts of the country in terms of provision of free internet access. This initiative is called "Pipol Konek" and is currently available in 13,024 sites, spread nation-wide in 4,568 public schools, 3,173 public parks and plazas, 2,277 government hospitals and regional health units, 677 public libraries, 1,557 national and local government offices, 682 state universities and colleges, and 90 seaports, airports, and train stations. More public sites are expected to be reached by the program, especially now that Republic Act No. 10929 or the Free Public Internet Access Act had been approved by President Duterte in 2016. Pipol Konek program is planned to reach 100,349 by 2026 (DICT 2017). With the numbers of publicly accessible Wi-Fi sites increasing and more government units, businesses, and citizens being connected to the internet, the government is now in a better position to put forward other actions to further spur the development of the ICT sector.

In view of the benefits of integrating ICT with the government, the DICT rolled out its **E-Government Master Plan (EGMP)**, i.e., the blueprint for the merging of ICT for the whole government, in order to create "a digitally empowered and integrated government that provides responsive and transparent online citizen-centered services for a globally competitive nation (DICT 2016, p. 2-3)." This master plan builds on new and existing government ICT-related initiatives; the building blocks needed to achieve the vision of the EGMP are also detailed in the plan, these include: *governance framework, basic and shared infrastructure,* and *core services*. This, together with specific actions, is shown in **Figure 6**. The e-government platform is seen to enhance not only government-to-citizen (G2C) centered services but also government-to-government (G2G) interconnectivity, and government-to-business (G2B) services. If properly utilized, the e-government could also be the key to addressing the longstanding issue of uncoordinated inter-agency actions that lead to overlapping and sometimes conflicting rules and regulations.

Figure 6. Building Blocks of e-Government

e-Government Governance: Organization, Regulation and Policies			
Client-centered Government Government Portal Open Government Open Data		**Networked Government** Groupware Planning/KM/Risk Management	
Citizen (G2C) e-Education e-Health & Welfare e-Justice, Peace and Order	**Business (G2B)** Investment/Tourism e-Logistics e-Agriculture	**Government to Government** Financial Management (GIFMIS, eTAX) Human Resources (HRIS) Asset Management and Procurement	
SHARED SERVICES			
e- Documents	e- Signatures (PKI)	e-Payment	GIS
REGISTRIES			
Citizen	Land	Business	Vehicles
INFRASTRUCTURE			
Internet Access, Data Center, Security			

Source: Department of Information and Communications Technology, 2016.

Successful execution of the EGMP will promote digital inclusion and bring the government closer to Filipinos in terms of easier access to education, health, and other services through public access sites. The basic and shared infrastructure services will be largely provided by the Integrated Government Philippines (iGovPhil) Program. The program is an important component of the e-government plan as it is tasked to provide the hardware and software needs of government units and agencies in order to be part of the e-government system. This includes, among others, Government Cloud (GovCloud) which provides cloud services and links government offices connected to it. Currently, the GovCloud offers an archiving and records management system (i.e. NARMIS, agRIS), data registries, a government online payment system (i.e. PhPay), and a secure government e-mail service (i.e. GovMail). In the near future, the GovCloud is expected to provide Forms Generator which would allow citizens to access and submit various fillable government forms. All these ICT-enabled frontline services will make the government more accessible to citizens and businesses. Once all agencies are integrated under the system, face-to-face interactions would also be minimized, and reduce the chances for graft and corruption (DICT 2017).

The huge volume of government, business, and personal information that will circulate in a fully-functioning e-government system demands an even stronger data security mechanism. The EGMP takes this into account by establishing the Public Key Infrastructure (PKI) which will tighten up security of online data and transactions. The PKI, once integrated with online government services will provide user authentication processes to assure confidentiality of personal documents (DICT 2017).

To promote inclusive growth in a time of digital transformation, the Technology for Education, Employment, Entrepreneurs, and Economic Development (Tech4Ed) project was launched to provide shared facilities and ICT-enabled services through Tech4Ed centers. The

Tech4Ed centers are established in areas where there is little to no access to ICT; it also intends to provide a one-stop shop for government services. Tech4Ed centers allow citizens to electronically process their application for government documents such as SSS and birth certificates. The centers also provide need-based educational and entrepreneurial content to targeted areas. For instance, eAgri provides contents and services on agricultural technologies for farmers and fisher folks. Those who want to gain knowledge and skills in Information Technology needed for employment may also access e-Learning systems provided by the centers. From 2015-2017, 2,121 centers have been established while registered users have risen from 35,824 in 2016 to 91,017 in 2017 (DICT 2017). In view of the FIRe, this DICT program is well-timed as digitization of industries would entail demand for knowledge and skills in ICT.

The data deluge arising from customer databases and transactions among businesses, from internet searches, from mobile phone usage, can provide many public benefits but these data include very precise, geo-location based personal information which can be misused and abused, potentially harming people. Following good practices in other countries, the Philippines passed the Data Privacy Act of 2012 or Republic Act 10173 to "protect the fundamental human right of privacy, of communication while ensuring free flow of information to promote innovation and growth." While the law recognizes the huge contributions of ICT for nation-building it provides for the regulate of the collection, recording, organization, storage, updating or modification, retrieval, consultation, use, consolidation, blocking, erasure or destruction of personal data[4]. The Data Privacy Act ensures that the country complies with international standards set for data protection through the National Privacy Commission (NPC), which it established.

As pointed out in Albert *et al.* (2016), privacy is a bedrock of human dignity, and one of the fundamental human rights recognized in the UN Declaration of Human Rights. Further, privacy has technological, ethical and legal issues. Privacy can be thought of in terms of data protection, and thus interpreted in terms of the management of personal information, i.e., the ability of individuals to determine who holds information about them and how is that information used. The country's Data Privacy Act grants specific rights to data subjects or persons whose personal or sensitive personal information are subject to processing, as contemplated by law. The Act imposes strict restrictions on the use of such information by third parties to ensure individual's privacy.

Companies with at least 250 employees and all government agencies that maintain databases of clients are required to register with the National Privacy Commission and held accountable not only for what they do with data on clients — but also how they protect that data from third parties. The NPC deems a company or government agency compliant with the Data Privacy

[4] Personal information, in the Data Privacy Act, is defined as "any information whether recorded in a material form or not, from which the identity of an individual is apparent or can be reasonably and directly ascertained by the entity holding the information, or when put together with other information would directly and certainly identify an individual." These include a person's residence, place of birth, the amount of salary, etc. The law further classifies personal information as sensitive personal information when they are: "1) about an individual's race, ethnic origin, marital status, age, color, and religious, philosophical or political affiliations; 2) about an individual's health, education, genetic or sexual life of a person, or to any proceeding for any offense committed or alleged to have been committed by such person, the disposal of such proceedings, or the sentence of any court in such proceedings; 3) issued by government agencies peculiar to an individual which includes, but not limited to, social security numbers, previous or cm-rent health records, licenses or its denials, suspension or revocation, and tax returns; and 4) specifically established by an executive order or an act of Congress to be kept classified."

Act if it has undertaken the following: (1) appointed a Data Protection Officer; (2) conducted a privacy impact assessment; (3) established a privacy knowledge management program (4) implemented a privacy and data protection policy; (5) exercised a breach reporting procedure.

Aside from protecting personal privacy, the government also protects internet users from harm through the **National Cybersecurity Plan** (NCSP) 2022 (DICT, 2017b). Security breaches in the "Comeleak incident" (see Albert, *et al*., 2016) and in a major bank have recently shown the extent of cybersecurity vulnerabilities.

The NCSP 2022 is the country's roadmap for key ICT stakeholders to take part in policing and safeguarding cyberspace against cyber threats. It maps the landscape of cyber threats especially to critical "infostructure", public and military networks, including government and emergency services, and supply chains. It envisions strategic cyber resiliency measures to enhance the country's ability to respond to cyber threats and promotes a whole-of-society approach to cybersecurity problems (which includes effective coordination with law enforcement agencies).

The NCSP envisions an incident reporting and response system through the establishment of layers of computer emergency response teams (CERTs) at the organizational, sectoral, and national levels. Capability building of the CERTs across government agencies is expected to take time. While government agencies are still in the CERT building stage, they will need to build awareness and understanding of what to do in the event of a cyberattack, who to report to, and how to deal with the impact. In the event of an actual cyberattack or cyber incidents, including prolonged cyberattacks, the NCSP calls for carrying out emergency protocols (including a Computer Emergency Strategic Communications Plan) as part of the operational environment of government agencies, all the way down to local government units.

However, while government agencies can be asked to report cybersecurity incidents and breaches, private sector firms are currently not mandated to report cybersecurity incidents except for breaches having to do with privacy (as provided in the Data Privacy Act). Incidents in the private sector could go unreported, due to fears of litigation by affected organizations or damages to their reputation. The DICT will need to promote voluntary cooperation of the private sector or alternatively legislate reporting of such breaches, as in the Data Privacy Act.

When the victim of a cybersecurity incident pursues legal action against the perpetrator, this becomes a law enforcement issue as the incident transforms into a cybercrime. Currently, anti-cybercrime units with the Philippine National Police and the National Bureau of investigation have been engaged in capacity development to conduct cybercrime investigations and digital forensics, but the extent to which they have been successful may be hampered by the fast-changing technological developments.

Although initiatives and plans for the future of the Philippine ICT sector are already in place, there are a number of roadblocks and bottlenecks that impede the development of the sector and most of these take root from decades-old laws and regulation that needs to be updated. The National Broadband Plan (2017), for instance, lists down priority policy and regulatory reforms that would promote the development in the telecommunications and the ICT sector. Included among these are the amendment of the penal provision of the Commonwealth Act No. 146 (Public Service Act) and exemption of telecommunications and value-added services from the sectors covered by the definition of "public utilities" in this law. This would result to the relaxation of foreign ownership restriction for the mentioned sectors and removal of the requirement to secure a franchise from the Congress before a service provider could establish a network (DICT 2017). Updating old laws such as this would result in the ICT sector and other ICT-enabled industries developing even amidst the entry and application of disruptive technologies brought about by the FIRe. As may be gleaned from the existing Philippine government ICT policies, plans, and initiatives above, the development and preparation of the ICT sector for the FIRe also means preparing and developing other industries as the revolution entails an increasing role of ICT in other fields and sectors.

Regulation of ICT

The poor regulatory environment for ICT in the Philippines is a major impediment to creating a digitally connected and inclusive economy. Using a scoring system developed by the International Telecommunications Union (ITU) called the ICT Regulatory Tracker, Ortiz *et al*. (2017) found that the quality of the Philippine telecommunication/ICT regulatory environment is significantly below what is considered international best practice. The Tracker is based on four major regulatory indicators, namely: 1) regulatory authority; 2) regulatory mandate; 3) regulatory regime; and 4) competition framework. Based on inputs from the National Telecommunications Commission (NTC) as well as the PCC and a review of existing regulations, Ortiz *et al*. (2017) scored the Philippines 52.5 points out of the possible 100 points, which is the second lowest in a group of seven ASEAN members. The Philippines is weakest in terms of the regulatory regime (e.g. quality of service is not monitored, interconnection prices are not made public) but strong, based on a review of the formal environment, in terms of the competition framework. This can be attributed to major reforms earlier undertaken, specifically, the creation of the Philippine Competition Commission through the approval of Republic Act No. 10667 in 2015.

While there are many gaps that need to be addressed, the study found that the regulatory regime (or specific rules) and the competition framework will only work if an effective regulatory authority with the right mandate is in place. Thus, they recommend the strengthening of the NTC as a matter of priority.

5.3 Industrial and related policies

Although Industry 4.0 is synonymous with the smart factory, in reality it will transform not only the manufacturing industry but all sectors such as agriculture, mining, construction, tourism, finance, transport, healthcare, and education. These new technologies will be instrumental in the transformation of all industries and in pursuing strategies identified in the Philippine Development Plan 2017-2022 (NEDA 2017), which include developing high-value added, competitive, and sustainable sectors (Chapter 9) and in encouraging innovation in the country's export-oriented industries through investments to catch up with higher levels of technology, meet international quality standards and product specifications, boost productivity, and facilitate the production of higher value-added products (Chapter 15).

In line with the Plan, a new industrial policy is being pursued where the private sector takes the lead while the government's main task is to resolve market issues and execute the needed policy reforms to create a fairer market environment for both domestic and international market players (Aldaba 2014). The government acts as an enabler and facilitator in crafting and implementing policies and regulations that will provide an environment conducive to growth. Additionally, government plays an important role in terms of coordinating policies and necessary support measures. Close coordination among government agencies and effective policy implementation are seen as the most crucial factors for industry development (DTI 2017).

Development of roadmaps and strategies under the new industrial policy

As discussed in Rosellon and Medalla (2017), the new approach to industrial policy evolved from having a sectoral focus (Manufacturing Resurgence Program) to the more comprehensive approach emphasizing stronger linkages with Services and Agriculture (the Comprehensive National Industrial Strategy) and most recently, integrating innovation and inclusiveness in the process (Inclusive Innovative Industrial Strategy).

Recognizing the pressing need for a new industrial policy, the Philippine government through the Department of Trade and Industry (DTI), collaborated with the private sector to undertake a sectoral roadmap project. Called the Manufacturing Industry Roadmap (MIR), the MIR uses the cluster-based development approach to take into account the varying resources, needs, and issues of regions and industries. The roadmaps formulated from the project were used as inputs to the **Manufacturing Resurgence Program (MRP)**, which aims to rebuild the existing capacity of industries, strengthen new ones and maintain the competitiveness of industries with comparative advantage to enhance the competitiveness of domestic manufacturing industries so they can be integrated in higher value-added, ASEAN-based production networks and global value chains (Aldaba 2015).

Building on the industry roadmaps, the DTI formulated the **Comprehensive National Industrial Strategy (CNIS)** with the general objective of creating higher quality jobs and attaining sustainable and inclusive growth by upgrading manufacturing and integrating it with the agriculture and services sectors. The idea was to encourage industries to shift to high value-added activities, link SMEs and large enterprises, foster an innovation-centered ecosystem, invest in upstream industries, promote upgrading and position Philippine industries into the regional production networks and global value chains. This employment and entrepreneurship strategy focused on five priority industries, namely: (1) manufacturing; (2) agribusiness; (3) IT-BPM, particularly Knowledge Process Outsourcing; (4) tourism; and (5) infrastructure and logistics. The CNIS sought to address supply chain gaps, capacity building via human resource development, SME development, innovation and R&D, and deepening the participation of domestic markets in global value chains. The overall goal was to produce more and higher quality jobs and attain sustainable and inclusive growth, through a new industrial policy, bolder trade policy, intense investment promotion, skills training and HRD, enhance innovation and R&D, and a modern policy for micro, small, and medium-sized enterprises (MSMEs).

In 2017, the government upgraded the CNIS framework and released the **Inclusive, Innovation-led Industrial Strategy (i^3S, "i-cube")**. While the upgraded industrial strategy has a similar underlying framework as the CNIS anchored on competition, innovation, productivity, the latest strategy puts greater emphasis on innovation. Recognizing that Industry 4.0 poses new challenges and opportunities, building an inclusive innovation ecosystem is listed as an additional goal.

The i^3S is based on five major pillars: (1) Building new industries, clusters, and agglomeration; (2) Capacity-building and human resource development; (3) MSME growth and development; (4) Innovation and entrepreneurship; and (5) Ease of doing business and investment environment. The government recognizes the importance of developing human capital with skills in science, technology, engineering, mathematics, and employing innovation-led technologies to improve productivity. Entrepreneurship is added the framework as it is also envisioned that the innovation ecosystem will produce a breed of Filipino entrepreneurs that will espouse ‘idea-based, demand-oriented, and research-driven innovation’ (DTI 2017). Furthermore, priority sectors for industry development were increased and now includes the following:

- Auto and auto parts: auto electronics, CARS Program, Public Utility Vehicle Modernization
- Electronic manufacturing services: auto electronics, medical devices, telecommunications equipment, power storage, civil aviation/aerospace);
- Semiconductor manufacturing service: integrated circuit (IC) design
- Aerospace parts and Aircraft Maintenance, Repair, & Overhaul
- Chemicals: petrochemicals, acyclic alcohols & derivatives, metallic salts & peroxy salts of inorganic acids, cyclic hydrocarbons, oleo chemicals
- Shipbuilding & Ship-repair: roll-on roll-off (RORO) as well as small- and medium-sized vessels
- Furniture, garments, creative industries manufacturing and design
- Iron and Steel, tool and die
- Agribusiness: rubber, coconut, mangoes, coffee, banana, and other high value crops
- Construction: roads, railways, bridges, ports, airports, & low-cost housing
- IT-BPM and E-Commerce: higher earning more complex non-voice services BPO, Knowledge Process Outsourcing in medical, financial, and legal services; game development; engineering services outsourcing (ESO), software development, shared services
- Transport and Logistics: land, air, & water transport, warehousing, support facilities for transport; and
- Tourism

Stronger linkages between the innovation ecosystem and the entrepreneurship ecosystem will be established as part of the **i³S**. In line with this, the DTI is collaborating with the Department of Science and Technology (DOST) to strengthen government-academe-industry networks and revive the Filipinnovation Council. The DTI plans to expand its existing Memorandum of Understanding (MOU) with DOST to involve other key agencies such as Department of Finance (DOF) for fiscal support, Department of Interior and Local Government to tap local government units, DICT for the needed physical innovation structure, NEDA for the monitoring and evaluation of innovation policy implementation, Department of Agriculture for the provision of commercialization support and market-oriented research grants, and Commission on Higher Education and Technical Education and Skills Development Authority for human resource development. The industries that will be prioritized include: electronics, auto, aerospace, chemicals, IT-BPM, and agribusiness (Aldaba 2018).

Incentive schemes

The government lays out its investment priorities through the Investment Priority Plan (IPP) of the Board of Investments (BOI). Compared to the previous IPP in 2014, the BOI Investment Priorities Plan 2017-2019 puts more focus on MSME development and innovation-driven activities. This is apparent with the inclusion of creative industry, knowledge-based services, inclusive business (IB) models, commercialization of new and emerging technologies, and many others, among the incentivized activities of the IPP. The presence of these incentives would allow the government to reach a broader segment of the population, and thus, help address issues on inequality of growth and the jobs gap.

In March 2018, the DOF also submitted its proposal for the second package of the Comprehensive Tax Reform Program (CTRP). The second package is focused on reforming the corporate income tax and modernizing fiscal incentives. Supplementary to the new industrial policy, part of the proposal is incentivizing technology-driven activities to promote innovation. Specifically, included under the performance-based conditions to avail tax incentives are the "use of modern technology" and "R&D expenditure" (DOF 2018). The proposal also includes complementary reform such as strengthening investment assistance and facilitation mandate of the BOI and Investment Promotion Agencies.

Servicification of manufacturing

The new industrial strategy does not simply focus on manufacturing per se but on the servicification of manufacturing, which connects manufacturing with service activities such as design, R&D, engineering, and after-sales services. Servicification is the process where goods-producing companies increasingly buy, produce, sell, and export services (Kommerskollegium 2012, 2013). With the advent of new technologies (e.g. IOT, 3D printing, big data, AI), the role of services in manufacturing value chains is likely to intensify.

As discussed in Serafica (2016), the country's manufacturing sector needs to ramp up servicification to be competitive and move up higher value-added activities as envisioned in their roadmaps. Based on trade in value added data, the share of services embodied in Philippine manufacturing exports is among the lowest in the region. Moreover, value added from 'ICT services' and 'Other business services' is low compared to patterns observed in other countries while the share of 'Wholesale and Retail services' is significantly high. Overall, the services intensity of Philippine manufacturing exports, declined through the years such that by 2011, it was the lowest compared to other countries in the same income group. Moreover, the inter-sectoral linkage between goods and services in Philippine exports was the weakest. Although the figures represent outsourced services, the limited splintering of services from goods reflect the slow pace of specialization that seem to have characterized Philippine manufacturing in the past.

To sustain manufacturing resurgence and promote further innovation, reliable, good quality, and affordable services are essential. Reforms needed include ensuring more effective competition and opening up key service industries to greater foreign participation as discussed below.

Complementary measures

In addition to the new industrial policy as embodied in the i^3S, there are other critical policy measures needed to encourage innovation and improve competitiveness. Key complementary measures are presented below.

Ease of doing business

The World Bank's annual *Doing Business* report provides an assessment of the regulatory environment affecting business entities (i.e. single proprietorship, partnership, and corporation) across 190 economies. It measures various aspects of business regulation including starting a business, dealing with permits, access to energy source, and access to credit, among others. In the most recent *Doing Business 2018* (2018) report, the Philippines ranking slipped from 99th in 2017 to 113th behind Vietnam and Indonesia at 68th and 72nd, respectively (World Bank 2018a). Among the indicators, the Philippines was ranked lowest in "starting a business" which covers paid-in minimum capital requirement, number of procedures, time and cost for a small- to medium-sized limited liability company to start and operate in the country's largest business city (i.e. Quezon City). Based on the report, the Philippines is ranked 173rd in "starting a business" as business procedures and the time it takes to complete these in the country totaled 16 procedures and 28 days, respectively. It must be noted that secondary registrations are not yet taken into account in this assessment. This is a lot higher than the averages of East Asia and the Pacific which are 7 procedures and 22.7 days (WB 2018b). In a similar survey of Philippine startups conducted by the PricewaterhouseCoopers (PwC) Philippines (2017), CEO and Founder respondents identified "ease of doing business and tax incentives" as the top areas that need improvement to help address issues of startups. These assessments show that burdensome regulatory procedures are impeding the entry and development of both domestic and foreign businesses in the country.

A study by Barcenas et al. (2017) provides an extensive review of the regulatory measures affecting services trade and investment in the Philippines, laying out the horizontal laws and regulations that fall under the following categories: Entry, Legal and Regulatory Compliance, and Exit Requirements for business entities. These are listed in **Box 11**.

Box 11. Exit and entry requirements for businesses

- Starting and operating a business in the Philippines remains burdensome for entrepreneurs due to the unnecessarily long and numerous acquisition of registration requirements
    - Common requirements include registration in local government units (LGUs), Bureau of Internal Revenue (BIR), Department of Trade and Industry (DTI) and Securities and Exchange Commission (SEC)
- With respect to businesses operating in regulated industries, an endorsement from the responsible regulatory authority is also needed
- In certain industries such as Telecommunications, a legislative franchise is also required before an entity can go into business
- The requirement to have at least five (5) incorporators who are natural persons to establish a corporation poses difficulties to new entrants, laid out as follows:
    - single investors who face the burden of looking for other four (4) shareholders to meet the requirement even if unnecessary

- exposure of foreign investors to untrustworthy nominee shareholders who have easy access to confidential business matters
    - discourages individual entrepreneurs from establishing corporations, which will allow them to enter the formal sector and gain better access to financing.
- Teleconferencing, either through video, computer, or audio conferencing, for shareholder's meetings do not meet the requirement for meeting in the location of the principal office of the corporation as stated in Section 51 of the Corporation Code
- Constitutional and statutory limitations on foreign participation in certain industries
- The Foreign Investments Act (FIA) allows 100% foreign equity ownership for non-nationalized industries, provided that it meets the export requirement (exporting at least 60% of their output or products purchased domestically) for export enterprises and minimum capitalization for domestic enterprises
- Foreign corporations are allowed to do business in the Philippines by securing a license to operate through the SEC as a branch office, representative office, regional or area headquarters (RHQ), or regional operating headquarters (ROHQ); each form of business requires a different set of requirements
- Exiting requirements also vary depending on the form and industry of the exiting business; these include cancelling registrations from and issuing notices to DTI, SEC, BIR, LGUs, and respective regulatory authority

Source: Barcenas *et al*. (2017)

Navigating these rules and requirements for business registrations and operations is even more challenging to foreign investors wishing to invest in the country. These regulations could negatively affect the investor's decision to invest or do business in the Philippines. The Philippine government aims to address these issues through several initiatives such as the issuance of Memorandum Circular No. 44 which orders all government agencies and GOCCs performing frontline services to respond within fifteen days to public requests and concerns. This directive reiterates Republic Act No. 6713 which also obliges all public officials and employees to process documents and respond to letters and requests expeditiously.

Complementary to this, Republic Act No. 11032 or the "Ease of Doing Business and Efficient Government Service Delivery Act of 2018," which will amend Republic Act 9485 or the "Anti-Red Tape Act of 2007," has been recently signed by President Rodrigo Duterte. The primary objectives of this legislation are to simplify and expedite the processing and delivery of government services – both business and nonbusiness related - in all government offices, as well as promote transparency. The former is expected to be achieved through the creation of a "One-Stop Business Shop" which would serve as the single common location to do such transactions, while the latter is through the "zero-contact policy" which does not allow government officers or employees to have contact with the requesting party except during preliminary assessment or under strictly necessary circumstances. Procedures for the issuance of common regulatory requirements such as business permits, local taxes, zoning and building clearances, and fire safety clearance will be streamlined.

A move towards utilizing technology for increased efficiency, convenience, and productivity is another feature of this law. For instance, the business permit and licensing system of government agencies and LGUs will be automated. The DICT is also tasked to establish a central business portal and the Philippine Business Databank through developing an interconnectivity infrastructure that would link concerned government office's database to one system, thus allowing each of them to access data and information on business entities. To attain the new law's objectives, the Anti-Red Tape Authority will be created. It will be in charge of heading the implementation of the national policy on anti-red tape and EODB, as well as monitor and evaluate the compliance of government agencies and offices to such policies. This new law is aligned with the current administration's 0+10-point socioeconomic agenda which includes increasing competitiveness and the ease of doing business.

The government also aims to facilitate trade and improve customs procedures by fully operationalizing the National Single Window (NSW), and linking it to the ASEAN Single Window (ASW). As discussed in Barcenas et al. (2017), one of the issues in the logistics sector of the Philippines is the need to submit physical copies manifests for imports and export declarations. The NSW and ASW is expected to address this by enabling the electronic exchange of documents, thus cutting down on customs processing time, speeding up cargo clearance, and reducing the cost of doing business (PortCalls Asia 2017).

In light of the FIRe, regulatory reforms to improve the business environment are needed as the roles and contributions of the private sector, most especially smaller forms of businesses (MSMEs), have become more transformative than ever. For instance, widely used technology products and services such as online ride-haling (e.g. Uber, Grab), online marketplaces (e.g. Airbnb, Amazon, Lazada), travel technology (e.g. Traveloka), among others, were not created by large multinational corporations but by startups which have achieved "unicorn[5]" status. These applications of disruptive technologies are constantly revolutionizing how people travel, work, communicate and live. The recently approved Senate Bill 1532 or the Innovative Startup Act aims to incubate and support enterprises that create such products and services. These are startups "whose core business function involves an innovative product, process, or business model" (SB 1532, p. 3) that bring unique and better solutions to problems in transportation, healthcare, and other industries. Once passed into law, support in the form of research and development grants, exemption from certain fees and charges, exemption from the alien employment permit, and access to various incentives will be provided to qualifying innovative startups. Complementing this with the necessary regulatory reforms will develop startups that offer innovative solutions, and hopefully pave the way for future Philippine "unicorns".

Establishing the National Quality Infrastructure

Standards and metrology are key components of the specialized service infrastructure needed by businesses to innovate and export (World Bank 2010). Currently, a number of different government agencies are responsible for setting standards, testing and certifying and there is a need to coordinate activities involving metrology, standardization, testing, and accreditation and certification under an integrated framework that will promote our ability to meet international standards for export readiness.

One of the legislative priorities identified in the PDP 2017-2022 is the establishment of the National Quality Infrastructure (NQI). The critical role of the NQI in achieving industry competitiveness was first recognized in the Philippine Development Plan 2011 – 2016 Midterm Update which came out in 2014. The NQI will be key to improving access to technology and innovation as it will harmonize the country's strategies on metrology, standards, and accreditation, where accreditation includes certification, inspection, and testing (NEDA 2017). Moreover, a unified NQI system will especially benefit MSMEs and cooperatives as it will enhance access to quality testing, calibration, and quality assurance services needed to produce safe and quality goods for the local and international markets

[5] Private companies valued at USD 1 billion.

(NEDA 2018). A bill establishing the NQI was filed in the Senate in 2016 (Senate Bill No. 707 or the National Quality Infrastructure Act). To date, its first reading was held in August 2016 but the schedule for the second reading in Congress is pending.

Fostering competition

Without the pursuit of competitive advantage over their rivals, firms will not be driven to create new goods and services (product innovation) or to employ new ways to produce and compete in the market (through process, marketing, and organizational innovation).

Republic Act (RA) No. 10667 or the Philippine Competition Act (PCA) of 2015 was a significant step in ensuring that competitive advantage is sustained through constant improvement and upgrading rather than through market power and the abuse of this market power through anti-competitive practices. With the law and the Philippine Competition Commission in place, the focus this year according to the Socio-Economic Report (NEDA 2018) is the formulation of a National Competition Policy (NCP). It aims to complement the PCA and provide a holistic and comprehensive framework for competition. This is to ensure that the public and the private sectors are working closely to boost market competition by addressing issues on competitive neutrality, anti-competitive behaviors, and unnecessary regulatory burdens. In addition, the Implementation Plan/Strategy of the NCP will also be crafted.

Removing barriers to trade and investment

An open trading environment promotes competition and innovation. Thus, the Philippine Develop Plan 2017-2022 underscores the need to liberalize trade and investment by relaxing restrictions on foreign investment and simplifying complex business procedures to avoid unnecessary and burdensome steps in doing business.

According to the OECD (2016), foreign direct investment (FDI) restrictions in the Philippines are high by both regional and global standards. In fact, based on the most recent OECD FDI Regulatory Restrictiveness Index, the Philippines is the most restrictive economy among the 62 OECD and non-OECD countries included in the database. In addition to equity limitations, there are other restriction which include for example, the reciprocity requirement and restrictions on land ownership. Compared to other countries, the regulatory environment for FDI in the Philippines has not changed much in the last two decades. For example, in 1997 Vietnam and China were more restrictive than the Philippines which was more or less at the same level as India, Indonesia, and Malaysia. By 2016 however, all these countries had overtaken the Philippines in opening up their economies to foreign direct investment.

On November 21, 2017, the President issued Memorandum Order (MO) No. 16, s. 2017 directing the NEDA Board and its member agencies to exert utmost efforts to lift or ease restrictions on certain investment areas or activities with limited foreign participation. Amendments to existing laws which restrict foreign investments are underway in Congress. For instance, HB 5828 which seeks to amend the Public Service Act was approved by the House of Representatives on its third reading on September 2017. It redefines ‘public utility’ and its coverage thereby effectively removing Constitutional restrictions on a number of key sectors such as telecommunications and transport services. The counterpart measure is being discussed in the Senate. Lowering capital requirements for foreign enterprises to participate in retail trade is also currently being discussed in the Lower House of Congress.

There are other limitations to trade and investment in important areas such as education, broadcasting, and the practice of professions, even for former Filipino citizens. As discussed at the beginning of this chapter, trade, FDI, the diaspora, and various international linkages are critical transmission channels for technology transfer including tacit knowledge. Thus, removing the various restrictions is necessary for technology upgrading. Apart from removing foreign equity limitations, other regulatory measures which discourage trade and investments (e.g. local presence requirements, performance requirements, requirement to divest) should also be addressed. Finally, facilitation must accompany liberalization. As an important step in facilitating FDI, Reyes (2018) stressed the need to improve the information content of the Philippine foreign investment negative list (FINL) to better capture the full range of restrictions faced by foreign investors. However, since this will require amending the Foreign Investment Act, she recommends that the executive department in the meantime urge its departments and agencies to come up with a transparency list to supplement and address the deficiencies of the FINL.

Regulatory responses to new technologies, products, and business models

Increased efficiency, productivity, and user convenience are just some of the benefits and reasons why disruptive technologies are being adopted globally. The use of such technologies, however, have also been revolutionizing the landscape of certain sectors, requiring a more thoughtful and adaptive regulatory approach to encourage the introduction of new technologies, products and business models. Below are some recent examples of the regulatory challenges in the Philippines.

Box 12 features the case of ride-hailing services.

Box 12. Regulating Transport Network Companies

The entry of application-based ride-hailing services such as Grab and Uber caused regulatory challenges for the Department of Transportation (DOTr) and its attached agency, the Land Transportation Franchising and Regulatory Board (LTFRB) when it disrupted the taxi industry. These services were eventually classified officially as Transportation Network Companies (TNCs) by the DOTr through Department Order No. 2015-011, making the Philippines the first country to regulate application-based ride-hailing services. The TNCs, which partners with Transportation Network Vehicle Services (TNVS) or registered drivers, partially displaced the taxi industry by offering higher quality transportation services. Specifically, it provided transparency in pricing, the luxury of riding a modern vehicle, and the convenience of being fetched from a user-specified location through the global positioning system (GPS). Aside from the quality of service, the TNCs also offered higher income than conventional taxi drivers, causing an unexpected rise of TNVS drivers who provided services even without complete accreditation by the regulator.

In 2016, the LTFRB estimated that only about 36 percent of 42,000 Grab and Uber drivers had adequate documents (Talabong 2017). This prompted the LTFRB to issue Memorandum Circular No. 2016-008 suspending the acceptance of new applications to become TNVS providers. Further to this, the regulator imposed a fine of PhP 5 million each for both Grab and Uber due to violations of various terms and conditions of TNC accreditation under the Memorandum Circular No. 2015-016 (Bondoc 2017). A 1-month suspension of Uber operations was also imposed by the LTFRB in addition the fine. Later, numerous complaints from consumers regarding exorbitant service rates also surfaced and reached the regulator, which then ordered TNCs to limit its surge pricing to make rides more affordable (Cabuenas 2016). In 2018, after selling its Southeast Asia operations to Grab, Uber ceased its operation in the Philippines, leaving Grab no one else to compete with. As a response, the LTFRB limited its surge cap again from 2x to 1.5x until the entry of new transport network company players (Bajo 2018).

Tiopianco (2015) identified some of the regulatory gaps in dealing with new services. One is the identification of the authority responsible for new-age technologies such as TNCs. Its classification falls under legal grey area as it could be regulated by the National Telecommunications Commission in charge of value added services (VAS) or the LTFRB in charge of transportation services. The same goes with which authority has jurisdiction over the TNCs' price surge issue, whether LTFRB or the Philippine Competition Commission (PCC). Tiopangco (2015) also identifies liability allocation as one of the gaps as TNCs have minimal liability in case of acts and negligence of partner drivers.

There are also cases when regulation of disruptive technologies in the Philippines goes beyond necessary and negatively impact related products. An example of which was the suspension of genetically modified organisms (GMO) described in **Box 13**.

Box 13. GMO eggplant suspension

GMO eggplant was introduced in the Philippines by the Institute of Plant Breeding of the University of the Philippines Los Banos (UPLB) using modern biotechnology. It was dubbed as the "Bt talong," short for the protective protein *Bacillus thuringiensis* applied to resist insect pests (Aning 2015). This was developed in hopes of providing an alternative to in fertilizers used by farmers, therefore reducing crop loss due to pests without having to be susceptible to health risks brought by exposure to toxic chemicals (Francisco et al. 2012).

However, Greenpeace Southeast Asia filed a petition stating that the field trials of using Bt crops "violated their constitutional right to health and a balanced ecology" (Aning 2015), claiming that it causes environmental damage and health hazards. As a result, in 2015, the Supreme Court nullified Administrative Order No. 08-2002, banning all field testing, propagation, commercialization, and importation of GMOs. Since previously approved and currently used GMO corn, cotton, and soybean undergo the same procedures as the Bt talong, the production, research, and commercialization of these were also halted. According to Philippine Maize Federation, Inc. President Roger Navarro, the decision threatened the welfare of corn farmers as well as disrupted the domestic supply chain (Torres and Domingo 2016). In 2016, after extensive public consultations with concerned petitioners, proponents, and biotechnology experts, the Court reversed its decision.

As may be gleaned from the GMO suspension, the well-intentioned regulation of disruptive technologies could also lead to detrimental effects if these are not properly classified. Biotechnology in this case have different applications and viewing this as homogenous may result to over-regulation. As highlighted by Briones et al. (2015 p. 15), "there is a need to educate the public of the significant contributions of these science-based initiatives to address agriculture-related problems, including food security". This also applies to the need to invest more on research and development, especially with the FIRe, to better understand disruptive technologies and allow the public sector to act upon them more appropriately.

Another industry that is benefiting from technological innovations is financial services. In contrast to the other regulators, the Banko Sentral ng Pilipinas (BSP) is more proactive. In regulating financial technology (fintech) it has created a regulatory environment that fosters innovations while ensuring that risks are effectively managed. Based on a flexible "test and learn" approach" or the "regulatory sandbox" approach to the regulation of financial innovations, the BSP continuously monitors fintech developments and, according to the BSP Governor, has developed a balanced regulatory approach anchored on three pillars: 1) risk-based and proportionate regulation; 2) active multi-stakeholder collaboration; and 3) consumer protection. Recently, the BSP launched a major initiative called the National Retail Payment System or the NRPS, a policy and regulatory framework for institutionalizing retail digital payments with the goal of increasing the use of electronic payments in the country from around 1 percent to at least 20 percent by 2020 (http://www.bsp.gov.ph/publications/speeches.asp?id=606). The "regulatory sandbox" approach could be applied to other regulated industries particularly those experiencing rapid technological innovations such as in healthcare and transport.

As discussed earlier, new technologies can be harnessed to meet the SDGs. ESCAP (2018) calls for responsive and adaptive regulation to avoid hindering the development of frontier technologies' application for sustainable development. Since creating the enabling regulation for innovation is difficult to formulate, it calls for innovations in regulation processes similar to BSP's regulatory sandbox approach to fintech. Such approach allows pilot trials and refinements before requiring full compliance with supervisory requirements in early stage development.

5.4 Education and Human capital development

Education policies and programs

Basic Education

The introduction of the Enhanced Basic Education Act of 2013 (RA 10533) is the most radical change to basic education in recent years. It introduced mother tongued-based multi-lingual education (MTB-MLE) into kindergarten[6] to grade 3 and added two years to secondary education making the total mandatory basic education a total of 13 years. The MTB-MLE is designed to improve learning outcomes, access and equity. The additional two years of secondary education, on the other hand, puts the country a par with other countries in terms of number of years of pre-university education and is designed to better prepare students for college or the world of work. It was also designed to decongest the junior high school (grades 7 to 10) curriculum. These are profound changes that if our assumptions are correct and are implemented well will set the Philippine education system into a better path. However, we will still need to understand how it is working out. We need to measure and know whether we are implementing these as planned and we need to know whether these are producing the results we expected them to produce.

The assessment done for basic education in the PDP 2017-2022 made the following observations: (a) the while enrollment rate increases the targets were missed; (b) raising quality remains a challenge, (b) efficiency improved at the elementary level but the results in the secondary is mixed, and (d) disparities within the sector and among regions persist. It also envisions the following for basic education: (a) strengthen ECCD programs; (b) full implementation of the K to 12 program; (c) strengthen inclusion programs; (d) keep children in school; (e) continue curricular reforms; and (f) enhance teacher competencies.

The importance of a solid basic education cannot be over emphasized. It makes learning in subsequent levels easier and cheaper because we don't need to spend resources recover learning missed in earlier years. In addition, it also makes graduates trainable which is key in rapidly changing labor markets for the future.

The question of low quality has been with us for a while now. We need to find solutions soon. We can't do this without DepEd becoming a learning institution. The department is implementing some of the most profound changes in the basic education sector in recent history. These constitute important learning opportunities for the sector to know what works and what does not in the Philippine context. Even though these initiatives are backed up by research done in other countries, it does not automatically follow that this will work as well in Philippine society. DepEd has to increase its capacity of monitoring and evaluation.

The importance of raising quality is even heightened by the FIRe. Higher quality means flexibility and trainability for our basic education graduates. Flexibility and trainability is key in the ability to respond to changing labor markets.

[6] This has been made part of basic education and compulsory requirement for entrance to Grade 1 a year earlier (2012) through RA 10157

Technical Vocational Education and Training (TVET)

Orbeta and Esguerra (2017) recently reviewed the Technical and Vocational Education and Training system. Again, like basic education, it was found that the system is doing well in enrollment and producing graduates. There are indications that it is also doing very well even in certification rates. But what remains is that employment rates are still low and there is an apparent lack of appreciation by domestic employers[7] of the certification they provide.

These assessments are echoed in the PDP 2017-2022 which have the following observations: (a) laudable overall performance; and (b) inclusive access, desirability, and quality remain a challenge. It envisions to (a) design TVET trainings to enhance equity; and (b) ensure that TVET programs are globally-competitive.

There is the seemingly unresolved problem of how TESDA need to reconfigure its training system in the light of the introduction of the SHS program. It may be noted that some of the training it provides are already incorporated in the TVL track of the senior high school. In fact, SHS is using the training regulations of TESDA and, in addition, many SHS TVL track students are passing the national certifications (NC) I and II. Moving forward, TESDA must think how it will complement rather than compete with the training already provided in SHS. The joint-delivery with DepED of the TVL track is an important example of collaboration.

Orbeta and Esguerra (2017) made several recommendations moving forward but these can be grouped into two. One, TESDA should focus on its regulatory and information dissemination functions and continuously build its capacity to do these primary public good functions well. Two, build and manage a TVET regulatory and financing system that generate graduates that are responsive to changing industry needs.

In the fourth industrial revolution, enterprise-based training will be critical. However, Orbeta and Esguerra (2017) pointed out that among the modes of delivery this is the smallest (3% in 2014). There is a need to build an incentive and financing system that will expand this mode of providing training. There are serious incentives issues in enterprise-based training. On the one hand, workers want to be fully paid while on training making training unattractive to the enterprises who spend resources and downtime to conduct training. On the other hand, enterprises need to recoup the resources spent on training to encourage it to conduct more training attractive. There is also a real possibility of poaching by competitors of trained workers. Government spends a lot of resources on many supply-driven training that has low employment probabilities. It would be much better to use more resources to finance more enterprise-based training which have better employment prospects. Enterprise-based training should be treated as training and financed like one. Workers need to contribute because they share in the benefits of training through better changes of employability and promotion and higher wages in the future. The firm benefits from higher productivity of trained workers. Government and society benefits from lowering unemployment and greater productivity overall. To have more enterprise-based training, financing then should be shared by workers, firms and government.

The case of community-based training need to be assessed. While this may promote access, there is a need to assess it for quality and relevance.

[7] There are some indications that the NCs have enabled OFWs to land in good jobs abroad.

TESDA has also embarked on blended learning utilizing online learning to complement teacher-led training and on some instances in collaboration with known providers such as Microsoft (Manmodiong, 2017). This is an important learning experience for TESDA not only for the trainees. Delivering training online will be an important mode in the future and every opportunity for learning how to do this well will be important for the future of TESDA training.

Higher Education

Before the free tuition for state colleges and universities (SUC) and local universities and colleges (LUCs), the single biggest intervention of government in higher education is direct provision through the state colleges and universities (SUCs). In 2017, the Universal Access to Quality Tertiary Education Act (RA 10931) was signed into law providing free tuition for all students admitted to SUCs and LUCs. It also provides tertiary education subsidies (TES) to poor students attending private higher education institutions (HEIs). The subsidies under the TES can go beyond tuition to include living allowance and other education costs. This can be the precursor of a grants-in-aid program. Finally, the law also provides a student loans program. It is noteworthy that in October 2015, the Unified Financial Assistance for Tertiary Education (UniFAST) law (RA 10687) was signed. It rationalizes the student financial assistance system (StuFAPs) by clarifying rationale, targeting and requirements of an effective student financing system (Orbeta and Paqueo, 2017). Funding free tuition for everyone admitted in SUCs, LUCs and TVIs was deemed to be a better alternative to the targeted programs envisioned in UniFAST law. It remains to be seen how this law will affect structure of enrollment in tertiary education and whether it will deliver on the promise of greater access particularly for the poor. It also remains to be seen whether the level of subsidy required from government can be sustained. It is noteworthy that at its initial year of implementation, it had to divert a substantial amount of money from basic education to finance the subsidy.

In terms of promoting quality, the system has both program-level and institution-level interventions. The program-level intervention consists of issuing policies, standards and guidelines (PSGs) that is constantly reviewed in cooperation with program technical panels to guide course offerings of programs. It also promotes adherence to qualification standards both domestic, such as the PQF, and international such as the AQRF and the mutual recognition agreements for ASEAN countries, Washington Accord for engineering, Seoul Accord for IT and Standards of Training, Certification, and Watchkeeping (STCW) for maritime. The institution-based interventions are a complex set of institutional standards and guidelines classifying HEIs vertically into Centers of Development (COD) or Centers of Excellence (COE), Autonomous and Deregulated institutions and promoting research networks. More recently, with the slowdown in enrollment because of the introduction of the K to 12 program, CHED has configured an adjustment programs that provides scholarships to increase the proportion of faculty with graduate degrees and promote research through individual as well as institutional grants (Licuanan, 2017).

The assessment done in the PDP 2017-2022 made the following observations: (a) enrollment and graduates in tertiary education exceeded expectations; (b) quality remains an issue; (c) while the number of HEIs in the country is 10 times more than neighboring countries, it has not been producing commensurate number of innovators, researchers and knowledge producers[8]; (d) low proportion of faculty with graduate degrees; (e) low number of accredited

[8] As indicated by its ranking in the Global Innovation Index, the number of research per million population, journals listed under Thomson Reuters, Scopus or both

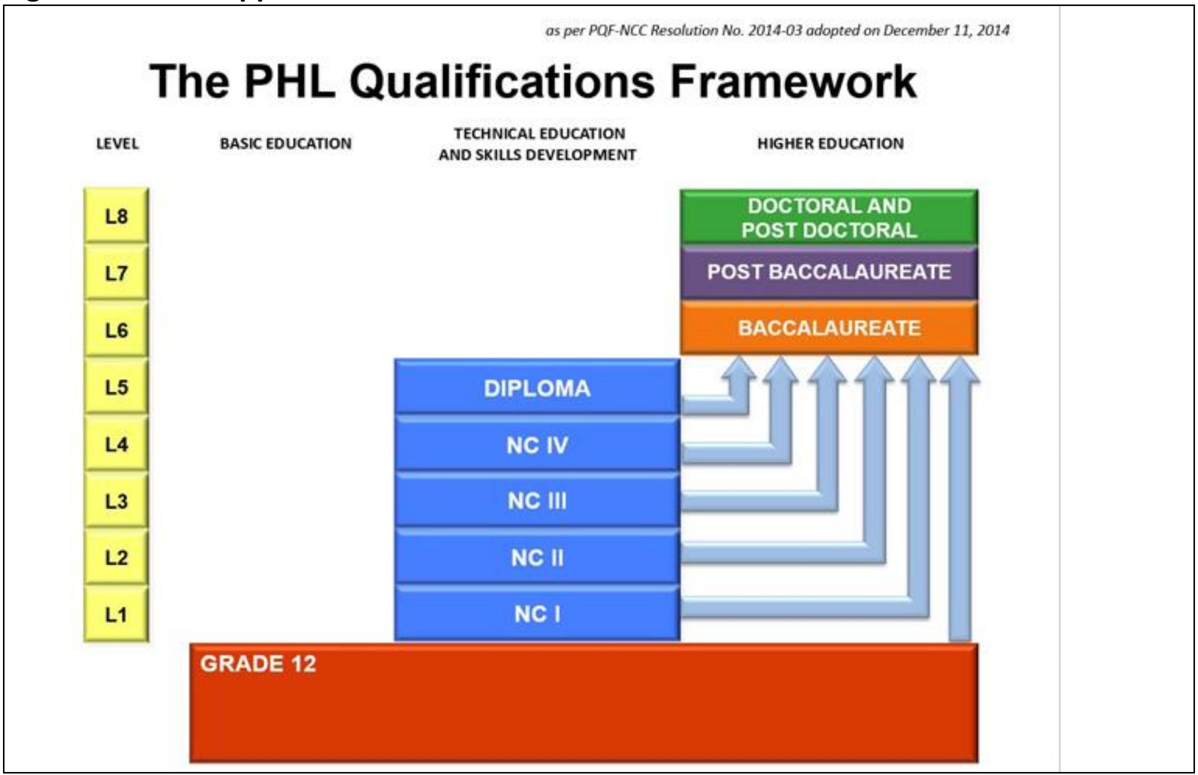
programs, (f) low average passing percentage in licensure examinations. The plan envisions that higher education would (a) be a force for socials and cultural transformation; and (b) an accelerator of innovation and inclusive economic prosperity

The Philippine Qualifications Framework

The Philippine Qualifications Framework has been institutionalized with the signing of the PQF Act in Jan 2018. However, institutionalization of the PQF has started earlier with the signing of Executive Order 83 in 2012 which created the National Coordinating Committee and the various technical working groups. The PQF law provides a common taxonomy and qualifications typology that will serve as basis for recognizing qualifications and their equivalents. It expected to encourage lifelong learning and the aligning of training and qualifications with industry standards. The law also created several task forces to develop implementation plans for the different aspects of the PQF including (a) the qualifications register, (b) Pathways and Equivalences, (c) Qualification assurance, (c) international alignment, (b) information and guidelines. The PQF is referenced to the ASEAN Qualifications Reference Framework (AQRF) and a report of the referencing is being prepared for submission to the ASEAN (Bautista, 2017).

The most recent available version of the PQF has eight levels described in **Figure 7**. There are unresolved issues including the (a) Grades 11 and Grade 12 who were encouraged to take NC I and NC II certifications to fulfill the original employment objectives of introducing senior high school; (b) graduate education which. is being reviewed to clarify the classification for Levels 7 & 8; and (c) implications on ladderized education.

Figure 7. The Philippine Qualifications Framework



Source: Bautista (2017)

Qualification Equivalency and Pathways

This subsection describes the primary programs that allow students to earn qualifications from learning and experiences obtained from different systems and allows them to continue to formal schooling. This system is expected to become important in the future where flexibility and modularity in gaining qualifications will be needed to respond to changing labor market requirements.

Ladderized Education. Ladderized education has been institutionalized by the Ladderized Education Act of 2014 (RA 10647). But even before the passage of this law, Executive Orders (EO) 358 series of 2004 and EO 694 series of 2008 already mandated the establishment of equivalency pathways to allow transition between TVET and higher education qualifications.

While the mandate has been around for more than two decades, there is no readily available inventory of how many programs and courses have defined pathways that allow crediting of training between TVET and HE programs even though there are CHED CMOs specifying model ladderized curricula for several programs[9] . Neither is there available record on how many have benefited from the ladderized program mandated by the law. Given this, it is not clear how easy or difficult it is to avail of the program.

Expanded Tertiary Education Equivalency and Accreditation (ETEEAP). The ETEEAP was introduced through Executive Order 330 issued on May 10, 1996. The EO empowered CHED to deputize higher education institutions to recognize, accredit and give equivalence to knowledge, skills, attitudes and values gain by individuals from relevant work. This covers those who are high school graduates who have worked at least five years in the field or industry related to the academic program they are seeking equivalency.

The HEI that can be deputized for the ETEEAP have stringent requirements, including, (a) being a Center of Excellence (COE) or Center of Development (COD) in the program applied for; (b) should have autonomous or deregulated status; (c) level II accreditation, and (d) category A under the CHED-IQuAME. As of the last count available, the CHED has deputized 96 HEIs that can award appropriate college degree. From AY1999-2000 to AY 2015-2016, the program has accredited 17,361 graduates or a little over 1,000 graduates per year.

Accrediting competencies gained outside the classroom will be an important way of gaining qualifications in the future. Improving systems of doing this will be an important part of education and training systems in the future.

Alternative Learning Systems. The establishment of the Alternative Learning System is provided in Governance Act for Basic Education (RA 9155) signed into law on August 2001. As implemented by DepEd, ALS has two components. One is the Basic Literacy Program (BLP) targeted toward illiterates. Another is the Continuing Education Program - Accreditation and Equivalency (A&E) targeted at those who dropped out of formal elementary schools. Those who completes the A&E can take appropriate elementary or secondary ALS accreditation and equivalency tests. This is a paper and pen test designed to measure competencies. Passers are given a certificate / diploma that certifies they have the competencies comparable to graduates of formal school systems. They are qualified to enroll in secondary and post-secondary schools.

[9] This include CMO 30 s2013 (Radiologic Technology), and CMO 05 s2013 (Midwifery), CMO 01 s2012 (Mechanical Engineering), CMO 56 s2007 (Technical Teacher Education) among others.

There are three modes of delivery, namely, (a) DepEd-delivered, (b) DepEd-procured, and (c) DepEd Partners-delivered. As the name implies, DepEd delivered are those DepEd teachers and coordinators, while DepEd procured are those programs delivered by NGOs and other organization contracted by DepEd. The DepEd-Partners-delivered are those delivered by NGOs, LGUs, GOs, donor agencies, church-based organizations using their own resources.

The recent World Bank report estimated the target population of ALS at about 5 to 6 million of aged 12-26 years using the 2013 FLEMMS data (World Bank, 2016). Furthermore, it also estimates that the program only serves less than 10% of this target population.

ALS offers a second chance to those who were not able to enter school or have not completed their schooling. Worldbank (2016) pointed out that there is a downside of expanding ALS to much as it may weaken the motivation of those who are currently in school and at a high risk of dropping out of not completing their formal schooling.

Issues and Challenges

Paqueo and Orbeta (2016) have listed several recommendations to prepare the country for FIRe. One is the need to expand access to all levels of education. Continued funding of the CCT will ensure expanded access for the poor where enrollment rates are always relatively low, particularly, in the case of secondary and tertiary education. It remains to be seen whether the choice of the current administration to finance for free tuition for everyone in SUCs, LUCs, and TVIs instead of the targeted subsidy envisioned in the UniFAST will deliver on expanding access, particularly for the poor. Increase access of everyone will be critical in the fourth industrial revolution.

An important component of access to learning are second chance programs such as the ALS and recognizing learning outside the classroom such as the ETEEAP. Ladderized programs will also facilitate obtaining qualifications for other sources. While we already have a semblance of the systems in place, it appears to be very limited in coverage and their performance of facilitating recognition of learning outside the usual sources unknown. These modes of assessing and certifying qualifications will become more important in the future as people need to learn, unlearn and relearn to avail of emerging work opportunities.

Another recommendation in Orbeta and Paqueo (2016) is improving quality at all levels. It has been shown that achievement test scores are lower than mastery (75% and above) in basic education particularly for the secondary level. Passing rate in professional board examinations are only around 40% (Paqueo, Orbeta and Albert, 2011; Manasan, 2016). Since this problem has been with us for some time already, we need to find solution that works soon. We need to learn well from the interventions that have proven to work in other countries, from the intervention we have already tried, and the ones we are still considering. Continuing to increase funding to the education sector, while may not be a sure-fire solution, will increase the likelihood of improving quality. We need all the resources we can assemble for the education sector – government and private. The decision to replace the contribution of households in the form of tuition fees with general tax money by legislating free tuition may not be a step in the right direction. Quality education will be key to surmount complex challenges in the future. It will also prevent losing scarce resources in remedial measures just to recoup lost learning opportunities because of low quality education in lower levels.

The promotions of R&D culture in all fields is an important objective both in the near term and long-term. One of the cited reasons why Philippine universities do not rank high in international rankings is that it produces little research outputs. The country spends way lower than the leading countries in East Asia and even lower than the ASEAN average (Licuanan, 2016).

To enable flexibility and modularity or a LEGO blocks-like mode of acquiring qualifications (Brown-Martin, 2017), the system of assessing and certifying competencies is critical. It may need us to think in terms of individual courses/subjects as blocks rather than entire programs consisting of a specific list of courses/subjects. Clarifying what is expected to be learned in each subject will also help in the mixing and matching qualifications. The practice in baccalaureate programs of delineation what are core and elective subjects would also help in mixing and matching of subjects and programs that led to a diploma/certificate. This will mean describing programs of studies leading to a certificate or a diploma in terms of areas of competence that can be satisfied not by a specific list of subjects but by several alternatives subjects. These areas of competencies can be subject to certification as well leading towards a diploma which can then be a combination of area certifications. A case in point is the practice of TESDA of issuing Certificate of Competencies (COCs) when a trainee fails in certain competencies and a national certification (NC) issued only when all requisite COCs are obtained. It will also mean recognizing substitutable subjects that can satisfy competency in an area. A well-accepted qualification framework is key in facilitating the mixing and matching of courses and programs that lead to a certificate or diploma. It should also facilitate defining the pathways of earning desired certification using different modes of learning from informal, non-formal and formal education settings.

FIRe will likely mean rising rates of return to human capital. While this trend would, happily, raise the wages of workers with the desired human capital, this trend coupled with increasing returns to physical capital will raise income inequality. Consequently, the future could see further widening of the social divide.

In a perfectly competitive market, economic theory argues that this widening income inequality would be transitory. Supposedly, the increased rate of return to human capital would induce increased supply of workers with competencies desired by competitive labor markets.

But the problem is that the poor (now already current lagging way behind) is unable to continuously invest and re-invest in their human capital to adapt to rapidly changing market requirements. The reality is that lifelong learning for them and others are likely to be seriously impeded by binding education financial constraints at the household and government levels. This impediment is compounded by asymmetric information problems about the value and effectiveness of the education and training that suppliers are providing. Further along, removal of these constraints and adoption of effective and pro-poor measures adapted to the needs of the future might be blocked for political economy reasons.

As Stiglitz (2017) and others have argued, there is no assurance that that those being left behind will actually be able to make needed human capital investments and avoid being further left behind. This risk could invite a disastrous political backlash that could lead to a downward spiral against policies and strategies needed for the Philippines to achieve inclusive growth and developed income status under FIRe.

To conclude, the various issues discussed above can be grouped into three overarching topics that need to be discussed and researched more systematically and coherently in light of the Great Transformation under FIRe. First, how should PH efficiently and equitably address the issue of financing lifelong learning (formal education and training)? Addressing this issue should take into account the country's history of both market and government failures to finance adequately and efficiently finance education and training.

Second, how should limited resources be allocated among different priorities; moreover, how should the education and training of workers be provided in the future? At present, the bulk of government subsidy to education is tied to SUCs and LUCs. Even if one were to assume that education at all levels would be provided for free, there is still the question about the wisdom of establishing a system of competing education providers (within and between public and private HEIs). Would such a system be more agile in adopting and adapting innovative educational models to respond to rapidly changing educational requirements of the market? How can such a system be made to work? Adaptability and agility are highly relevant characteristics of the education system of the future for the country to be able to take advantage of the many new models and ways of teaching and learning, made possible by new technologies for delivering education and training that can be less expensively tailored to the specific needs and abilities of learners.

Further on this second topic, there is most of all a need to develop a coherent and informed policy and strategy framework that would clarify the roles of private and public education and combine them in ways that would take advantage of their specific strengths. The research challenge here is to find the right combination of public-private roles and supporting policy and regulatory environment. The question is: How can PH maximize their respective strengths and attenuate their weaknesses in ways that encourages the private and private education sectors to complement and stimulate each other. Finding this combination could lead to greater flexibility, agility, efficiency, and equity (through appropriate targeting and prioritization).

Finally, the research agenda for education and training should include a transition strategy grounded on the nature of the political economy involved. Many policy recommendations in the Philippines and elsewhere have floundered because of failure to develop a transition strategy that effectively addresses political economy issues. Understanding of these issues is key to making the research outputs of this proposed research program viable in practice.

5.5 Labor market and social protection policies and programs

Labor market policies and programs

The assessment provided in the PDP 2017-2022 argues that while employment targets were achieved but the underemployment target are not. In addition, while labor productivity improved, it remained below targets. There is a continuing challenge is providing opportunities for the unemployed youth particularly those who are neither studying nor employed (NEETS).

The primary employment facilitation program is the public employment services offices (PESO). The institutionalization of the PESO has been firmed up under RA 10691 which amended RA 8759 by expanding the PESOs from capital towns of provinces, key cities and strategic areas operated by DOLE to all municipalities to be operated by LGUs under the office of the Mayor. The PESOs are linked to the regional offices of DOLE for coordination and technical supervision and to the DOLE Central office as part of the national public employment service network. Complementing the PESO is the PhilJobNet which is the government's web-based labor market information (LMI) system. There appears to be no readily available assessment of the how effective if PhilJobNet is in facilitating employment.

Programs facilitating school-to-work transition programs include Government Internship Program (GIP), JobStart, and enterprise-based apprenticeship, learnership and dual-training programs. JobStart Program addresses the need of “at-risk” youth. The employer-based training such as internship, apprenticeships and dual-training programs have been promoted for some time now. But program is saddled by low take up. Until today the contribution of employer-based training to enrollment and graduate is low at 3% in 2014 (Orbeta and Esguerra, 2016). This will become an important component in the adjustment to keep up with the FIRe. As technology changes rapidly, so does the need for enterprise-based training that are expected to address directly rapidly changing competency needs of firms.

There is an intense pressure from many sectors to ban contractualization. Paqueo and Orbeta (2017) argued that there is an important role that temporary employment contracts (TECs) play in efficient labor markets. These give firms the flexibility needed to efficiently deal with economic shocks and uncertainty in demand. It also a device for screening or filtering work applicants to ensure quality worker-job matches. In addition, temporary work give workers and opportunity to demonstrate not easily observable and measurable characteristics to employers. Consequently, even though well intentioned, it has been argued that a total prohibition can undermine the goal of achieving rapid, inclusive, and sustained economic growth.

Another favorite labor market policy is imposing legal minimum wages (LMW). This policy is supposed to (a) let workers earn income that would allow them to maintain healthy and dignified life, (b) protect workers from exploitation, and (c) motivate workers and firms to increase productivity. But it is also well known that huge increases in LMW that is unrelated to productivity can have boomerang effect. Paqueo, Orbeta and Lanzona (2017) argued that this could significantly hurt disadvantaged groups which are the very people the policy is intending to protect. It was pointed out that studies show that higher LMW have (a) adverse impact on employ, income and poverty, (b) discriminatory impact against the poor, women, young and inexperienced, and less educated workers, and (c) reduced the labor demand of SMEs. Thus, big increases in LMWs can make difficult achievement of inclusive growth.

Social Protection Policies and Programs

Orbeta (2010) reviewed the SP system in the Philippines. It points out that the primary problem of social protection in the Philippines is low coverage of the main bulk of formal private sector workers which in 2014 is found to be less than 40%. Even if by law voluntary coverage for own-account, overseas workers, housewives and domestic workers are provided, it is not surprising that actual coverage is low given that a large proportion of the main statutorily covered population – the formal private sector workers - are not actually contributing even if they are supposed to be contributing through mandatory salary deductions. The viability of the fund is also threatened by the continuing pressure and political leaders giving in to increasing benefits that is not accompanied by commensurate increase in contributions. The fund has also been called upon to respond to social financing needs such as housing programs and disaster relief which may not be the best investment opportunities available to the fund.

The PDP 2017-2022 states that the primary strategy for reducing vulnerability is to focus on job creation and employment-centered growth and asset reforms. It also wants to prioritize the most vulnerable members of the community.

Protection for the vulnerable has improved in recent years with the investment in building the Listahanan – the government database of poor households - to improve targeting effectiveness (Orbeta, 2018). The health insurance coverage of the poor has also improved with the mandatory coverage of those in the Pantawid Pamilya Pilipino Program (Pantawid) funded through earmarked earnings from “sin taxes.” There is also the social pension program for the indigent elderly although threats of leakages have been pointed out due to the decision to let local government units identify the indigent elderly rather than the Listahanan (Velarde and Albert, 2018).

The review done in Orbeta (2010, 2018) seems to indicate that most risks are statutorily covered except for unemployment insurance. The main issue for social protection in the country is that actual coverage by all indications is low. Actual contributing members of formal private sector workers is less than 40%. Participation in voluntary contribution schemes for own-account workers, OFWs, housewives, and domestic workers is also low.

Piza, Edillon and del Mundo (2016) argues that unemployment protection should have three elements, namely, (a) reduction in unemployment, (b) reduction in unemployment duration, and (c) unemployment insurance. They have argued that the country’s unemployment protection in the Philippines is concentrated on reducing unemployment and lacks the two other components. The issue of providing unemployment insurance remains unresolved until today.

With the country deploying more than million workers annually since 2005, protecting overseas Filipino workers (OFWs) is an important policy concern. The social protection for OFWs consists of the unilateral and bilateral programs. Unilateral programs include (a) voluntary membership of the OFWs and their dependents to the Philippine Health Insurance Corporation, (b) the voluntary membership of OFWs in the Social Security System, and (c) the mandatory membership in the Overseas Workers Welfare Administration which administers several social protection programs (Orbeta, 2017). Bilateral programs consist of bilateral social security and labor agreements forged with destination countries of OFWs.

Issues and Challenges

Paqueo and Orbeta (2016) recommended the avoidance of regulations that makes employment costly and the labor market inflexible. For one, it may just hasten the substitution of machines for workers. There is a need to keep the labor market flexible given the uncertainties rapid changes in technology brings to the shop floor.

Rapid technological changes also call for creating a chain of value-adding high quality lifelong learning opportunities for all. Investment in human capital is still is the best protection against skill obsolescence and finding good jobs. Solutions need to be found in the low uptake of enterprise-based training. Enterprise-based training is still the best method of producing competencies that firms need.

In the case of social protection, the review in Orbeta (2010, 2018) seem to indicate that most of the risks, with the exception of unemployment insurance, are already statutorily covered. The continuing challenge is low actual coverage as exemplified by the formal private sector workers only about 40% are actually contributing. Next to this is the challenge of providing adequate benefits. This is exemplified by the health insurance program where coverage is high but the out-of-pocket cost is still high indicating low support value. The clamor for increase pension rates also indicates low support value. Nonetheless, sustainability of the fund should be a primordial concern in any move to increase benefits.

For social assistance programs, finding effective programs and better targeting are the primary challenges. The 4Ps has proven to be effective in keeping children of poor households in school and healthy. These are two critical human capital investments that the poor normally does not value much because the impact is longer down the horizon when the immediate need is the next meal. Social pension for retired indigents maybe another effective program but there seems to be indication of potential leakage as beneficiary identification is veering away from the objective methods such as the use of the Listahanan. Sponsored health insurance program also appears to be well targeted but effectiveness is hampered by the low utilization rates particularly among the poor. Still, another challenge is that targeting of social assistance still relies on the static concept of poverty even though it has been shown that households go in and out of poverty depending on the shocks that they are facing (Reyes, et al, 2011). Recognizing the vulnerability to poverty of the near poor should be an important pillar of social protection (Paqueo, et al, 2014).

6. Summary, conclusion, and next steps

In this report, we present a broad integrative view of the Fourth Industrial Revolution (FIRe). We have laid out the broad contours of the FIRe's nature, direction, potential consequences and policy implications from the lens of science, technology, economics and social development.

The integrative discussion of the FIRe from those various perspectives should raise people's awareness of the multidimensional nature of the revolution and should broaden their horizon in regard to future opportunities for wealth creation and sharing as well as the challenges ahead. Moreover, the discussion should give people a sense of the kind of preparation and re-positioning the country must undertake to thrive in a vastly more dynamic and competitive world of the future – and thereby avoid the dismal consequences of failure to take appropriate adaptation measures.

Government, enterprises, communities and, yes, families should find in the report's systematic discussion of adaptation issues that they need to address individually and collectively to take full advantage of the benefits of the FIRe. In this regard, the report not only highlights potentially massive opportunities for wealth creation and increased national capacity to eliminate poverty; it also calls attention to attendant risks of adverse unintended consequences.

To that point, it is necessary to have a balanced perspective. On the one hand, it is critically important to recognize and address those potential adverse consequences, because failure to do so could lead to greater inequality, exclusion, insecurity and social division. On the other hand, the fear of taking bold adaptation moves could leave the country vulnerable to slow growth, if not stagnation – unable to accelerate achievement of zero poverty and the development of national strength needed to defend the integrity and sovereignty of the Philippines.

Relative to issues that need addressing, the report points to various potential solutions (both conventional and unconventional) and invites the nation to think them through. In this regard, the Philippines needs continuing and robust conversations about how the Government, private enterprises, communities and families (again, individually and collectively) can contribute to the country's ability to achieve sustained inclusive growth under the FIRe. Apropos, it is critical that they have up-to-date and relevant information to make those conversations and ensuing policy debates productive.

In summary, the central message of the report is that to fully take advantage of the FIRe and ensure that every Filipino has a fair chance of enjoying its benefits, the country should do away with its business-as-usual attitude. It should not assume, as Stiglitz (2017) advises, that FIRe will automatically lead to the "lifting of all boats".

In addition to the usual arguments of market and Government failures, the Philippines like other developing countries that are far from the technological and knowledge frontier must also contend with the lack of a broad set of complementary capabilities, including human, physical, institutional, organizational and other types of capital accumulation (Cirera and Maloney 2018).

It is arguable that weaknesses in the availability and quality of such capabilities among developing countries that are lagging behind technologically are binding constraints to their ability to benefit from current technology and knowledge. Moreover, largely the same weaknesses impede those countries' ability to profitably invest in current and future advances in science and technology.

Further to this hypothesis is the observation that in turn the accumulation of mentioned types of capital depends on underlying conditions that are particular to innovations such as intellectual property rights protection as well as market and government failures to incentivize and facilitate investment in R&D and accumulation of knowledge. But beyond those conditions, there is a broad set of familiar determinants that policy makers need to pay attention to, such as cost of doing business, trade regime, competitiveness framework, as well as investment and capital markets.

The implication is that for a country to increase its likelihood of fully benefiting from the FIRe, it is risky to rely on hubristic leapfrog strategies. Instead, it is safer to focus on learning how to walk straight first before running and jumping. In other words, the country needs to focus on establishing a solid basic foundation for sustained learning and on accumulating various types of capital, while progressively and systematically closing the existing technological and knowledge gaps.

Yet another implication is that Government as a whole should systematically review and adapt its policies, institutions and development efforts in light of upcoming revolutionary changes. The report could be useful in such review. On this score, the Philippines needs to pay attention to the miniscule investment it has been putting in R&D; concomitantly, the Government must have an informed view on how to improve the efficiency of its deployment.

Consistent with the above integrative view, the report points to the following interrelated measures to be able to catch up technologically and benefit from FIRe: (i) openness to international trade and investment, which can be useful vehicles for faster transfer of innovative ideas and technology; (ii) reduced anti-competition practices and more competition in key industries like ICT; (iii) better educated and more trainable workers and more flexible and less costly labor market regulatory environment; (iv) development of the education and training systems, including both Government and private sectors, that can efficiently and equitably produce malleable human capital; (v) accumulation of other types of complementary capital like institutional, organizational and physical capital; (vi) progressive establishment of a universal social protection system to keep the people secure, especially the poor and vulnerable, in the face expected unprecedented business and employment disruptions; and (vii) more investment in data collection, monitoring, testing and evaluation.

We conclude with points (vi) and (vii) above. Highlighting them here is appropriate. That's because at the end of it all the country's future success or failure would depend on whether the Government is ready and able to keep the nation socially and politically cohesive. The concern is that the coming waves of business and employment disruptions could create widespread insecurity and, therefore, political backlash that could constrain Government's ability to adopt and adapt needed policy and institutional reforms. To minimize this risk, the Government needs to develop, test and progressively scale up an affordable, fair and efficient universal income/unemployment risk sharing system suitable to the changing nature of employment. Another concern is the challenge of ensuring that the present poor and disadvantaged could overcome longstanding intergenerational barriers to social and economic mobility. How to keep them invested in the nation's future and enable them to participate in the knowledge-driven economy of the future is the question. Fortunately, we have the 4Ps to build on. This program, however, need to be reviewed and analyzed as to how the Government can build modified or supplementary programs that will effectively assist the poor and disadvantaged to give them a fair chance of benefiting from the expected abundance of the age of the FIRe.

7. Bibliography

2012. 3D printing growth. On3DPrinting.com. http://on3dprinting.com/2012/11/01/3d-printing-industry-growth-forbes-incorrectly-says-52b-by-2020/ (accessed on September 2017).

2012. Sales of 3D printers to reach $5 billion by 2017. http://wirthconsulting.org/2012/10/16/sales-of-3d-printers-to-reach-5-billion-by-2017/ (accessed on February 2018).

2016. Automation and anxiety: Will smarter machines cause mass unemployment? The Economist. https://www.economist.com/special-report/2016/06/25/automation-and-anxiety (accessed on April 25, 2018).

2017. Man drives F1 car with the power of his mind. eTeknix. https://www.eteknix.com/man-drives-f1-car-with-the-power-of-his-mind/ (accessed on 2018).

2017. Nanotechnology sees big growth in products and applications. BBC Research. https://globenewswire.com/news-release/2017/01/17/906164/0/en/Nanotechnology-Sees-Big-Growth-in-Products-and-Applications-Reports-BCC-Research.html (accessed February on 2018).

Acemoglu, D. and Autor (2011) "Skills, Tasks and Technologies: Implications for Employment and Earnings," In Handbook of Labor Economics, Vol 4.

Acemoglu, D. and P. Restrepo (2017) "Robots and Jobs: Evidence from US labor markets," NBER Working Paper 23285

ADB (2018) Asian Development Outlook 2018.

Agarwal, K., R. Jegadeesan, Y.X. Guo, and N.V. Thakor. 2017. Wireless power transfer strategies for implantable bioelectronics: Methodological Review. *IEEE Reviews in Biomedical Engineering* 10.

Albert, J.R.G., D.B. Yasay, and R.E. Gaspar. 2016. Examining processes in research & development at the Department of Science and Technology (DOST). PIDS Discussion Paper Series No. 2016-04. Philippines: Philippine Institute for Development Studies.

Albert, J. R. G., Serafica, R. B., Lumbera, B. T. 2016. Examining trends in ICT statistics: How does the Philippines fare in ICT? Discussion Paper Series No 2016-16. Philippines: Philippine Institute for Development Studies.

Albert, J.R.G., F.M. Quimba, R.B. Serafica, G.B. Llanto, J.F.V. Vizmanos, and J.C.A. Bairan. 2017. Measuring and examining innovation in Philippine business and industry. PIDS Discussion Paper Series No. 2017-28. Quezon City, Philippines: Philippine Institute for Development Studies.

Alexandros, G., C.N. Doll, M. Esteban, A. Ahmed, and T.A. Olang. 2016. Renewable energy and biodiversity: Implications for transitioning to a green economy. *Renewable and Sustainable Energy Reviews* 70: 161-184.

Ament, P. 2015. Transistor history: Invention of the Transistor.

American Association for the Advancement of Science (AAAS). 2016. *Shaping robotics policy for the 21st century*. Washington, D.C.: AAAS.

Amponsah, N.Y., M. Troldborg, B. Kington, I. Aalders and R. Hough. 2014. Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations. *Renewable and Sustainable Energy Reviews* 39: 461-475.

Andes, S. and M. Muro. 2015. Don't blame the robots for lost manufacturing jobs. Brookings.edu. https://www.brookings.edu/blog/the-avenue/2015/04/29/dont-blame-the-robots-for-lost-manufacturing-jobs/ (accessed on September 2017).

Anjali, P., G. Aggarwal, and A. Sharma. 2016. A machine learning approach for identification & diagnosing features of Neurodevelopmental disorders using speech and spoken sentences. Paper presented at the 2016 International Conference on Computing, Communication and Automation (ICCCA), April 29-30, Noida, India.

Aric`o, P., G. Borghini, G. Di Flumeri, A. Colosimo, S. Pozzi, and F. Babiloni. 2016. A passive brain-computer interface (p-BCI) application for the mental workload assessment on professional air traffic controllers (ATCOs) during realistic ATC tasks. *Progress in Brain Research* 228: 295– 328.

Arntz, M., T. Gregory and U. Zierahn. 2016. The risk of automation for jobs in OECD countries: A comparative analysis. OECD Social, Employment and Migration Working Papers No. 189. Paris: OECD Publishing.

Atzori, L., A. Iera, G. Morabito, and M. Nitti. 2012. The social internet of things (siot) - when social networks meet the internet of things: Concept, architecture and network characterization. *The International Journal of Computer and Telecommunications Networking* 56: 3594-3608.

Auer, P. (2006) "Protected mobility for employment and descent work-labor market security in a globalized world," Journal of Industrial Relations, 48(1) 21-40.

Aurelio, J.M. 2018. Duterte orders agencies to respond public requests within 15 days. Philippines: Inquirer.net. http://newsinfo.inquirer.net/988347/duterte-orders-agencies-to-repond-public-request-within-15-days (accessed on May 8, 2018).

Autor, David H., Frank Levy and Richard J. Murnane (2003) "The Skill Content of Recent Technological Change: An Empirical Exploration," The Quarterly Journal of Economics, 118(4): 1279–1333.

Autor, D. and D. Dorn (2013) "The Growth of Low-Skill Service Jobs and the Polarization of the U.S. Labor Market," NBER Working Paper 15150

Autor, D. and D. Dorn (2013) "The Growth of Low-Skill Service Jobs and the Polarization of the U.S. Labor Market," American Economic Review, 103(5): 1553–97.

Autor, D.H. 2015. Why are there still so many jobs?: The history and future of workplace automation. *Journal of Economic Perspectives* 29(3): 3–30.

Bajo, A.F. 2018. LTFRB orders Grab to lower surge cap from 2x to 1.5x. Manila, Philippines: GMA News Online.

http://www.gmanetwork.com/news/money/companies/649663/ltfrb-orders-grab-to-lower-surge-cap-from-2x-to-1-5x/story/ (accessed on April 27, 2018).

Bak D. 2003. Rapid prototyping or rapid production? 3D printing processes move industry towards the latter. *Assembly Automation* 23(4): 340–345.

Baldwin, R. 2006. Globalization: The great unbundling (s). In *Globalisation challenges for Europe*, reported by the Secretariat of the Economic Council. Finland: Prime Minister's Office.

Banafa, A. 2016. IoT standardization and implementation challenges. IEEE.org. https://iot.ieee.org/newsletter/july-2016/iot-standardization-and-implementation-challenges.html (accessed on November 29, 2017).

Barcenas, L.L., G.T. Reyes, J.L. Tongzon, and R.B. Serafica. 2017. Regulatory measures affecting services trade and investment: Distribution, multimodal transport and logistics services. PIDS Discussion Paper Series No. 2017-40. Quezon City, Philippines: Philippine Institute for Development Studies.

Barkin, H.I. 2016. Scoping out the internet of things in the Philippines. PositivelyFilipino.com. http://www.positivelyfilipino.com/magazine/scoping-out-the-internet-of-things-in-the-philippines (accessed on September 2017).

Barreiro Jr., V. 2017. PH has slowest average internet speed in Asia Pacific – report. Rappler.com. https://www.rappler.com/technology/news/171680-philippines-akamai-broadband-adoption-internet-speed-rankings (accessed on December 04, 2017).

Battmer, R.D., G.M. ODonoghue, and T. Lenarz. 2007. A multicenter study of device failure in european cochlear implant centers. *Ear and Hearing* 28(2): 95S–99S.

Bauer, H., O. Burkacky, and C. Knochenhauer. 2017. Security in the internet of things. McKinsey&Company. https://www.mckinsey.com/industries/semiconductors/our-insights/security-in-the-internet-of-things (accessed on November 29, 2017).

Bautista, C. 2017. Qualifications frameworks for global competitiveness: The PQF's potential contribution. Presentation at the 2017 Education Summit, December 5-6, 2017, Manila Hotel, Manila.

Behrendt, C., and Q. Nguyen (2018) "Innovative approaches for ensuring universal social protection for the future of work." ILO Future of Work Research Paper Series

Bell, A.J. and T.J. Sejnowski. 1995. An information-maximization approach to blind separation and blind deconvolution. Institute for Neural Computation Technical Report No. INC-9501(7): 1129–1159. CA: Institute for Neural Computation.

Benabid, A.L, P. Pollak, A. Louveau, S. Henry, and J. de Rougemont. 1987. Combined (thalamotomy and stimulation) stereotactic surgery of the vim thalamic nucleus for bilateral parkinson disease. *Applied Neurophysiol*ogy 50(1-6): 344–346.

Bernard, A., K.P. Karunakaran, S. Suryakumar, L. Dembinski, G. Taillandier. 2012. Rapid manufacturing of metallic objects. *Rapid Prototyping Journal* 18(4): 264–280.

Bilgili, M., A. Ozbek, S. Besir, and K. Ali. 2015. An overview of renewable electric power capacity and progress in new technologies in the world. *Renewable and Sustainable Energy Reviews* 49: 323-334.

Blankertz, B., G. Dornhege, M. Krauledat, K.R. Muller, and V. Kunzmann. 2006. The Berlin brain-computer interface: Progress beyond communication and control. *English IEEE Transactions on Neural Systems and Rehabilitation Engineering* 10(530): 1–24.

Bondoc, M.R. 2017. LTFRB slaps Grab, Uber with P5-m fine for various violations. Manila, Philippines: GMA News Online. http://www.gmanetwork.com/news/money/companies/617615/ltfrb-slaps-grab-uber-with-p5-m-fine-for-various-violations/story/ (accessed on April 25, 2018)

Boon, T.T. 2016. The fourth industrial revolution: Coping with disruptive change. S. Rajaratnam School of International Studies (RSIS) Commentary No. 264. Singapore: RSIS.

Borghini, G., L. Astolfi, G. Vechhiato, D. Mattia, and F. Babiloni. 2014. Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload, fatigue and drowsiness. *Neuroscience & Biobehavioral Reviews* 44: 58–75.

Briones, L. .2017. State of basic education. Presentation at the 2017 Education Summit, December 5-6, 2017, Manila Hotel, Manila.

Briones, R.M, I.M. Galang, and D.C. Israel. 2015. Inputs for Philippine hosting of APEC 2015: Food security. PIDS Discussion Paper Series No. 2015-19. Quezon City, PH: Philippine Institute for Development Studies.

Broman, S.H. and J. Fletcher. 1999. The changing nervous system: neurobehavioral consequences of early brain disorders. US: Oxford University Press.

Brown, E. 2016. Who needs the internet of things? Linux.com. https://www.linux.com/news/who-needs-internet-things (accessed on November 25, 2017).

Brown-Martin, G. 2017. Education and the fourth industrial revolution. https://www.groupemediatfo.org/wp-content/uploads/2017/12/FINAL-Education-and-the-Fourth-Industrial-Revolution-1-1-1.pdf (accessed on April 9, 2018).

Brunner, P., L. Bianchi, C. Guger, F. Cincotti, and G. Schalk. 2011. Current trends in hardware and software for brain–computer interfaces (BCIs). *Journal on Neural Engineering* 8: 1–7.

Brynjolfsson, E., A. McAfee, and M. Spence. 2014. Labor, capital, and ideas in the power law economy. *Foreign Affairs* 93(4): 44.

Bughin, J., E. Hazan, S. Ramaswamy, M. Chui, T. Allas, P. Dahlstrom, N. Henke, and M. Trench. 2017. Artificial intelligence - the next digital frontier? New York, US: MGI.

Bughin, J., J. Manyika, M. Miremadi, M. Chui, K. George, P. Willmott, and M. Dewhurst. 2017. A future that works: Automation, employment, and productivity. New York, US: McKinsey Global Institute.

Burns, P. 2017. Now this is the way to make GPS way better for the IoT. Medium.com. https://medium.com/@patburns/now-this-is-the-way-to-make-gps-way-better-for-lpwans-ddad647784cd (accessed on December 03, 2017).

Cabuenas, J.V. 2016. Uber limits fare surge until January 15. Manila, Philippines: GMA News Online. http://www.gmanetwork.com/news/money/companies/593732/uber-limits-fare-surge-until-january-15/story/ (accessed on April 25, 2018).

Chang, Y. and L. Yanfei. 2015. Renewable energy and policy options in an integrated ASEAN electricity market: Quantitative assessments and policy implications. *Energy Policy* 85: 39-49.

Chang, J-H and P. Huynh. 2016. ASEAN in transformation: The future of jobs at risk of automation. Bureau for Employers' Activities (ACT/EMP) Working Paper No. 9.

Geneva: International Labour Office, Bureau for Employers' Activities, ILO Regional Office for Asia and the Pacific.

Chitkara, R., W. Ballhaus, O. Acker, D. Song, A. Sundaram, and M. Popova. 2015. The internet of things: The next growth engine for the semiconductor industry. Germany: PricewaterCoopers.

Chitkara, R., A. Rao, and D. Yaung. 2017. Leveraging the upcoming disruptions from AI and IoT: How artificial intelligence will enable the full promise of the internet of things. Germany: PricewaterCoopers.

Christensen, C.M. 1997. The innovator's dilemma: When new technologies cause great firms to fail. Boston, MA: Harvard Business School Press.

Christensen, C.M. 2013. *The innovator's solution*. Boston, MA: Harvard Business Review Press.

Cirera, X. and W. Maloney. 2017. The innovation paradox developing-country capabilities and the unrealized promise of technological catch-up. Washington, DC: World Bank.

Citigroup. 2016. Technology at work v2.0: The future is not what it used to be. Citigroup.

Citturu, S., D.Y. Lin, K. Sneader, O. Tonby, and J. Woetzel. 2017. Artificial intelligence and Southeast Asia's future. McKinsey Global Institute Discussion Paper September 2017. New York, US: MGI.

Corona-Strauss, F.I. and D.J. Strauss. 2013. On the objective assessment of the auditory brainstem response measurement quality. Paper presented at the 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2013.

Cororaton, C. B. 2002. Research and development and technology in the Philippines. PIDS Discussion Paper Series No. 2002-23. Philippines: Philippine Institute for Development Studies.

Data2X. 2017. *Big data and the well-being of women and girls: Applications on the social scientific frontier*. http://data2x.org/wp-content/ uploads/2017/03/Big-Data-and-theWell-Being-of-Women-and-Girls.pdf (accessed on February 20, 2018).

Davis, C. 2006. Robots at work. *The Lancet* 368(9533): 358.

Davis, N. 2016. What is the fourth industrial revolution? *World Economic Forum*. January 19.

De Backer, K., I. Desnoyers-James, and L. Moussiegt. 2016. Reshoring: Myth or reality? OECD Science, Technology and Industry Policy Papers No. 27. Paris, France: OECD Publishing.

De Clercq, W., A. Vergult, B. Vanrumste, W.V. Paesschen, and S.V. Huffel. 2006. Canonical correlation analysis applied to remove muscle artifacts from the electroencephalogram. *IEEE Transactions on Biomedical Engineering* 53: 2583–2587.

Department of Energy (DOE). 2016. Power Development Plan 2016-2040. Taguig City, Philippines: DOE.

Department of Information and Communications Technology (DICT). 2016a. *E-government master plan 2016-2022*. Quezon City, PH: DICT.

Department of Information and Communications Technology (DICT). 2016b. What is the juan, konek! free wi-fi internet access in public spaces project? http://freepublicwifi.gov.ph/what-is-the-juan-konek-free-wi-fi-internet-access-in-public-places-project/ (accessed on February 26, 2018).

Department of Information and Communications Technology (DICT). 2017a. *National broadband plan: Building infostructures for a digital nation*. Quezon City, PH: DICT.

Department of Information and Communications Technology (DICT). 2017b. *National Cybersecurity Plan 2022*. Quezon City, PH: DICT.

Department of Science and Technology (DOST). 2015. *Roadmap for digital startups: 2015 and beyond*. Quezon City, PH: Information and Communications Technology Office, DOST.

Department of Science and Technology (DOST). 2017. *Harmonized research and development agenda 2017 – 2022*. Taguig, Philippines: DOST.

Department of Trade and Industry (DTI). 2017. *DTI chief explains the government's I3 strategy*. http://www.dti.gov.ph/media/latest-news/11189-dti-chief-explains-i3-strategy (accessed on February 12, 2018).

DiMarco, J.P. Implantable cardioverter-defibrillators. *New England Journal of Medicine* 349(19): 1836–1847.

DTI. 2017. *The Philippines in the automotive global value chain*. DTI Policy Briefs Series 2017-02. Makati City, PH: DTI.

DTI. 2017. Philippine inclusive innovation industrial strategy (I3S): Propelling jobs, investments, and shared prosperity for all. DTI Policy Briefs Series 2017-05. Makati City, PH: DTI.

DTI. 2016. *MSME development in the Philippines*. Makati City, PH: Bureau of Small and Medium Enterprise Development, DTI.

DTI. *The 7Ms of successful entrepreneurs*. http://www.dti.gov.ph/businesses/msmes/the-7ms-of-successful-entrepreneurs (accessed on February 15, 2018).

Duffy, J. 2014. IoT in the enterprise up three-fold, study finds. https://www.networkworld.com/article/2851717/internet-of-things/iot-in-the-enterprise-up-three-fold-study-finds.html (accessed on November 28, 2017).

Elliston, C., M. Fenech, and O. Buston. 2017. Artificial intelligence: The road ahead in low. World Wide Web Foundation.

Espenilla, N.A., Jr. 2018. Thrive not just survive. Speech at the 39th National Conference of Employers – The Future is Now: Survive, Compete and Grow Amidst Radical Changes in Labor and Employment Policies, April 18, 2018, Manila, Philippines.

Estepp, J.R. and J.C. Christensen. 2015. Electrode replacement does not affect classification accuracy in dual-session use of a passive brain-computer interface for assessing cognitive workload. *Frontier Neuroscience* 9(54): 1–20.

Eyers, D.R. and A.T. Potter. Industrial additive manufacturing: A manufacturing systems perspective. *Computers in Industry* 92-93.

Faraday, M. 1911. Wayback Machine. Encyclopedia Britannica.

Florentine, S. 2017. 10 most in-demand internet of things skills. https://www.cio.com/article/3072132/it-skills-training/10-most-in-demand-internet-of-things-skills.html (accessed on November 28, 2017).

Fortmann-Roe, S. 2012. Understanding the bias-variance tradeoff. http://scott.fortmannroe.com/docs/Bias Variance.html (accessed on 2018).

Francisco, S.R., C.A. Aragon, and G.W. Norton. 2012. Potential poverty reducing impacts of Bt eggplant adoption in the Philippines. *Philippine Journal on Crop Science* 37(3): 30-39. Philippines.

Freeman, C. and F. Louçã. 2002. As time goes by: From the industrial revolutions to the information revolution. US: Oxford University Press.

Frey, C.B. and M.A. Osborne. 2013. The future of employment: How susceptible are jobs to computerization? Oxford, UK: University of Oxford.

Friston, K.J., S. Williams, R. Howard, R.S. Frackowiak, and R. Turner. 1996. Movement-related effects in fMRI time-series. *Magnetic Resonance in Medicine* 35: 346–355.

Frost and Sullivan. 2016. *From $600m to $6 billion, artificial intelligence systems poised for dramatic market expansion in healthcare.* https://ww2.frost.com/ news/press-releases/600-m-6-billion-artificial-intelligence-systems-poised-dramatic-market-expansion-healthcare (accessed on December 4, 2017).

Furman, J., and R. Seamans (2018) "AI and the Economy." NBER Working Paper 24689 http://www.nber.org/papers/w24689

Gandhi, O.P. 2002. Electromagnetic fields: human safety issues. *Annual Review of Biomedical Engineering* 4(1): 211–234.

Gao, W., Y. Zhang, D. Ramanujan, R.K.,Chen, C.B. Williams, C.C.L. Wang, Y.C. Shin, and S. Zhang. 2016. The status, challenges, and future of additive manufacturing in engineering. *Computer Aided Design* 69: 65-69.

Gartner, Inc. Gartner says 6.4 billion connected "things" will be in use in 2016, up 30 percent from 2015. 2015. https://www.gartner.com/newsroom/id/3165317 (accessed on December 02, 2017).

Geddes, M. 2016. The future of everything: Making sense of the sensor revolution from a telecoms perspective. https://iot.ieee.org/newsletter/july-2016/the-future-of-everything-making-sense-of-the-sensor-revolution-from-a-telecoms-perspective.html (accessed on November 27, 2017).

Gelber, M. 2017. 5 "internet of things" jobs you can apply for right now. https://www.monster.com/career-advice/article/internet-of-things-jobs (accessed on November 28, 2017).

George, A. 1955. The development of French romanticism: the impact of the industrial revolution. New York, US: Syracuse University Press.

Giges, N.S. 2013. Top 5 trends in nanotechnology. The American Society of Mechanical Engineers. https://www.asme.org/engineering-topics/articles/nanotechnology/top-5-trends-in-nanotechnology (accessed on 2018).

Global Industry Analysts, Inc. *The Global Internet of Things (IoT) Market*. http://www.strategyr.com/MarketResearch/Internet_of_Things_IoT_Technology_Market_Trends.asp (accessed on November 27, 2017).

Goos, M., A. Manning and A. Salmons (2014) "Explaining job polarization: routine-biased technological change and offshoring," Americal Economic Review, 104(8), pp 2509-2526.

Graetz, G. and G. Michaelz (2018) "Robots at Work". London School of Economics

Guevera, R.C. 2017. Harmonized national R&D agenda (HNRDA) 2017-2022. Proceedings of the CHED National Conference on Research, Innovation and Extension.

Guevera, R.C. 2018. Science for change program (S4CP). Presented at the S4CP Orientation & Call for Proposals, February 22, 2018, SMX, Pasay City.

Gupta, V. 2017. The emerging industrial app economy. https://www.ge.com/digital/blog/emerging-industrial-app-economy (accessed on December 03, 2017).

Gurnaney, T. 2017. IoT may rescue telcos when revenues from voice and data services decline: Analysts. The Economic Times. *https://telecom.economictimes.indiatimes.com/news/iot-may-rescue-telcos-when-revenues-from-voice-and-data-services-decline-analysts/60227229* (accessed on December 03, 2017).

Hall, A., and G. Zoega. 2014. Values and labor force participation in the Nordic countries. *The Open-Access, Open-Assessment E-Journal* 8: 2014-2041.

Halmes, M. and L. Pierreu. 2014. Additive manufacturing: The effects of 3D printing. *Deloitte.* https://www2.deloitte.com (accessed on September 2017)

Hei, X. and X. Du. 2013. *Security for wireless implantable medical devices*. New York, US: Springer.

Hoekman, B. and B.S. Javorick. 2006. Global integration and technology transfer. Washington, DC: World Bank.

Hongjun, Z, H. Wenning, H. Dengchao, and M. Yuxing. 2014. Survey of research on information security in big data. Congresso da sociedada Brasileira de Computacao.

Hopkinson, N., R. Hague, P. Dickens. 2006. *Rapid manufacturing: an industrial revolution for the digital age*. UK: John Wiley & Sons, Ltd.

Horn, J., L. Rosenband, and M. Smith. 2010. *Reconceptualizing the industrial revolution*. Cambridge, MA: MIT Press.

Huang, P., D. Deng , and Y. Chen. 2013. Modelling and fabrication of heterogeneous three-dimensional objects based on additive manufacturing. Paper presented at the ASME 2013 International Mechanical Engineering Congress and Exposition, San Diego, California, USA, November 15-21.

IAEResearch. 2013. How will 3D printing impact the manufacturing industry? https://seekingalpha.com/article/1284331-how-will-3d-printing-impact-the-manufacturing-industry (accessed on 2018).

IBM. 2016. Preparing for the future of artificial intelligence: IBM response to the White House Office of science and technology policy's request for information. IBM.

Ibrahim, T., Y. Abaker, and A. Badrul. 2015. Big data on cloud computing. *Information Systems* 47: 98-115.

Industry 4.0: The fourth industrial revolution – guide to industrie 4.0. https://www.i-scoop.eu/industry-4-0/#Interoperability_interconnection_connectivity (accessed on January 22, 2018).

International Federation of Robotics (IFR). 2017. *The impact of robots on productivity, employment and jobs*. International Federation of Robotics Positioning Paper. Frankfurt, Germany: IFR.

Internet Society. 2017. *Artificial intelligence and machine learning: Policy paper*. Washington, D.C.: Internet Society.

Investopedia. *Disruptive Technology.* https://www.investopedia.com/terms/d/disruptive-technology.asp (accessed on 2018).

IoT Devices & Products. Postscapes. https://www.postscapes.com/internet-of-things-award/winners/ (accessed on December 03, 2017).

Jones, J. and P.B. Jones. 2017. IoT global trends for 2017 and beyond. https://www.solid-run.com/internet-things-global-trends-2017-beyond/ (accessed on November 27, 2017).

Juliussen, E. and J. Carlson. 2014. Autonomous Cars - Not if, but when. IHS Automotive.

Kanchana, K., B.C. McLellan, and H. Unesaki. 2016. Energy dependence with an Asian twist? Examining international energy relations in Southeast Asia. *Energy Research and Social Science* 21: 123-140.

Kaur, B. and D. Singh. 2017. Neuro signals: A future biomertic approach towards user identification. Paper presented at the 2017 7th International Conference on Cloud Computing, Data Science & Engineering – Confluence.

Kesner, S. B. and R. D. Howe.2011. "Position control of motion" compensation cardiac catheters", *IEEE Trans. Robot.*, vol. 27, no. 6, pp. 1045-1055

Kim, Jong-Hwan, Seung-Hwan Choi, In-Won Park, and Sheir Afgen Zaheer, 2013 "Intelligence Technology for Robots That Think", *IEEE Computational Intelligence Magazine*, Vol. 8, No. 3, pp. 70-84.

Knight, J.N. 2003. Signal fraction analysis and artifact removal in EEG. Master thesis. Colorado State University.

Landes, D. S. 1969. *The unbound Prometheus*. UK: Cambridge University Press.

Landes, D. 1999. *The wealth and poverty of nations*. New York, US: W.W. Norton & Company.

Lanz, R., S. Miroudot, and H. K. Nordås. 2011. Trade in tasks. OECD Trade Policy Working Papers No. 117. Paris, France: OECD Publishing.

La Viña, A.G., J.M. Tan, T.I. Guanzon, M.J. Caleda, and L. Ang. 2017. Navigating a trilemma: Energy security, equity, and sustainability in the Philippines' low-carbon transition. *Energy Research and Social Science* 35: 37-47.

Lazcano, J.M. 2017. DOST eyes research on artificial intelligence. Department of Science and Technology. http://www.stii.dost.gov.ph/2-uncategorised/589-dost-eyes-research-on-artificial-intelligence (accessed on 2018).

Lee, Y. and E. Newcomer. 2018. Uber pulls out of Southeast Asia, selling operation to rival Grab. Bloomberg. https://www.bloomberg.com/news/articles/2018-03-26/uber-cedes-southeast-asia-to-chief-rival-grab-in-latest-pullout

Leipziger, D., and V. Dodev. 2016. Disruptive technologies and their implications for economic policy: Some preliminary observations. Institute for International Economic Policy White Paper No. 2016-13. Washington, DC: George Washington University.

Lemm, S., B. Blankertz, T. Dickhaus, and K.R. Muller. 2011. Introduction to machine learning for brain imaging. *NeuroImage* 56(2): 387–399.

Liao, L.D., C.T. Lin, K. McDowell, A.E. Wickenden, K. Gramann, T.P. Jung, L.W. Ko, J.Y. Chang. 2012. Biosensor technologies for augmented brain–computer interfaces in the next decades. *Proceedings of the IEEE* 100: 1553–1566.

Licuanan, P. 2016. Driving Philippine higher education to meet goals of human capital development and the knowledge economy in the 21st century. Presentation at the 2016 Education Summit, November 2-3, 2017, SMX Convention Center, Manila.

Licuanan, P. 2017. The state of Philippine higher education. Presentation at the 2017 Education Summit, December 5-6, 2017, Manila Hotel, Manila.

Lier, A.H. 2016. The fourth industrial revolution in the energy industry. AltEnergyMag. http://www.altenergymag.com/article/2016/02/the-fourth-industrial-revolution-in-the-energy-industry/22789/ (accessed on 2018).

Liu, C. 2017. Artificial intelligence is on the rise in Southeast Asia, helping everyone from fashion designers to rice growers. South China Morning Post. http://www.scmp.com/week-asia/business/article/2118345/artificial-intelligence-rise-southeast-asia-helping-everyone (accessed on 2018).

Liu, W. and J. DuPont. 2003. Fabrication of functionally graded tic/ti composites by laser engineered net shaping. *Scripta Materialia* 48(9): 1337-1342.

López González, J. and M. Jouanjean (2017), Digital trade: Developing a framework for analysis. OECD Trade Policy Papers No. 205. Paris, France: OECD Publishing.

Löwy, M., and R. Sayre. 2001. *Romanticism against the tide of modernity*. US: Duke University Press.

Machado, S., F. Araujo, F. Paes, B. Velasques, M. Cunha, H. Budde, L.F. Basile, R. Anghinah, O. Arias-Carrión, M. Cagy, R. Piedade, T.A. de Graaf, A.T. Sack, P.

Ribeiro. 2010. EEG-based brain–computer interfaces: An overview of basic concepts and clinical applications in neurorehabilitation. *Reviews in Neurosciences* 21(6): 451-468.

Mahmoud, R., T. Yousuf, F. Aloul, and I. Zualkernan. 2015. Internet of things (IoT) security: Current status, challenges and prospective measures. Paper presented at the 10th International Conference for Internet Technology and Secured Transactions (ICITST), December 14-16.

Mampusti, E.T., J.S. Ng, J.J. Quinto, G.L. Teng, M.T. Suarez, and R.S. Trogo. Measuring academic affective states of students via brainwave signals. Paper presented at the 2011 Third International Conference on Knowledge and Systems Engineering, 2011.

Mannino, A., D. Althaus, J. Erhardt, L. Gloor, A. Hutter, and T. Metzinger. 2015. Artificial intelligence: Opportunities and risks. Effective Altruism Foundation Policy Paper No. 2. Germany: Effective Altruism Foundation.

Manmodiong, G. 2017. The state of Philippine TVET. Presentation at the 2017 Education Summit, December 5-6, 2017, Manila Hotel, Manila.

Manyika, J., M. Chui, J. Bughin, R. Dobbs, P. Bisson, and A. Marrs. 2013. Disruptive technologies: Advances that will transform life, business, and global economy. New York, US: MGI.

Martins, A. and P. Rincon. 2014. Paraplegic in robotic suit kicks off world cup. BBC. http://www.bbc.com/news/science-environment-27812218 (accessed on 2018).

Marquardt, J. 2015. The politics of energy and development: Aid diversification in the Philippines. *Energy Research & Social Science* 10: 259-272.

Marr, Bernard. 2016. Why everyone must get ready for the 4th industrial revolution. Forbes Tech. https://www.forbes.com/sites/bernardmarr/2016/04/05/why-everyone-must-get-ready-for-4th-industrial-revolution/2/#5ff67e705877 (accessed on December 2017).

McKinsey & Company. 2018. Industry 4.0: Reinvigorating ASEAN manufacturing for the future. McKinsey & Company.

McKinsey Global Institute (MGI). 2013. Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey and Company.

Mckinsey Global Institute (MGI). 2016. *Digital globalization: The new era of global flows*. McKinsey Global Institute, McKinsey & Company.

McKinsey Global Institute (MGI). 2017. *Artificial intelligence and Southeast Asia's future.* MGI Discussion Paper September 2017. McKinsey and Company.

Medalla, E.M., and M.A. Rosellon. 2017. Macroeconomic overview of the Philippines and the new industrial policy. PIDS Discussion Paper Series 2017-48. Quezon City, PH: Philippines Institute for Development Studies.

Merswolke, B. 2017. The internet of things and transportation. Miovision. https://miovision.com/blog/the-internet-of-things-and-transportation/ (accessed on December 03, 2017).

Meyer (n.d.) Will robots take your job: Understanding the Digital Revolution. Social Europe.

Mijares, E.Z. 2016. Improving access to trade finance. July 5. *BusinessMirror*. https://businessmirror.com.ph/improving-access-to-trade-finance/ (accessed on February 15, 2018)

Misa, T.J. 1995. *A nation of steel: The making of modern America*. US: Johns Hopkins University Press.

Molthof, I.C. 2016.Neurotechnology and dynamic flow: The influence of brain stimulation technologies and neurofeedback on the self and self-understanding. Master thesis. University of Twente.

Monostori, L, B. Kadar, T. Bauernhansl, S. Kondoh, S. Kumara, G. Reinhart, I. Sauer, G. Schuh, W. Sign, and K. Ueda. 2016. Cyber-physical systems in manufacturing. *CIRP Annals - Manufacturing Technology* 65(2): 621-641.

Montero, M., S.H. Ahn, D. Odell, S. Roundy, P.K. Wright. 2002. Anisotropic material properties of fused deposition modelling abs. *Rapid Prototype Journal* 8(4): 248–57.

Moore, J. and C.B. Williams. 2012. Fatigue characterization of 3D printed elastomer material. Paper presented at the International Solid Freeform Fabrication Symposium, Austin, Texas, US, August 6-8.

Moraje, S. 2017. Seizing the automation opportunity in the Philippines. Manila: McKinsey & Company Manila.

Morris, D.Z. 2016. Leaderless, blockchain-based venture capital fund raises $100 million, and counting. Fortune. http://fortune.com/2016/05/15/leaderless-blockchain-vc-fund/ (accessed onDecember 23, 2017).

Muntone, S. Second industrial revolution. The McGraw-Hill Company.

Narayanan, A., J. Bonneau, E. Felten, A. Miller, and S. Goldfeder. 2016. *Bitcoin and cryptocurrency technologies: a comprehensive introduction*. Princeton: Princeton University Press.

National Economic and Development Authority (NEDA). 2016. *Vision 2040*. http://2040.neda.gov.ph/wp-content/uploads/Vision2040_final.pdf (accessed on April 27, 2018).

National Economic and Development Authority (NEDA). 2017a. *Philippine Development Plan 2011-2017*. Pasig City, Philippines: NEDA.

National Economic and Development Authority (NEDA). 2017b. *Philippine Development Plan 2017-2022*. Pasig City, Philippines: NEDA.

Navea, R.F., E. Dadios. 2015. Classification of tone stimulated EEG signals using independent components and power spectrum vectors. Paper presented at the 2015 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), July 9.

Nehmeh, S.A. and Y. E. Erdi. 2008. Respiratory motion in positron emission tomography/ computed tomography: a review. *Seminars in Nuclear Medicine* 38: 167–176.

Newton, P. 2015. Nanotechnology: A disruptive technology shaping the future and the economy. https://www.intelligenthq.com/innovation-management/nanotechnology-a-disruptive-technology-shaping-the-future-and-the-economy/ (accessed on 2018).

Niehaus, M. and J. Tebbenjohanns. 2001. Electromagnetic interference in patients with implanted pacemakers or cardioverter-defibrillators. *Heart* 86(3): 246–248.

Noronha, A., R. Moriarty, K. O'Connell, and N. Villa. 2014. Attaining IoT value: How to move from connecting things to capturing insights gain an edge by taking analytics to the edge. CISCO. https://www.cisco.com/c/dam/en_us/solutions/trends/iot/docs/iot-data-analytics-white-paper.PDF (accessed on November 29, 2017).

North, R. 2008. Neural interface devices: spinal cord stimulation technology. *Proceedings of the IEEE* 96: 1108–1119.

Orbeta, A (2018) "Social Protection Floor: Philippines" in M Asher, F. Zen and A. Dita (eds.) Social Protection Goals in East Asia. Routledge. 2018.

Orbeta, A. (2010) "Social Protection in the Philippines: Current State and Challenges," in Asher, M, S. Oum and F. Parulian (eds) Social Protection in East Asia – Current State and Challenges. 2010.

Orbeta, A. and E. Esguerra. 2016. The national system of technical vocational education and training in the Philippines: A review of and ideas for reforms. PIDS Discussion Paper No. 2016-07. Philippines: PIDS.

Orbeta, A. and E. Esguerra (2016) "The National System of Technical Vocational Education and Training in the Philippines: A review of and ideas for reforms," in A. Isgut and J. Weller (eds.) Protection and Training: Institutions for improving workforce integration in Latin America and Asia. ECLAC Books, No. 140.

Orbeta, A. and V. Paqueo. 2017. Who benefits and loses from untargeted tuition subsidy for Students in SUCs? PIDS Policy Notes No. 2017-03. Philippines: PIDS.

Organization for Economic Cooperation and Development (OECD). 2011. *Skills for innovation and research*. Paris, France: OECD Publishing.

Organization for Economic Co-operation and Development (OECD). 2016. OECD science, technology, and innovation outlook 2016. Paris: OECD Publishing.

Organisation for Economic Co-operation and Development (OECD). 2017. ICT investment. https://data.oecd.org/ict/ict-investment.htm (accessed on 02 December 2017).

Ortiz, E. (2018) "Transformation or destruction: The uncertain future of work in the fourth industrial revolution," Equal Times. (Available: https://www.equaltimes.org/transformation-or-destruction-the#.W0fJ6tJLiUk, accessed May 23, 2018)

Ortiz, M.K., Serafica, R.B., and J.C. Bairan. 2017. Rebooting Philippine telecommunications through structural reform. PIDS Discussion Paper Series No. 2017-19. Quezon City, PH: Philippine Institute for Development Studies.

Oullier, O. This is your brain on business. Fortune. http://fortune.com/2017/05/02/neurotechnology-brainstorm-health-oullier/ (accessed on 2018).

Pacific Bridge Medical. Philippine medical market. http://www.pacificbridgemedical.com/target-asian-markets/philippines-medical-market/ (accessed on 2018).

Parraa, D., M. Swierczynskib, D.I. Stroeb, S.A. Normanc, A. Abdond, J. Worlitschekd, T. O'Dohertye, L. Rodriguese, M. Gillotte, X. Zhangf, C. Bauerf, and M.K. Patela. 2017. An interdisciplinary review of energy storage for communities: Challenges and perspectives. *Renewable and Sustainable Energy Reviews* 79: 730-749.

Paqueo, V. and A. Orbeta. 2016. *Unlocking the Filipino people's potential in the next six years and beyond*. Stratbase Albert del Rosario Institute for Strategic and International Studies Special Study. Quezon City, Philippines: Rex Publishing.

Paqueo, V. and A. Orbeta (2016) "Unlocking the Filipino People's Potential in the Next Six Years and Beyond" Stratbase Albert del Rosario Institute for Strategic and International Studies.

Paqueo, V. and A. Orbeta (2017) "Beware of the "End Contractualization!" Battle Cry," in

Paqueo, V., E. Orbeta, S. Cortes, and A. Cruz (2014) "Analysis of the near-poor challenge and strategy development ideas," Processed DSWD.

Paqueo, V., A. Orbeta and G. Llanto Unintended Consequences: The Folly of Uncritical Thinking. Philippine Institute for Development Studies

Paqueo, V., A. Orbeta and L. Lanzona (2017) "The impact of legal minimum wages on employment, income and poverty incidence in the Philippines," in Paqueo, V., A. Orbeta, and G. Llanto (eds.) Unintended Consequences: The Folly of Uncritical Thinking. Philippine Institute for Development Studies

Peet, A. and T. Wilde. 2017. Artificial intelligence: the investment of 2017 and beyond. Financier Worldwide. https://www.financierworldwide.com/artificial-intelligence-the-investment-of-2017-and-beyond/#.WieDP0qWZPY (accessed on 2018).

Petrick, I.J., T.W. Simpson. 2013. 3D printing disrupts manufacturing: How economies of one create new rules of competition. *Research-Technology Management* 56(6): 12-16.

Piza, S., R. Edillon, M. del Mundo (2016) "Unemployment protection in the Philippines," in A. Isgut and J. Weller (eds) (2016) Protection and Training: Institutions for Improving Workforce Integration in Latin America and Asia. UN ECLAC and ESCAP.

Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD). 2016. *Innovations: Annual report 2015*. Manila, PH: DOST-PCIEERD.

Philippine Statistics Authority. 2015. http://psa.gov.ph/sites/default/files/attachments/cls/E-CLS_O.pdf

PortCalls Asia. 2017. TradeNet is online platform for PH national single window. Philippines: PortCalls Asia. https://www.portcalls.com/tradenet-online-platform-ph-national-single-window/ (accessed on May 8, 2018).

Prakash, A. 2016. Why robot law around industrial automation varies worldwide. Robotics Business Review. https://www.roboticsbusinessreview.com/manufacturing/why_robot_law_around_industrial_automation_varies_worldwide/ (accessed on 2018).

Prevett, R. 2016. 15 disruptive technology trends to watch in 2017. Disruption. https://disruptionhub.com/15-disruptive-technology-trends-watch-2017/ (accessed on 2018).

PricewaterhouseCoopers (PwC) Philippines and QBO Innovation Hub. 2017. *2017 Philippine startup survey*. Makati City, Philippines: Isla Lipana & Co.

Quimba, F.M., J.R.G. Albert, and G. B. Llanto. 2017. Innovation activity of firms in the Philippines. PIDS Discussion Paper Series No. 2017-44. Philippines: Philippine Institute for Development Studies.

Rahm, J. 2017. Internet of things, manufacturing industry. http://blog.flexlink.com/internet-of-things-in-the-manufacturing-industry/ (accessed on November 22, 2017).

Rahul. 2017. IoT applications spanning across industries. Internet of things blog. http://media.tvilight.com/download/361622/iotapplicationsspanningacrossindustries-internetofthingsblog.pdf (accessed on November 25, 2017).

Ramamurthy, A. and P. Jain. 2017. The internet of things in the power sector opportunities in Asia and the Pacific. ADB Sustainable Development Working Paper Series No. 48. ADB.

Rayna, T. and L. Strukova. 2016. The impact of 3D printing technologies on business model innovation. *Advances in Intelligent Systems Book Series* 261: 119-132.

Reyes, C., A. Tabuga, C. Mina, R. Asis and M. Datu (2011) "Dynamics of Poverty in the Philippines: Distinguishing the Chronic and the Transient Poor. PIDS Discussion Paper Series No. 2011-31

Reyes, C.E., J.L. Rugayan, C. Jason, G. Rullan, and C.M. Oppus, G.L. Tangonan. 2012. A study on ocular and facial muscle artifacts in EEG signals for BCI applications. Paper presented at the TENCON 2012 IEEE Region 10 Conference, November 19-22, Cebu, Philippines.

Rijmenam, M. Where does the internet of things come from? Datafloq. https://datafloq.com/read/where-does-the-internet-of-things-come-from/524 (accessed on November 22, 2017).

Rohit, A.K. and S. Rangnekar. 2017. An overview of energy storage and its importance in Indian renewable energy sector: Part II – energy storage applications, benefits and market potential. *Journal of Energy Storage* 13: 447-456.

Royal Academy of Engineering. 2013. Additive manufacturing opportunities and constraints. London: Royal Academy of Engineering.

Russell, S., D. Dewey, and M. Tegmark. 2015. Research priorities for robust and beneficial artificial intelligence. AI Magazine Winter 2015. Association for the Advancement of Artificial Intelligence.

Salmi, J. 2016. Tertiary education and the SDGs.

Sawyer, K. 2008. Optimizing learning: Implications of learning sciences research. Paris, France: Center for Education Research and Innovation, OECD.

Santiago, A. and F. Roxas. 2016. Alternative framework for renewable energy planning in the Philippines. *Renewable and Sustainable Energy Reviews* 59: 1396-1404

Schettini F., F. Aloise, P. Arico, S. Salinari, D. Mattia, and F. Cincotti. Self-calibration algorithm in an asynchronous P300-based brain-computer interface. *Journal of Neural Engineering* 11(3).

Schoenherr, S. 2004. The digital revolution. *Wayback Machine Internet Archive.*

Schreckinger, B. 2013. Yes, Obama did mention '3D printing' at the state of the union. National Journal. http://www.reshorenow.org/library/3531/yes-obama-did-mention-3d-printing-at-the-state-of-the-union/ (accessed on 2018).

Schwab, K. 2015. The fourth industrial revolution. *Foreign Affairs.* December 12.

Schwab, K. 2016. The fourth industrial revolution: What it means, how to respond. *World Economic Forum.* January 14.

Senjen, R., G. Foladori, and D. Azoulay. 2013. Social and environmental implications of nanotechnology development in the Asia-Pacific region. *IPEN*.

Sebastian, M. and O. Khan. 2015. 3D printing and supply chains of the future. Proceedings of the Hamburg International Conference of Logistics (HICL).

Serafica, R.B. 2016. Why manufacturing resurgence will mean more services, not less. PIDS Discussion Paper Series 2016-46. Quezon City, PH: Philippine Institute for Development Studies.

Singh, A., E. Hirsh, J. Jullens, and R. Wilk. 2016. 2016 auto industry trends. https://www.strategyand.pwc.com/trends/2016-auto-industry-trends (accessed on November 27, 2017).

Sitaram, R., S. Lee, S. Ruiz, M. Rana, R. Veit, and N. Birbaumer. 2011. Real-time support vector classification and feedback of multiple emotional brain states. *Neuroimage* 56: 753–765.

Slav, I. 2017. The fourth industrial revolution is fueled by oil. https://oilprice.com/Energy/Energy-General/The-Fourth-Industrial-Revolution-Is-Fueled-By-Oil.html (accessed on 2018).

Smil, V. 2005. Creating the twentieth century: Technical innovations of 1867–1914 and their lasting impact. New York, US: Oxford University Press, Inc.

Smith, C., A. Mashadi, and L. Capra. 2013. Ubiquitous sensing for mapping poverty in developing countries. Proceedings of the Third Conference on the Analysis of Mobile Phone Datasets.

Technology Application and Promotion Institute. Programs and services. http://www.tapi.dost.gov.ph/programs-and-services (accessed on February 15, 2018)

Soumitra, D. B. Lanvin, and S. Wunsch-Vincent, Editors. 2017. *The global innovation index 2017: Innovation feeding the world*. Ithaca, Fontainebleau, and Geneva: Cornell University, Institut Européen d'Administration des Affaires (INSEAD), and World Intellectual Property Organization (WIPO). 2017.

Sriramoju, S.B. 2017. Introduction to big data: Infrastructure and networking considerations. US: Horizon Books.

Stiglitz, J. 2017. The coming great transformation. *Journal of Policy Modeling* 39: 625-638

Stiglitz (2017) “The coming great transformation” Journal of Policy Modeling 29:625-638
T.A. Grimm & Associates, Inc. 2010. *3D printer benchmark injection*. http://www.tagrimm.com/benchmark-2010/ (accessed on 2018).

Talabong, R. 2017. MMDA chief orders colorum Grab, Uber drivers to get off the streets. 2017. Manila, Philippines: Rappler. https://www.rappler.com/nation/176720-mmda-danny-lim-orders-colorum-grab-uber-drivers-get-off-streets (accessed on April 25, 2018).

The Economist. 2009. *Disruptive technology/innovation*. https://www.economist.com/node/13636558 (accessed on April 15, 2018).

The Economist. 2016. *Precision agriculture: TV dinners*. https://www.economist.com/news/science-and-technology/21707242-unused-tv-spectrum-and-drones-could-help-make-smart-farms-reality-tv-dinners (accessed on December 03, 2017).

The Information and Communication Technological Council (ICTC). 2016. *Additive manufacturing in Canada: The impending talent paradigm*. ICTC.

The internet of things in manufacturing: benefits, use cases and trends. https://www.i-scoop.eu/internet-of-things-guide/internet-of-things-in-manufacturing/ (accessed on November 22, 2017).

Tiopangco, F.P. 2015. Rethinking regulation: Uber and the ride-sharing industry. *Philippine Law Journal* 666. Quezon City, PH: College of Law, University of the Philippines.

Tolentino, M. 2014. Most influential countries for the internet of things. Silicon Angle. https://siliconangle.com/blog/2014/03/21/most-influential-countries-for-the-internet-of-things/ (accessed on December 02, 2017).

Torres, E. and R.W. Domingo. 2016. SC reverses ruling on Bt 'talong' tests. Manila, Philippines: Inquirer.net. http://newsinfo.inquirer.net/800262/sc-reverses-ruling-on-bt-talong-tests (accessed on April 26, 2018).

Ueda, J, D. Ming, V. Krishnamoorthy, M. Shinohara, T. Ogasawara. 2010. "Individual muscle control using an exoskeleton robot for muscle function testing", *IEEE Trans. Neural Syst. Rehab. Eng.*, vol. 18, no. 4, pp. 339-350

United Nations (UN). 2017. The impact of the technological revolution on labor markers and income distribution. Department of Economic and Social Affairs

UN. 2016. *Global Sustainable Development Report 2016*. New York: Department of Economic and Social Affairs, UN.

United Nations Educational, Scientific, and Cultural Organization (UNESCO). 2016. *Nanotechnology is a growing research priority*. UNESCO Science Report.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 2018. Frontier Technologies for sustainable development in Asia and the Pacific.

United Nations Global Compact. *Additive Manufacturing: The rise of the makers*. Project Breakthrough Disruptive Technology Executive Briefs. London, UK: PA Knowledge, Ltd.

Weiland, J.D. and M.S. Humayun. 2008. Visual prosthesis. *Proceedings of the IEEE* 96: 1076–1084.

Velarde, R. and J. Albert. 2018. The Socpen and Its Role in Closing the Coverage Gap Among Poor Elderly Filipinos. World Bank Social Protection Policy Note No. 14. World Bank, Washington, DC. Available at: World Bank. https://openknowledge.worldbank.org/handle/10986/29874

We Are Social and Hootsuite. 2018. Digital in 2018 in Southeast Asia. SlideShare. https://www.slideshare.net/wearesocial/digital-in-2018-in-southeast-asia-part-2-southeast-86866464 (accessed on 2018).

Wile, R. 2014. This technology could have the biggest impact on American jobs since offshoring. BusinessInsider. http://www.businessinsider.com/how-3d-printing-will-affect-manufacturing-jobs-2014-8 (accessed on 2018).

Wolpaw, J.R., N. Birbaumer, W.J. Heetderks, D.J. McFarland, P.H. Peckham, G. Schalk, E. Donchin, L.A. Quatrano, C.J. Robinson, and T.M. Vaughan. 2000. Brain-computer interface technology: *IEEE Transactions on Rehabilitation Engineering* 8(2): 164–173.

World Bank. 2003. Lifelong learning in the global knowledge economy: Challenge for developing countries. Washington, DC: World Bank.

World Bank. 2010. Innovation policy: A guide for developing countries. Washington, DC: World Bank.

World Bank. 2016. Republic of the Philippines: Alternative learning system study. Washington, DC: World Bank.

World Bank. 2016a. *World development report 2016: Digital dividends*. Washington, DC: World Bank.

World Bank. 2016b. Doing business 2016: Measuring regulatory quality and efficiency. Washington, DC: World Bank.

World Bank. 2017. Doing business 2017: Measuring regulatory quality and efficiency. Washington, DC: World Bank.

World Bank (2018) World Development Report 2019. Draft.

World Bank. 2018a. *Doing business 2018: Reforming to create jobs.* Washington, D.C.: World Bank.

World Bank. 2018b. Doing business 2018: Reforming to create jobs – region profile of East Asia and the Pacific (EAP). Washington, D.C.: World Bank.

World Economic Forum (WEF). 2012. The future of manufacturing: Opportunities to drive economic growth.

World Economic Forum. 2013. *Global Innovation and Technology Report 2013,* edited by B.B. Osorio, S. Dutta, and B. Lanvin. Geneva: WEF.

World Economic Forum (WEF). 2015. New vision for education: Unlocking the potential of technology. Geneva, Switzerland: WEF.

World Economic Forum (WEF). 2016a. The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution. Global Challenge Insight Report.

World Economic Forum (WEF). 2016b. Manufacturing our future: Cases on the future of manufacturing. Geneva: WEF.

World Economic Forum (WEF). 2017. *Global Risks Report 2017*. Geneva: WEF.

World Economic Forum (2017) "Global Risk Report 2017."

World Federation of Engineering Organizations. 2017. *Industry 4.0: Engineering the interface with real world.* Technology Innovation Productization 5(1). Paris, France: WFEO.

Wright, I. 2017. Bridging artificial intelligence to manufacturing. www.Engineering.com/AdvanceManufacturing/ArticleID/15670/Bridging-Artificial-Intelligence-to-Manufacturing.aspx (accessed on 2018).

Yamio, R. 2017. Is the Philippines ready for the Internet of Things? FlipScience. https://www.flipscience.ph/technology/iot-philippines/ (accessed on December 04, 2017).

Yee, J. 2018. LTFRB to Grab: Reduce cap on surge pricing. Manila, Philippines: Inquirer.net. http://business.inquirer.net/249046/ltfrb-grab-reduce-cap-surge-pricing (accessed on April 26, 2018).

Younus, U.M. 2017. Fourth industrial revolution. *Dawn.* May 9.

Yu, Y.H., S.W. Lu, L.D. Liao, and C.T. Lin. Design, fabrication, and experimental validation of novel flexible silicon-based dry sensors for electroencephalography signal measurements. *IEEE Journal of Translational Engineering in Health and Medicine* 2: 1–7.

Zeng, F.G., S. Rebscher, W. Harrison, X. Sun, and H. Feng. Cochlear implants: System design, integration, and evaluation. *IEEE Reviews in Biomedical Engineering* 1: 115–142.

Zhang, C., Y.L. Wei, P.F. Cao, M.C. Lin. 2017. Energy storage system: Current studies on batteries and power condition system. *Renewable and Sustainable Energy Reviews* 82(3): 3091-3106.

Zhao, K. and L. Ge. 2013. A survey on the internet of things security. Proceedings of the 2013 Ninth International Conference on Computational Intelligence and Security (CIS). Sichuan Province, China: IEEE.