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Contents

Industrial Technology Competitive Analysis and Its Implications

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1. Introduction

Amidst the chaos of the 4th Industrial Revolution, the leaders of the pack are emerging. On the foundation of the digital revolution, the world is entering the era of an industrial big bang, in which the boundary between the actual and the digital world is crumbling into pieces. Major countries have recognized the 4th Industrial Revolution as the innovative agent not only of national development but also of the development of the economy and society, and have announced national development strategies to break through the Age of Austerity; these include the 'industrial internet' (United States), 'Industrie 4.0' (Germany), 'JAPAN is BACK' (Japan), and 'Made in China 2025 Strategy' (China). Furthermore, a few innovative enterprises which achieved early dominance in the platform ecosystem are leading the global economic order, with the R&D investment of the top 1,000 global corporations exceeding USD 700 billion for the first time in the history of mankind in 2017.

While Korea also invests a substantial amount into R&D, quantitative expansion of investment has failed to facilitate growth, and thus the country is in a growth recession. As of 2016, Korea's R&D spending to GDP ratio ranked second-highest in the world, a 1.5 fold increase (2.83% in 2006 → 4.24% in 2016) from 2006. However, the growth rate and technological competency of Korea is stagnant, or even has decreased, and the path from quantitative expansion of investment to growth has been blocked. Also, in recent years, Korea's R&D investment has entered a recession due to weakened growth potential and an increase in demand for welfare. The government's R&D growth rate, which exceeded 10% on average in the 2000s, gradually decreased after 2008, and has been maintained at around 1% since 2016 based on the R&D efficiency policy.

Establishing plans to respond to the increasing uncertainties and changes in the social, political and economic sector is crucial to maintaining industrial and national competitiveness. To this end, the lifespan of IT, science and technology, and the impacts of the rapid pace of their development on the industry and industrial technology should be identified in advance to prepare the response strategy. Predicting the environment of future industrial technology is also becoming important, as the speed of change is accelerated through globalization and ICT such as social media, increasing the level of uncertainty of

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the future.

In this light, an analysis and enhancement of the political usability of policy paradigms for global innovative nation and the changes in the future industry environment is needed. An in-depth review on the factors which influence the current industry—such as the economic, social and political environment—should take place, based on which the analysis paradigm of the industrial technology R&D competitiveness should be designed. It is urgent to establish short-term, medium-term and long-term growth strategies in order to lead and achieve preemptive responses to the global competition caused by the rapid changes in the industrial environment such as the 4th Industrial Revolution.

This study aims to suggest a methodology for such a competitiveness analysis, verify its potential for application in the future and derive implications by implementing the method in the actual industrial technology sector.

2. Industrial Technology Competitiveness Analysis

2.1 Overview

Industrial Technology Competitiveness Analysis refers to the analysis of the environment of industrial technology in the market using quantitative and qualitative methodologies. Qualitative analysis includes analysis on private and government investment while quantitative analysis includes Value-chain Analysis, Industrial Structure Analysis and Patent Analysis.

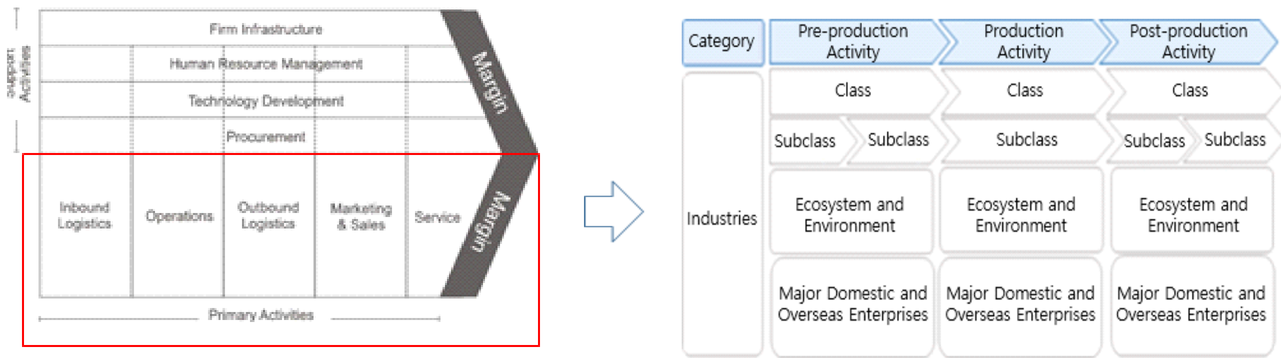
The final outcome of a competitiveness analysis is not expressed in a single numerical value, but consists of multiple results from the aforementioned various methods of analysis. These results are ultimately used as basic data in establishing the visions and strategies of industries. Table 1 shows an example of the application of competitiveness analysis on'Industrial Technology R&BD Strategy' and 'Industrial Technology Roadmap.'

Table 1. Cases of Application of Industrial Technology Competitiveness Analysis

[Industrial Technology R&BD Strategy]	[Industrial Technology Roadmap]
Ⅰ. Concepts and Characteristics Ⅱ. Current Industrial Issues and Key Trends 1. Current Industrial Issues and Other Major Issues 2. Global Trend Ⅲ. Industry Competitiveness Analysis 1. Investment Analysis 2. Business Value-chain Analysis 3. Industrial Competitiveness: 5-Forces Model, Patent Analysis 4. SWOT Analysis Ⅳ. Vision and Strategy	Ⅰ. Changes in Megatrends 1. Definition and Scope of Industry 2. Changes in Megatrends Ⅱ. Global Industrial Ecosystem Analysis 1. Industry Trends and Prospects 2. Industrial Structure Analysis: Value-chain Analysis, 5-Forces Model Ⅲ. Industry Development Strategy 1. SWOT Analysis 2. Industry Objectives and Strategy

* Source: Ministry of Trade, Industry and Energy (2018), Korea Institute for Advancement of Technology (2017)

Figure 1. Value Chain Analysis

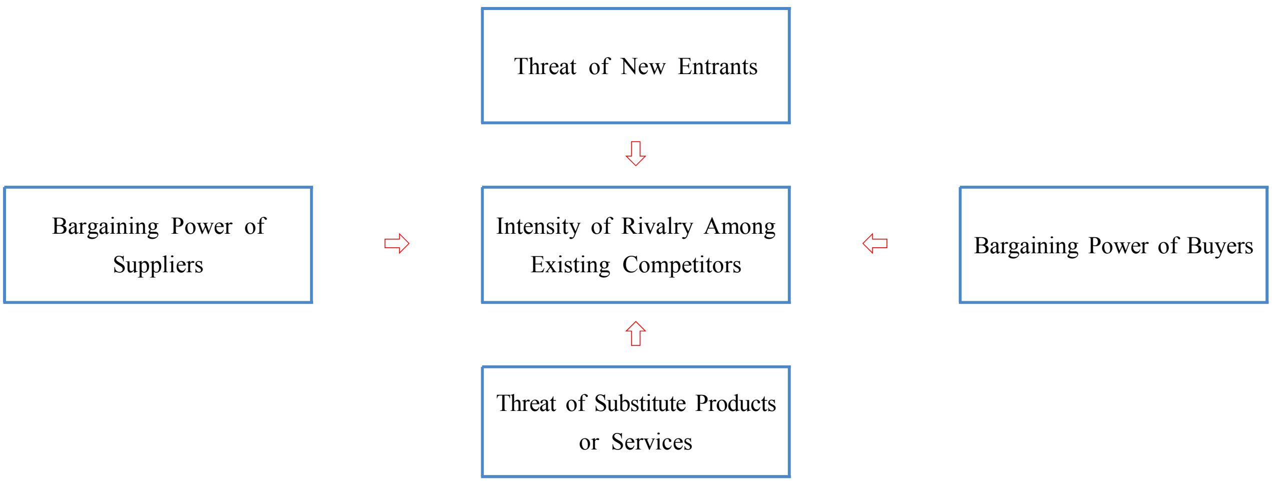


* Source: M.Porter, 1985

<Michael Porter's Value-chain Model>

<Value-chain Model of this Study>

Figure 2. 5-Forces Model



* Source: M.Porter, 1979

2.2 Value-chain Analysis and 5-Forces Model Analysis

This study aims to provide an explanation of both Value-chain Analysis and 5-Forces Model Analysis (two quantitative methods of competitiveness analysis) and provide the results of the two analyses. Both methodologies were developed by Michael Porter, an American economist, and are the most widely used methodologies in analyzing the competitiveness of industry.

Value-Chain Analysis was originally developed to categorize strategic unit activities of enterprises in order to understand the strengths and weaknesses of a company and analyze the source of incurred costs and existing and potential sources of differentiation with competitors (Porter, 1985), but nowadays it is widely used not only in corporate-level analysis, but also in understanding the ecosystem of a sector or industry. This study also took a more expansive approach by replacing primary activities with industrial activities.

The 5-Forces Model (Porter, 1979), a method of industrial structure analysis, lists five major factors which influence the industrial environment (5-Forces), as following: threat of new entrants, bargaining power of buyers, bargaining power of suppliers, threat of substitutes and industry rivalry. By analyzing the five forces while considering the internal capacity of an industry, it is possible to effectively determine which threats to respond to and which to avoid. In this study, this method was used to analyze the current condition and the future of certain fields of industry.

3. Result of Industrial Technology Competitiveness Analysis

3.1 Subject and Method of Analysis

In this study, an Industrial Technology Competitive Analysis was conducted on 20 industrial technologies as defined in the 'Industrial Technology R&BD Strategy[1)]' of the Ministry of Trade, Industry and Energy.

Table 2. Definitions of the Topics of Analysis

Field	Industry	Definition
Transportation	Highly Convenient Long Distance Electric Vehicle	Electrically Propelled Vehicle (xEV) is a vehicle which uses electrical energy supplied from a secondary battery or fuel cell as the source of power for driving
	Highly Reliable Autonomous Vehicle	Vehicle which allows safe driving through autonomous control and minimization of driver control through automatic autonomous control based on self-recognition of surrounding environment and route planning
	High Performance Drone	Drone refers to an aerial vehicle or its system which performs designated tasks without a pilot aboard the vehicle
	Environment-friendly Smart Shipbuilding & Offshore Plant	Vessels, offshore plants and equipment with environment-friendly and smart technology. Vessels, offshore plants and equipment with environment-friendly technologies to reduce energy consumption and atmospheric·marine pollution and ICT for autonomous·unmanned navigation·operation, remote diagnosis and maintenance
Bio-Health	Digital Health Care	Industry of convergence between ICT and health care, which provides advanced patient-customized medical service and health management products·services to improve public health using ICT such as big data or AI
	Customized Bio Medicine	Industry which provides ideal outcomes through a comprehensive diagnosis of genetic attributes and biochemical reaction mechanisms based on genetic information and blood
	Smart Medical Appliance	Industry which produces customized smart medical appliances and services, providing preventive and customized treatments based on measurement, diagnosis and treatment using miniaturized, intelligent and responsive devices
Smart Electronics	Convenient and Safe Smart Home	New service industry which converges ICT with the residential environment to improve quality of life. Home appliance·home-net + Convergence of IoT·AI·big data ➡ establishment of people-centered residential environment

1) Master plan for the Plan for Innovation of Industrial Technology (Five-year plan) in accordance with the Industrial Technology Innovation Act, which serves as the basic strategy for R&D task planning. While the Strategy includes the energy sector, this excluded from analysis for this study.

	Human-friendly Service Robot	Service robots refer to all robots except for base fixed robots used in manufacturing
	Customized Interactive Wearable Device	Provides physical and cognitive augmentation using wearable devices and related service platforms, and creates new industries which provide better quality of life through interaction between the reality and virtual information
Smart Manufacturing	Flexible Intelligent Information Display	Flexible boards which exceed the level of performance of existing glass boards or vacuum technology-based LCD and OLED, providing new video display functions through ultra-high definition, non-vacuum process and convergence with other technologies
	Intelligent Semiconductor	Industry of semiconductors for smart services including calculation, control, transmission, conversion, and storage in IT convergence products (smart cars, IoT, wearable smart devices, etc.) and materials, components and equipment used in the production of such.
	High-tech Manufacturing Process·Machinery	Industry which provides customized equipment and systems through the convergence of production and manufacturing equipment and innovative technologies (robot, AI, big data, IoT) to supply components·products for strategic industries
	Smart Industrial Machinery	Smart industrial machinery refers to an engineering solution which supplies the intelligent machineries and systems needed for future construction and farm works, and provides environment control systems and physical flow to precision manufacturing processes and large-scale buildings
	3D Printing	A technique which produces 3D materials by laminating materials using digital design data rather than through cutting and molding
Infrastructural Investment	Intelligent Information Service	New knowledge-convergent technology which strengthens the competitiveness of the industry and creates added value for products and services through systematic service internalization based on diverse industrial knowledge
	Smart Engineering	Advanced engineering industry which accomplishes comprehensive optimization throughout the entire cycle of engineering of design – construction – operation through the adoption of smart technologies in generic engineering technology, such as design·project management (PM)·plant operation & management (O&M) and the establishment of a digital cooperation environment, based on the application of data-based ideal decision-making technology developed through the convergence and integration of intelligent information technologies of the 4th Industrial Revolution
	Design Convergence	Industry which provides comprehensive product·service concept design and user-focused problem-solving technology development
	New High-tech Material	Innovative materials which can achieve new performances and functions that can lead the advancement of five new industries and other major industries
	Clean Manufacturing	Technology which minimizes environmental load (resources·energy consumption and generation of pollutants) throughout the entire process of material adoption, production, utilization and disposal, and includes clean process, environmental products and services businesses

* Source: Ministry of Trade, Industry and Energy (2018)

Two analyses were conducted on 20 fields of industry to determine outcomes. First, a planning committee consisting of around 10 experts from the industry, academia and research institutes in each field was formed and operated to conduct Value-chain analysis, and an on-line survey[2)] of experts was conducted as the second phase of the analysis. For industrial structure analysis, the planning committee conducted the first phase evaluation based on the points of five factors of competition, which was then supplemented with a peer review by experts.

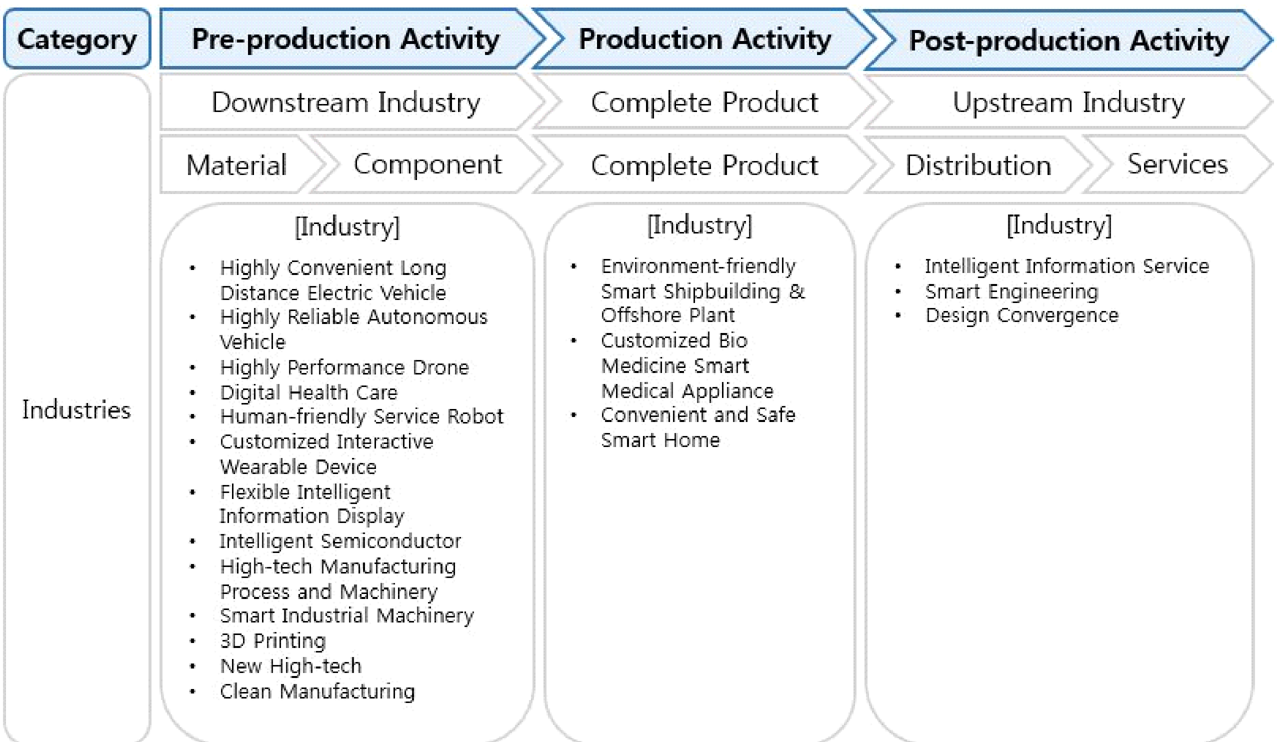
3.2 Results of Analysis

By first conducting a Value-chain analysis on 20 industrial technologies, it was found that the ecosystem of all fields was arranged in the form of a value chain consisting of downstream industry → complete product → upstream industry. Downstream and upstream industries were each segmented into material and component, and distribution and service, while the complete product was not segmented.

The stages of the ecosystem which the 20 industrial technologies place their emphasis vary. By field, transportation, smart electronics and smart manufacturing place an emphasis on downstream industries, while bio-health focuses on complete products, and infrastructural investment focuses on upstream industries.

Downstream industries consist of materials and components industries, and upstream industries consist of distribution and services industries. The results of the detailed analysis by industry is shown in Table 3.

Figure 3. Results of Value Chain Analysis



2) An on-line survey was conducted on 11,710 experts in 20 fields at KIAT, and the responses of 530 experts were used to analyze the results.

Table 3. Detailed Results of Value Chain Analysis

Category		Downstream			Complete Product	Upstream			Others
		Total	Material	Component		Total	Distribution	Service	
Transportation	Highly Convenient Long Distance Electric Vehicle	70.8	24.8	46.0	19.8	8.3	4.6	3.7	1.0
	Highly Reliable Autonomous Vehicle	78.1	17.5	30.6	30.8	20.0	6.9	13.1	1.1
	High Performance Drone	28.5	10.9	17.6	41.5	24.5	7.1	17.4	5.6
	Environment-friendly Smart Shipbuilding & Offshore Plant	42.3	6.3	36.0	26.3	25.0	6.0	19.0	6.7
Bio-Health	Digital Health Care	45.7	21.1	24.6	32.5	21.8	10.7	11.1	0.0
	Customized Bio Medicine	35.0	29.5	5.5	38.9	23.6	9.8	13.8	2.5
	Smart Medical Appliance	25.5	11.2	14.3	48.6	25.9	11.9	14.0	0.0
Smart Electronics	Convenient and Safe Smart Home	35.0	10.3	24.7	37.3	28.3	5.3	23.0	0.0
	Human-friendly Service Robot	59.2	21.5	37.7	15.4	23.1	7.7	15.4	2.3
	Customized Interactive Wearable Device	50.6	30.3	20.3	22.2	20.9	7.5	13.4	6.3
Smart Manufacturing	Flexible Intelligent Information Display	49.7	21.2	28.5	27.7	8.4	4.6	3.8	6.5
	Intelligent Semiconductor	62.5	20.7	41.8	23.6	11.4	6.4	5.0	2.5
	High-tech Manufacturing Process·Machinery	49.6	19.4	30.2	39.2	10.9	4.0	6.9	0.3
	Smart Industrial Machinery	46.0	15.0	31.0	31.3	19.2	9.8	9.4	3.0
	3D Printing	58.5	29.6	28.9	18.9	20.3	6.4	13.9	2.1
Infrastructural Investment	Intelligent Information Service	10.3	3.1	7.2	18.6	70.8	11.4	59.4	0.0
	Smart Engineering	21.0	9.4	11.6	16.9	53.4	8.1	45.3	8.1
	Design Convergence	31.1	17.6	13.5	21.3	39.0	14.5	24.5	8.5
	New High-tech Material	69.1	45.2	23.9	17.6	12.4	7.0	5.4	0.7
	Clean Manufacturing	50.5	30.3	20.2	21.7	24.0	11.0	13.0	3.8

Table 4. Results of Industrial Structure Analysis

Category		Threat of New Entrants	Bargaining Power of Suppliers	Bargaining Power of Buyers	Threat of Substitute Products or Services	Intensity of Rivalry Among Existing Competitors
Transportation	Highly Convenient Long Distance Electric Vehicle	⬆	⬆	⬆	⬇	⬆
	Highly Reliable Autonomous Vehicle	⬆	⬆	⬆	⬇	⬆
	High Performance Drone	⬇	⬆	⬆	⬇	⬆
	Environment-friendly Smart Shipbuilding & Offshore Plant	⬆	⬆	⬆	⬇	⬆
Bio-Health	Digital Health Care	⬆	⬆	⬆	⬇	⬆
	Customized Bio Medicine	⬇	−	⬇	⬇	⬆
	Smart Medical Appliance	⬇	⬇	⬆	⬇	⬆
Smart Electronics	Convenient and Safe Smart Home	⬆	⬆	⬆	⬇	⬆
	Human-friendly Service Robot	⬆	⬆	⬆	⬇	⬆
	Customized Interactive Wearable Device	⬆	⬆	⬆	⬆	⬆
Smart Manufacturing	Flexible Intelligent Information Display	⬇	⬇	⬆	⬇	⬆
	Intelligent Semiconductor	⬆	⬆	⬆	⬇	⬆
	High-tech Manufacturing Process·Machinery	⬇	⬆	⬆	⬇	⬆
	Smart Industrial Machinery	⬆	⬇	⬆	⬆	⬆
	3D Printing	⬇	⬇	⬆	⬇	⬆
Infrastructural Investment	Intelligent Information Service	⬇	⬇	⬆	⬇	⬆
	Smart Engineering	⬇	⬇	⬆	⬇	⬆
	Design Convergence	⬆	⬇	⬆	⬇	⬆
	New High-tech Material	−	⬆	−	⬇	⬆
	Clean Manufacturing	⬇	⬆	⬆	⬇	⬆

* : ⬆(High, 5 Points), −(Normal, 3 Points), ⬇(Low, 1 Point)

Next, the results of the 5-Forces Model analysis showed that ‘Customized Interactive Wearable Device’ scored the highest points, and ‘Customized Bio Medicine’ scored the lowest. Overall, three industries in the field of bio-health showed less intensity of competition, which implies that there is not much that can be done considering that global pharmaceutical companies are monopolizing the market. In addition, the intensity of competition in the field of infrastructural investment did not converge towards a certain direction.

4. Conclusion and Implications

The study suggested Value-chain analysis and 5-Forces Model as the method of competitiveness analysis on 20 industrial technologies, and is presumed to have developed meaningful findings reflecting the characteristics of the industry. Based on this, the methodology suggested by the study can be used in the competitiveness analysis of other industries.

Two implications can be derived from the findings of the study. First, from the perspective of the industrial technology ecosystem, the proposed methodology can be used in the establishment of a new industrial technology strategy. That is, an industrial technology competitive analysis will enhance political utilization at three points in time to promote a growth strategy for Korea to become a global technology leader.

From the short-term perspective, the methodology can be used in the establishment of trend analysis and structure analysis (Value-chain analysis, current status of major enterprises, industry competitive analysis, etc.) in various R&D strategies implemented by government ministries. From a medium-term perspective, the methodology can be used by ministries to set the direction of investment in establishing the budget plan for the following year. For example, the results can be used to set the direction of investment of new financial resources from the R&D budget of MOTIE, which has been reduced from 2019 due to closed government projects. Lastly, in the long-term perspective, the results can be used by ministries to establish medium- and long-term R&D strategies. As the Ministry of Trade, Industry and Energy should establish and promote ‘Plan for Innovation of Industrial Technology’ every five years as per Article 5 of the Industrial Technology Innovation Act, the ministry can utilize the results of the analysis in its domestic/overseas environment analysis or R&D diagnosis to establish the plan.

Second, the significance of Global Value Chain (GVC), a concept referring to activities which mobilize products and services from the initial stage of conceptualization to the final stage of utilization, is increasing due to the rapid changes in the business paradigm, based on the development of new technologies such as AICBM[3] and blockchain, and changes in the global environment such as the expansion of protectionist trade policies. Therefore, by expanding the concept of Value-chain analysis of industries provided by the study, political measures for the Global Value Chain can be developed to allow Korea to take advantage of the Global Value Chain Network and enhance the competitiveness of global leader enterprises.

3) AI, IoT, Cloud, Big Data, Mobile

Table 6. Plans for the Utilization of the Results of Industrial Technology Competitiveness Analysis

Category		Point of Utilization	Content
Industrial Technology Competitiveness Analysis	⇨	Short-term (Following year)	(ex) Government Agency Budget Strategy (MOTIE's R&BD Strategy, etc.)
	⇨	Short·Mid-term (2-3 years)	(ex) Mid-term budget plan establishment of government agencies
	⇨	Mid·Long-term (Over 5 years)	(ex) Five-year Plan for Innovation of Industrial Technology, Science and Technology Basic Plan, etc.

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Measures to promote public technology-based startups : Focusing on entrepreneurship for scientists and engineers

In-jong Lim

Abstract

Technology-based startups are known to contribute to the growth of national economy by creating high-paying jobs, promoting R&D investment, exporting goods and services, etc. Technology-based startups created by using the outcome of government-sponsored R&D projects, namely, public science and technology-based startups, are particularly considered important as their survival rate is over 80 percent and they continue to operate their business for a long period of time.

The purpose of this study is to provide measures to promote public technology-based startups by revitalizing technology entrepreneurship. After examining a hypothesis on factors affecting startup business based on science and technology, it was confirmed that startup training programs and cooperation with external organizations had a positive impact for scientists and engineers to create companies. This study provides following measures to promote startups based on public science and technology. First, expand a cooperative network with outside specialized agencies and share the information focusing on their competencies. Second, encourage to conclude business agreements with regard to startups and provide related guidelines. Third, operate a startup related consultative body for regular exchanges. Lastly, create and expand startup support projects that both public research institutes and specialized agencies can jointly participate.

Keywords: technology-based startup, scientists and engineers, entrepreneurship, promotion of startups, public technology

1. Introduction

1.1 Purpose and background of the study

Korea and the world's leading countries have begun to emphasize the importance of startups and entrepreneurship as their survival strategies and strived to secure new growth engines for the future by promoting startups since the global financial crisis (Lee Yun-jun, 2013). Countries with the top tech-based startups have recognized their importance and made active efforts to secure and maintain national competitiveness continuously by fostering venture companies with innovative new technologies. Korea has also considered creating tech startups as the essence of strategy from the perspective of market dynamism as well as a new growth engine for sustainable development, and implemented various policies to support the efforts to foster tech-based companies. However, the quantitative growth of tech startups in Korea is far behind qualitative one (Hyundai Research Institute, 2013; 2016).

It is known that tech-based startups contribute to the growth of national economy by creating high-paying jobs, promoting R&D investment,

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exporting goods and services, etc. According to the research on job growth of 14 high-tech industries ('90~'11) conducted by Kauffman Foundation, the employment rate of high-tech companies that continue their business for 1~5 years since their inception was two time higher than general companies that operated for the same period.

Tech-oriented startups based on the outcome of government-sponsored R&D projects are particularly important as over 80 percent of them had survived and they showed a high survival rate for a long time after the foundation.

If a researcher, who leads a R&D activity of public science and technology, creates a company based on the technology concerned, positive effects to the business can be maximized as the researcher is in a position that can easily bring innovation to the product and production process by developing new application technologies and speeding up the product time to market (TTM).

However, scientists and engineers hesitated to challenge to start a new business in reality due to a high opportunity cost as they have to take a risk of failure that is huge compared to the benefits of working at a company including high wages, job security, and others (Korea Institute of Startup & Entrepreneurship Development (KISED), 2017).

In the past, being a specialist who focuses on the given area of research and development only was a sole capacity that was required for R&D staff. However, researchers should be generalized specialists now that have the problem-solving capability with macroscopic and comprehensive approaches to R&D by encompassing the entire process such as R&D related management, maintenance, assessment, and policies (Ministry of Science and Technology, 2006). Namely, scientists and engineers of the 21st century should acquire entrepreneurship skills that can wisely respond and even lead dynamic changes in the surrounding environment.

The entrepreneurship is a critical driver that triggers innovative activities and enables to seize market opportunities and create new products and process by differentiating a company from its competitors by being connected to creation, development, and management activities of resources (Miller, 1983; Dollinger, 1983).

In order to promote entrepreneurship for scientists and engineers, this study explored measures that could solve related problems based on the concepts from institutional and network theory. As researchers are from public research institutes with a high risk appetite, it is considered that providing them with institutional frameworks such as support system or entrepreneurship training programs, etc. would help them realize entrepreneurship. This study also looks into the network theory as it is expected that cooperating with external organizations can be effective to complement lack of capacity in starting a new business as companies are making constant efforts to create a network to maintain their competitiveness and complement core competencies in general.

The purpose of this study is to provide measures to promote tech startups based on public science and technology by revitalizing technology entrepreneurship and it is differentiated from the following points.

First, this study deals with public science and technology-based startups and entrepreneurship for scientists and engineers. There are many studies on startups and entrepreneurship in general. However, there is little that directly conduct researches on public science and technology-oriented startups or the ones created by research personnel of public research institutes.

Second, this study focused on the analysis based on institution and network theory. It is true there is almost no academic approaches on tech startups based on the technologies of public research institutes as most studies of this kind were conducted by related ministries and offices in the form of policy research report. Considering the fact that previous studies mainly focused on analyzing the current status and case study only, this study intended to conduct an in-depth analysis and draw on improvement measures based on the theoretical framework of institutional and network theory.

Third, this study was conducted by using highly reliable data and voice of customer (VOC). Basic data of this study, 「Survey report on technology transfer and commercialization of Korea」, that was issued by the Ministry of Trade, Industry and Energy (MOTIE) each year since 2007 by collecting the data of public research institutes of Korea including universities and their research institutes, is more reliable than other survey results of individual researchers and it is a highly valuable analysis material thanks to its representation. This study also reflected qualitative analysis results by conducting focus group interviews (FGIs) on researchers, members of technology licensing offices (TLOs), and others.

1.2 Contents and composition of the study

This study consists of 6 chapters.

Chapter 1 explains the background and purpose of the study. Chapter 2 relates to a theoretical research that defines the concepts of scientists and engineers, technology-based startups, and technology entrepreneurship and looks into the concepts of institutional and network theory. Chapter 3 explores the status of public science and technology-based startups, emphasizes its significance comparing to general startup businesses, and analyzes the state based on the data surveyed. Chapter 4 examines tech startup support policy of the US, Europe, and Japan to benchmark overseas cases, and explains the result of FGIs conducted on scientists and engineers, members of TLOs, technology trade agencies, and companies specializing in technology commercialization. Hypotheses were established in chapter 5 drawing on concepts of institutional and network theory in order to analyze factors affecting public science and technology-based startups and explained the result of data analysis obtained from the 2016 survey report on technology transfer and commercialization of Korea. Lastly, chapter 6 summarizes key findings of this study and provides policy recommendations to promote public science and technology-oriented startups based on the result.

2. Theoretical Review

2.1 Definition of scientists and engineers

An official definition of scientists and engineers of Korea can be found in 「Special Act on Support of Scientists and Engineers for Strengthening National Science and Technology Competitivenes s」 (hereinafter referred to as 'Special Act on Support of Scientists and Engineers') that was established in March, 2004. The term "scientist and engineer" means persons, who have majored in the fields of natural science and engineering, and of interdisciplinary convergence relating thereto, who have a degree in the fields of science and engineering at a two-year bachelor course college or higher education institution or industrial engineers and technicians in accordance with the National Technical Qualifications Act or ones of having equal to or higher than the concerned qualifications (Lee Jung-jae et al., 2008).

According to the definition of Organization for Economic Cooperation and Development (OECD), scientists and engineers (S&E) refer to persons who have completed a higher education in the fields of science and engineering or ones who are engaged in professional work on science and technology

(S&T) without completing such education (Byun Soon-chun et al., 2013).

United Nations Educational, Scientific and Cultural Organization (UNESCO) defines S&E as persons who are directly engaged in S&T activities in certain organizations or fields by being paid for the service they provide (Byun Soon-chun et al., 2013). As for the definition of National Sanitation Foundation (NSF), S&E refer to persons who have majored in science or engineering with a bachelor's or higher degree or ones aged under 75 who are working as scientists or engineers. The definition of NSF encompasses more comprehensive areas of studies than those of OECD or UNSECO. Such comprehensive definition of scientists and engineers could be more desirable considering recent trends of converging S&T, humanities, and social science (Jin Mi-seok & Um Mi-jeong, 2007). The scope of S&E is classified differently according to the academic background, occupation, and related tasks. However, they refer to persons who are working at (or having occupation) in the fields of science, engineering, and R&D (Kim Hong-young et al, 2015).

Table 1. Comparison of international standards on S&E

Item	OECD	UNESCO	NSF	Korea
Title	HRST	STP	S&E Workforce	S&E personnel
Classification	Degree, Major, Occupation	Occupation	Degree, Major, Occupation	Degree, Major, Technical Qualification
Academic attainment	2-year bachelor's or higher degree	X	Bachelor's or higher degree	2-year bachelor's or higher degree
Major	Natural science, Engineering, Medical science, Agricultural science, Social science, and Humanities	X	Natural science, Engineering, Medical science, Agricultural science, and Social science	Natural science, Engineering, and Interdisciplinary convergence relating thereto
Occupation	Professional work on S&T activities	Scientists, engineers, technicians, and assistant staff	Scientists and S&T related occupation	X
Remarks	(Degree∩Major)∪Comprehensive scope of occupation and major	Focusing on the engagement in S&T activities	(Degree∩Major)∪Unique occupation classification system	Degree∩Major

Source: Byun Soon-chun et al., (2013); Kim Hong-young et al, (2015), cited

Table 2. Definitions of technology-based startups

Researcher	Definition
Samsung Economic Research Institute (2004)	• Starting a business that creates innovative technologies • Creating a venture, technology innovation, innovation leading, and technology-intensive business are also included comprehensively
Kim Dae-ho·Kim Hong (2009)	• Starting a business of creating innovative technologies • Starting a technology intensive company that creates jobs and high value-added business such as venture company, INNO-Biz, etc.
Korea Business Incubation Association (2015)	• Technology intensive startup that creates a new market based on innovative technologies and entrepreneurship
Jelinek (1996)	• Refers a series of consistent approaches that are aligned with common understanding to continue joint and technological efforts to interpret undefined data and materials to keep up with technological changes
The Canadian Academy of Engineering (1998)	• Innovative application of scientific and engineering knowledge by an individual or multiple person who create and operate a business and take financial risks to achieve a goal and vision
Garud and Karnøe (2003)	• Play a role of an agency that connects actors with various capabilities, increase the involvement of technology and process, and help to provide more input during the process of changing new technologies
Liu (2005)	• A method of relying on resources and structures for an entrepreneur to pioneer emerging technology opportunities
Dorf and Byers (2005)	• A type of business leadership with capabilities of identifying a high potential and commercialization opportunity of technology intensive products, collecting resources such as talents and financial supports, and solid decision-making skills that manage rapid growth and risks

Source: Kim Yong-jeong (2014); An Seung-gu (2017), cited

2.2 Definition of the concept of technology-based startups

2.2.1 Definition of technology-based startups

The dictionary definition of startup is to initiate a business or the formation of a company. There are many definitions of technology-based startups at home and abroad (Table 2).

2.2.2 Characteristics of technology-based startups

The characteristics of technology-based startups are clearly defined by comparing them with general ones. According to Korea Technology Finance Corporation (Kibo), technology-based startups have different characteristics in terms of types of business, forms of business implementation, and general characteristics as follows.

Table 3. Comparison between tech-based and other startups

Classification	Types of business	Forms of business implementation	Characteristics
Tech-based startups	Manufacturing Professional service (specialization,science,technology) Cultural and knowledge-based business	Produce goods (and services) and engages in sales activities based on new ideas or technologies	Must take a high risk for a high return, if successful Start small with a potential to become an established company through rapid growth
Startups in general	General service Wholesale and retail business (construction)	General forms of business such as restaurants, beauty-related business, and simple product distribution process	A low barrier to entry and frequent creation and extinctions of startups Small business with small budget in general and creates low added-value

Source: Korea Technology Finance Corporation (www.kibo.or.kr)

Academically, Klofsten & Jone-Evans (2000) defined characteristics of research-based spin-offs or technology-based startups, objective of this study, as follows.

First, a research-based spin-off is a new company as a legal entity. It is a company of a legal status with an autonomous structure of its main activities are generating income. Second, it is created based on a parent organization. In general, a spin-off has its root on a public research institute, universities, and other research-oriented organizations and it can be specialized as a research-based spin-off. Third, it utilizes the knowledge generated as a result of academic activities. Here, the knowledge includes technologies, patents, know-how, etc. that are amassed during the process of academic activities.

2.3 Definition of the concept of technology entrepreneurship

The terms of entrepreneurs and entrepreneurship were popularized by Austrian economist J. A. Schumpeter. In 1934, he said that the capitalism progressed based on a new combination of elements such as manufacturing of new goods, quality improvement of existing products, adoption of new manufacturing methods, advancement of new markets, acquisition of new sources of parts and raw materials, and formation of new industrial organizations. He also defined an entrepreneur as a person who is engaged in innovative activities that trigger such ‘creative destruction.’

Since then, entrepreneurship had cited and expanded by various researchers through researches and in many cases. However, most definition of entrepreneurship that came after Schumpeter include activities that ‘accept uncertainties,’ ‘conduct innovative activities,’ and ‘seize opportunities’ in general.

Technological entrepreneurship that emphasized the importance of technology innovation activities in tech-based industries has emerged as a new concept, while studies on entrepreneurship required according to the functional elements of an organization along with the determination of its concept.

For instance, Globe et al., (1973) first used the term of ‘Technology Entrepreneur’ in their study on critical elements of certain complex activities determining the success of technological innovation and defined the person who led an organization for the success of scientific or technological activities. Since then, researchers are taking different views on technological entrepreneurship from various perspectives.

Table 4. Definitions of technology entrepreneurship

Researcher	Definition
Rothwell & Zegveld (1982)	A person who is interested in commercializing the potential of technologies in long-term
The Canadian Academy of Engineering (1998)	Innovative application activities of scientific and technological knowledge by persons who operate a business and assess financial risks to achieve technology goals and visions
Shane & Venkataraman (2003)	A process of integrating resources and technological structure of an organization that is conducted by an entrepreneur for innovative companies to pursue commercial opportunities
Dorf & Byers (2005)	Business style encompassing activities to manage rapid growth and risks by identifying technology-oriented business opportunities with a high growth potential by using decision-making capabilities based on principles and by creating resources and capital that are needed

2.4 Review of related theories

2.4.1 Institutional theory

The essence of institutional theory is that a corporate should achieve and maintain an environmental legitimacy, which refers to a general recognition or assumption that determines whether corporate behaviors are desirable, righteous, and proper with regard to the norms, values, beliefs, and justice established in a system of a social structure (Suchman, 1995). Namely, a corporate is required to comply with the rules and belief system that exist in the surrounding environment for its survival according the institutional theory (DiMaggio and Powell, 1983). Therefore, companies that share the same environment select the same practices and strategies, and undergo isomorphic changes (DiMaggio and Powell, 1983). It means that main reasons for having the same corporate practices are closely related to the surrounding managerial environment or institutional norms of a social structure (Rudolf Sinkovics and Byung Il Park, 2017).

DiMaggio and Powell (1983) clarified the meaning of institution by providing a definition on new institutionalism. In the fields of organization and social theory, a new institution is an independent variable that excludes a theoretical behavior model and includes an individual property or direct interest to motive that cannot be defined as a group in institutional interest, changes in cultural-cognitive aspects, or properties of analyzing ultrafine units. They are forced and supported by the establishment and reproduction of an institution and actors serving as a board of directors (including organizations and individuals). One explanation of the theory from cognitive orientation perspective is that a given institution is encoded by actors through a social process and internalized societal attitudes are transformed into scripts. An institution is taking place when actors take actions according to the scripts and the institution is constantly reproduced following such mechanism. The establishment of institution externalizes or objectifies the institution and other actors witness that the institution is implemented and a new phase of socialization begins. As time passes by, the institution submerges and is considered as natural. After that, actors barely recognize the fact that their actual behaviors are partially controlled by the institution as taking actions following the institution is considered as rational based on the shared institution (Lee Chang-Kuk & Kim Yong-jin, 2015).

With the emergence of neo institutionalism starting from the study of Meyer & Rowan (1977), the significance of institution has been particularly emphasized in organizational studies and studies on institutions and relationships between institution and organization are actively carried out. The emergence of neo institutionalism in organizational studies has its root in the recognition that an institutional environment of which scope is wider than that of task or technological environments significantly affect the structure and operation of an organization (Kyungmook Lee, 1999).

2.4.2 Network theory

A network refers to a 'connection system of various relations' and it is commonly used as a general term with a high interest by many areas of studies. Recently, efforts are made to interpret and analyze social and economic symptoms based on the network theory in various forms (Barnes, 1979).

The network theory is mainly used to the research on relations between organization and the inside of the market as discussions on traditional relations between actors can be carried out by including both economic and non-economic activities. Hence, the network theory provides a comprehensive explanation on a network based on values of both utilitarian or exchange theory, and non-utilitarian perspective. According to the network theory, as a result, an efficiency and network value of an actor through exchange is specified through the network structure (Mizruchi, 1994). A network communication structure that strikes its balance by rational choices of individual actors is structured by combining both rational choices of humans and social values (Jackson and Rogers, 2007). Evaluation, acquisition, integration of a new knowledge and whether it can be commercialized are greatly affected by close and frequent interactions with other companies (Cohen & Levinthal, 1990; Dyer & Singh, 1998; Lane & Lubatkin, 1998). Also, most knowledge and capabilities created through such network are implicit intangible assets and close and frequent interactions between the members of network are needed to create a new knowledge and capability (Kogut & Zander, 1992, Hallėn et al, 1991; Hakansson & Snehota, 1997). It means that companies interact with many actors of innovation and they have closer relations and conduct relation-specific investments on certain actors (Andersson et al, 2001). Therefore, a possibility of creating a new knowledge increases according to the embeddedness between partners who more closely interacts with each other than other network partners (Eung Sok Lee, 2007).

Table 5. Previous studies on public S&T based startups

Author	Level of analysis	Data/methodology	Key findings
Louis et al. (1989)	Faculty of Life Science	Regression analysis on 788 professors at 40 colleges and universities	Determinants of faculty-based entrepreneurship: standards of local groups; policies and structures of universities have little impact
Zucker et al. (1998b)	Relations in which 'star' scientists and US biotech companies are included	Academic journal of science containing the discovery of sequencing and related data of a biotech company from North Carolina Biotechnology Center (1992) & Bioscan (1993)/ Count model analysis	The status of star scientists can predict the entry of biotech companies into the market

Zucker et al. (2000)	Relations in which 'star' scientists and US biotech companies are included	Academic journal of science containing the discovery of sequencing and related data of a biotech company from NCBC (1992) & Bioscan (1993)/ Count model analysis	Cooperation between a star scientist and corporate researchers lead to a better achievement of US biotech companies and the achievement can be measured by: number of patent registration, product developed, and products on the market
Audretsch (2000)	Biotech entrepreneurs	101 founders of 52 biotech companies / Hazard function used for regression analysis	University-based entrepreneurs tend to have more scientific experiences as they get older
Zucker and Darby (2001)	Relations in which 'star' scientists and Japanese biotech companies are included	Biotech companies and Nikkei biotech directory data	Cooperation between a star scientist and corporate researchers lead to a better achievement of Japanese biotech companies and the achievement can be measured by: number of patent registration, product developed, and products on the market
Franklin et al. (2001)	Relations in which 'star' scientists and US biotech companies are included	Quantitative survey of British TTOs by the author	Universities intend to transfer their technologies to startups successfully apply both academic and proxy entrepreneurship
Lockett et al. (2003)	TTOs and university-based startups	Quantitative survey of British TTOs by the author	Universities where startups are created mostly have transparent and well-defined venture strategies, entrepreneurship experts, and large social networks
Di Gregorio and Shane (2003)	University-based startups	AUTM survey/ count regression analysis on determinants by the number of startups	Two determinants of creating startups: capacity of universities and investors that can improve the professor quality and share of startups instead of license royalty fees; royalty distribution methods that are favorable to professors serve as a factor negatively affecting to startup creation
O'Shea et al. (2005)	University-based startups	AUTM survey/ count regression analysis on determinants by the number of startups	Successful technology transfer of university is a critical factor affecting the startup rate
Lockett and Wright (2005)	TTOs and university-based startups	Quantitative survey of British TTOs by the author/ count regression analysis on determinants by the number of startups	The ratio of university-based startups from the total has a positive relation to the amount of investment on IPR protection, project development capacity of TTOs, and the amount of royalty distribution for the faculty

Nerkar and Shane (2003)	MIT startups	Longitudinal data of MIT startups/ Hazard function used for regression analysis	'Fundamental character' of new technologies and their scope of patent application increases more in concentrated businesses than in distributed industries in terms of survival rate; effectiveness of technology strategy of startups is reflected by depending on the environment surrounding the industry
Meseri and Maital (2001)	TTOs and university-based startups	Quantitative survey of Israel TTOs by the author	To assess startup entrepreneurship, Israeli TTOs use standards that are similar to those that venture investors apply
Markman et al. (2004)	TTOs and university-based startups	AUTM survey/ survey by the author/ lineal regression analysis	Equity or licensing, and startup have correlations to the payment of TTOs; they do not have a correlation to royalties paid to the professors or have negative relations
Markman et al. (2005b)	TTOs and university-based startups	AUTM survey/ survey by the author/ lineal regression analysis	Three determinants of speeding up TTM; TTO resources, capability to identify licenses, involvement of faculty inventors during the licensing process
Markman et al. (2005a)	TTOs and university-based startups	AUTM survey/ survey by the author/ lineal regression analysis	It is highly likely that universities prefer an attractive combination of technology development phase and licensing strategy of a venture startup (licensing on initial state technology and its value) as it maximizes short-term profits and due to the fear of taking risks

Source: Siegel (2007), S&M Business Administration· Korea Institute of Startup & Entrepreneurship

2.5 Analysis on precedent studies and oversea cases

2.5.1 Analysis on precedent studies

Table 5 indicates previous studies on public S&T based startups.

2.5.2 Analysis on overseas cases[1)]

2.5.2.1 USA

The Bayh-Dole Act of 1980 was one of the most important measures that allowed public research institutes to actively engaged in the creation and management of intellectual property rights (IPRs) and the act permitted public research institutes to pursue a patent registration and license fee of inventions they made using federal funding.

Later, the US has implemented various policies to promote the technology transfer and commercialization of public R&D achievements for the growth of national economy based on technology innovation. Former president Obama sought the 'Startup America Initiative' to promote startups and emphasized the importance of commercializing public R&D inventions (Jan, 2011), and pursued the 'Lab-to-Market' policy to support major public agencies to commercialize their inventions they own and promote their technology transfer.

1) KISED (2017), Measures to promote strategic tech-based startups for the development of research institutes

Table 6. Main contents of Lab-to-Market

Dept./Institute	Description
Dept. of Energy (DOE)	Sponsored the National Incubator Initiative for Clean Energy (NIICE)
Dept. of Defense (DOD)	Sponsored the Pracademic Center of Excellence in Technology Transfer (PACE/T2), a center for commercialization and technology transfer of Arizona State University
National Health Institute (NIH)	Implemented the Breast Cancer Startup Challenge
National Science Foundation (NSF)	Provided entrepreneurship training programs to researchers through the Innovation Corps (I-Corps)

The US government has set cross-agency priority goals to manage the outcome of lab-to-market initiative in order to encourage related activities. When requesting the congress for the 2015 federal spending, the government stressed the significance to speed up the implementation of ‘Lab-to-Market’ initiative and provided related plans through President’s Management Agenda (PMA).

A representative case of Lab-to-Market is collaboration between NIH and NSF to encourage entrepreneurship for scientists. The NIH plans to induce researchers and corporates supported by the small business innovation research (SBIR) and small business technology transfer (SBTT) programs to participate in NIH Innovation Corps (I-Corps) program, an adjusted version of NSF’s I-Corps for biomedical technology. NSF has been operating NSF I-Corps that provides researchers funded by NSF with training programs and consulting services since 2011.

2.5.2.2 Europe

France, a traditional science and technology powerhouse, has institutionalized the establishment of a company and participation of management by public research institutes since 1982. The French Institute for Research in Computer Science and Automation (INRIA) and the French Alternative Energies and Atomic Energy Commission (CEA), and other public research institute has established subsidiaries to commercialize the inventions with ownership by themselves. The increase of portfolio companies that public R&D institutes are directly and indirectly involved in the management leads to the foundation of a specialized company for commercialization (or technology holding company) with expertise in effective investment and performance management, and promotion of activities related to the foundation of new companies.

Sweden, a country that is constantly ranked among the highest in national competitiveness and innovation indicator, has a characteristic of university-centered technology commercialization policy. At first, there were many restrictions as they were managed as a public sector under the influence of the government. For example, they were not allowed to establish a company by themselves. Also, the startup rate of universities based on the inventions they owned was low compared with other OECD companies as the supporting structure and incentives for new technology-based startups were relatively weak, despite university-centered public R&D structure. However, the country allowed universities to establish technology holding companies in 1994 based on the decision that innovating its economic structure through startups was needed. As a result, many technology holding companies, of which stakes were owned by universities, were founded by 11 universities including GU Holding by University of Gothenburg and Uppsala universitets Utveckling AB (UUAB) by Uppsala University in 1994 and 1995.

Denmark, a small but strong country, established related laws in 2004 and began to encourage activities to promote technology transfer, establish companies, and invest on existing companies of public research institutes. At the same time, the country has provided clear principles on the scope of (capital) investment and area of business of public research institute. For instance, where a public research institute establishes or takes part in the establishment of a company, there should be no conflicts to its public duty, and the equity value or and amount of investment for starting a business should not excess 3% of R&D budget or about $75,000. It was designed to contain concerns about decreasing publicness while realizing expected effect when public research institutes participate in technology commercialization by establishing subsidiaries and with other methods.

3. Status of public technology-based startups

Although the ratio of creation and extinction of startups in Korea is at high class among OECD countries as of 2013 and Korea is a very active country in both emergence and collapse of new companies, it is difficult to evaluate that startups in Korea bring fruitful results. As for the ratio of startup creation, the UK showed the highest score with 15.4% and Korea was in the upper ranks with 13.8%. However, its rate of startup extinction is also relatively higher than that of other countries with 12.1% (2nd place) (National Assembly Secretariat, 2017).

As of 2014, the survival rate of startups in Korea was less than 50% and about 27% after 3 years and 5 years from their inception, respectively, and the figure decreases as the years of survival extend. However, the survival rate of public technology-based startups is higher than the total number of companies. Over 80% of public technology-based startups survive after 1 to 5 years from their inception and showed a high survival rate even if the period of operation gets longer. It can be said that public technology-based startups are created by having their roots in technologies that are developed through government-led efforts and they are usually related to big science and technical skills that civilians are hard to get access to. Hence, public technology-based startups have a huge growth potential in the future for a long period of time.

Table 7. Survival rate of public technology-based startups in South Korea

Classification	2011	2012	2013	2014	2015
1-year	100.0%	94.3%	96.0%	89.3%	98.3%
2-year	81.8%	100.0%	94.3%	96.0%	83.9%
3-year	77.%	81.8%	100.0%	85.7%	92.0%
4-year	-	77.8%	81.8%	93.1%	74.3%
5-year	-	77.8%	77.8%	68.2%	89.7%

Source: National Assembly Research Service (2017)

Table 8. Classification of public technology-based startups

(unit: Number of cases)

Organization		Startups created by concerned researchers and institutes	Companies established through technology transfer	Total
	Public research institute	48	7	55
	Universities	171	33	204
	Others	6	1	7
Total		225	41	266

Source: Survey report on technology transfer and commercialization of Korea (2017)

As of 2017, a total number of 266 startups was created based on public technologies owned by public research institutes (including public research institutes and universities). Among them, 225 cases were directly created by the researchers and institutes, and 41 companies were newly set up through technology transfer.

4. FGI analysis

4.1 Respondents and methods of FGIs

Focus group interviews (FGIs) on experts of concerned areas were made for reference to the analysis on issues for scientists and engineers to start a new business and development of improvement measures. Some of them were used to solidify the validity of hypotheses developed in chapter 5 and others were used as grounds for policy establishment in chapter 6.

The FGI was conducted on 8 persons including 3 researchers, 3 TLO members, and 2 employees of a technology trading association and company specializing in technology commercialization in order to reflect opinions of various fields. The years of service of selected respondents were over 5 years in an effort to ensure their expertise.

Also, S&E respondents who actually try to realize entrepreneurship were selected among the ones who had experienced to start a business or ones who were preparing to start a new one in order to collect the information that is needed for startups in reality.

TLO members of public research institutes frequently communicate with researchers for technology transfer and play leading roles in carrying out commercialization activities. Hence, their opinions were collected from the perspective of overseeing the entire process. Technology trading association and commercialization expert companies were chosen as interviewers as they could provide their opinions as the technology market participants. Face-to-face interviews were made in principle and additional opinions were often reflected via e-mail and on the phone.

4.2 Result of FGI analysis

The following table provides a summary of opinions collected from the FGIs. They were classified into four categories of institution, training, cooperation, and organization.

Table 9. Result of FGI analysis

Respondents	Opinions	Type
Scientists & engineers	There is a less chance to get access to technology entrepreneurship and startups created by researchers. It would be better to have an opportunity to learn about them in depth.	Training
	Comparing to incentives provided after conducting government funded R&D project on a stable basis, conditions to compensate the difficulties and uncertainties of startups (concurrent position, reinstatement, winning R&D bidding, etc.) are insufficient and not unattractive	Institution
	There are not many successful cases of tech-based startups created by S&Es	Training
	Many have little knowledge of detailed procedure or support projects to start a business based on the inventions with ownership	Training
	It is difficult to prepare startups in reality due to complex startup application and deliberation process, and too many documentation works	Institution
	There are many irrational terms and conditions of agreement between a researcher and institute that would break one's will to start a business	Instituion
	Lack of training and education programs related to corporation establishment, taxation, and accounting for startups built by researchers	Training
TLO	Strategic directions of an agency or department goals are focused on technology transfer and it is difficult for researchers to make efforts for tech-based startups	Organization
	It is difficult to actively promote successful cases of tech-base startups built by researchers as they are rare except but Kolmar BNH Co., Ltd.	Training
	Organizational culture of public research institutes does not encourage researchers to start a business directly and they do not have sufficient organizational capacities to support the operation from the initial stage of startups	Organization
	Most TLO resources are concentrated on technology transfer that take the largest part of its business due to manpower shortage and it is difficult to inject the resource to commercialization or startup phase in reality	Organization
	It is difficult to find out external organizations specializing in startups built by researchers	Cooperation
	For a researcher to start a business, much support is needed. Lack of feedback from TLO members may lead to lack of drive	Instituion
Technology trading agencies and commercialization expert company	As for startups by a researcher, it is difficult to share the information as most projects were conducted within the public research institute. Hence, joint participation from the initial period can be hard	Cooperation
	Relationships to public research institutes are related to inquiry on relatively stereotypical business such as technology licensing, valuation, etc. and are mostly about outsourcing requests. Therefore, complex issues such as startups are difficult areas of collaboration	Cooperation
	Difficult for employees to acquire expertise in concerned areas as startup by researchers are not many	Organization
	There are no mandatory rules for private institutes get a separate stake or royalty even when a startup built by researchers were established successfully and there was a fruitful result	Institution

4.3 Problems and improvement measures

The FGI analysis was carried out and identified issues were summarized by classifying them into 4 categories (including institute, training, cooperation, and organization).

As for institution, internal regulations related to startups were established in favor of the institution and which makes researchers difficult to prepare new business and run a company. Lack of incentive systems that may induce cooperation from the inside and outside of an institution was also identified. As for training, learning opportunities for scientists and engineers to cultivate entrepreneurship are basically insufficient as well as the ones to experience practical business related to startups. As for cooperation, lack of mutual information for cooperation between public research institutes and private companies (such as technology trading association and companies specializing in commercialization, etc.) is considered as a problem and they do not well aware of the need to share the information. As for organization, lack of ability to set up management goals, supporting organization, and resources for startups make researchers difficult to get the support they need to prepare for starting a business or carrying out following process.

To come up with improvement measures to resolve issues listed as above, first, there is a need to revise or establish internal regulations related to startups and establish an incentive system for startup contributors (including TLO members, external agencies, etc.). Second, include and operate startup related courses to the job training programs and install regular online/offline programs in Korea Institute of R&D Human Resource Development (KIRD) which is in charge of government-funded training so that researchers can access to various startup related training programs. Third, there is a need to frequently hold meetups and work meetings between public research institutes and private companies before they enter into agreement officially in order to increase mutual understanding on their business, and prepare standard contract forms of each type of business cooperation. Lastly, public research institutes by themselves should make efforts to create a mood for startups by including starting a business as a work task and actively support startups built by research teams by increasing the number of experts in TLO.

5. Analysis on factors affecting public technology-based startups

5.1 Hypothesis establishment

As for market-friendly advanced countries, public research institutes are easy to engage in activities to start a business with their own strategies. However, in Korea, activities related to starting a business are affected by internal regulations established in line with upper levels of government legislation. Also, it is true that startups involving in direct market participation activities, rather than traditional R&D business are taking passive approaches to startups from the institutional level as it has an impact on both the individual and the reputation of the institution concerned. Hence, it is expected that reviews on hypothesis related to the training system to activate startup support system and startups that regulations of institutions are directly applied.

The role and importance of innovative network for a company to maintain its competitiveness continuously in uncertain management environment have been stressed out. An innovative network helps to acquire new knowledge from partners, share risks and uncertainties with them, and provide effective mechanisms in order to respond to organizational innovation (Gilsing & Nooteboom, 2005; Rampersad et al., 2010). Companies are well aware that it is impossible to provide all resources required to obtain and maintain their competitive edge and innovation with internal resources only and are making many efforts to secure measures to utilize resources from external networks to overcome such disadvantages (Yu et al., 2004). Cooperation between internal and external members of network is considered to have a positive impact on startups of scientist and engineers working at public research institutes.

However, it turned out after reviews on precedent studies that there are not ones analyzing factors affecting startups of scientists and engineers from the perspectives of institution and cooperation. Hence, 2 hypotheses were established based on institutional and network theory for each.

5.1.1 Institutional aspect

As for institutional aspect, an analysis was made on determinants of creating research-based spin-offs and their outcome focusing on research institutes such as technology transfer organizations of public research institutes, and unofficial institutions including policies, procedures, practices with regard to commercialization of public research institutes (Kim Yi-soo, 2009).

Public research institutes have unique culture, inducing systems, and rules and procedures (Moray & Clarysse, 2005). Therefore, impacts posed by policies, procedures, and practices of research institutes regarding the commercialization of their research outcome are significant to the achievement of research-based spin-offs and they can serve to trigger more entrepreneur activities (Kim Yi-soo, 2009).

Considering that researchers of public research institutes relatively more tend to avoid risks and hesitate to engage in challenging activities to start a business (KISED, 2017) as they are highly paid and due to a high job security, it is expected that providing programs from the institute level that support startups of researchers will promote more creation of startups.

(Hypothesis 1) A startup support program would have a positive impact on startups of scientist and engineers.

Firms' ability to constantly acquire intellectual resources (such as technology, knowledge, know-how, and skill) is considered as a factor creating their competitive edge (Wernerfelt, 1984;, Teece et al., 1997; McGrath, 2001) and it is an important determinant that maintains their such capability. Hence, the importance of training program to enhance the learning capability of the inside of organization is stressed. Phan et al. (2006) said that training programs for researchers serve as a positive factor in increasing the effectiveness of technology transfer of universities, and Lee Seung-keun et al., (2005) argued that education and training during the process of technology transfer provide a positive impact on the performance. Therefore, it is expected that running training programs for researchers such as technology commercialization, entrepreneurship, startups, etc. will be helpful in promoting activities with regard to startups.

(Hypothesis 2) Training programs will have a positive impact on startups of scientists and engineers

5.1.2 Network aspect

Many research findings confirmed that a network capability is important to both technology transfer and commercialization. In particular, Santoro and Chakrabarti (2002) emphasized the importance of communication between members of technology transfer-related organizations, and they said that free and flexible exchanges between researchers and engineers of universities, and research staff of companies promote the technology commercialization as the technology transfer takes place through a close and individual network between them. In addition, external cooperation among various external partners, customers, experts, etc. (Laird & Sjoblom, 2004) and use of a close external cooperative network are significantly important for the success of technology commercialization (Santoro & Chakrabarti, 2002).

When it comes to startups of researchers, cooperation with TLOs is necessary and it is expected that continuous efforts to create a network with various external actors (such as VCs, RTTCs, and technology commercialization companies, etc.) will play a critical role.

(Hypothesis 3) Regular exchanges between researchers and TLOs will have a positive impact on startups of scientists and engineers.

(Hypothesis 4) Work exchanges with external organizations will play a positive role for scientists and engineers to start a business.

5.2 Methods of analysis and its design

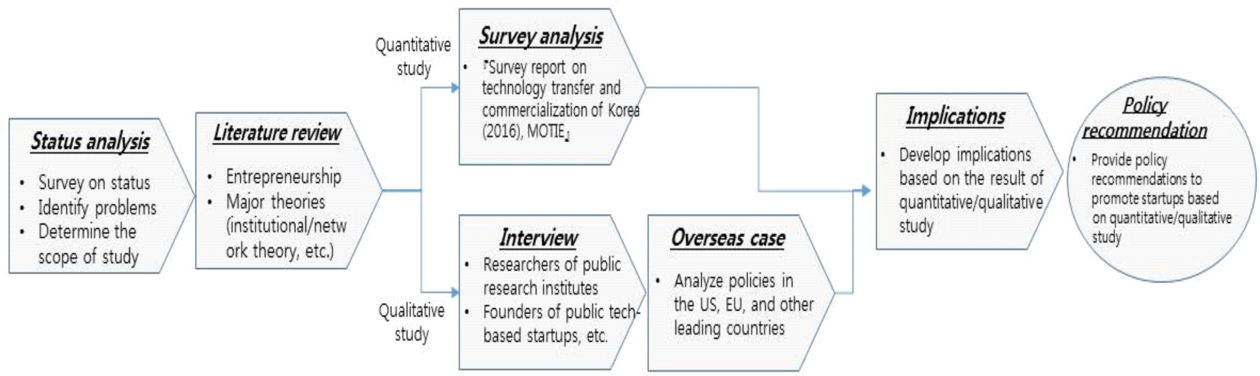
5.2.1 Data and analyzing methods

This study used 「Survey report on technology transfer and commercialization of Korea」, as a basic material. MOTIE releases the survey each year on public research institutes of Korea (including universities and research organizations) since ’07. It is an official survey conducted on public research institutes defined in 「Technology Transfer and Commercialization Promotion Act」 according to KOSTAT approved statistics (Government approved statistics No. 11522) and highly reliable compared with other surveys conducted by individual researchers. It has high analytical values from its representativeness as it surveyed all public research institutes of Korea. This study used the 2016 data that surveyed on 250 public research institutes with smallest missing values for the analysis.

The subjects of analysis were public research institutes, representative public research organizations. Universities carry out education and training activities to nurture research talents and mainly conduct researches on the fields of basic science (Cho Hyun-dae, 2007). University professors work within an academia group where they belonged, and their research activities are mostly taking place by presenting thesis on academic journals (Kim Hyung-joo et al., 2013). However, research institutes are given tasks to conduct public R&D projects that are difficult to be carried out by corporates and universities, assigned such identity within the framework of national innovation system, and they are operated as leaders in implementing national R&D projects to prevent market failures and fill the institutional loopholes in national R&D (Lee Jang-jae et al., 2011).

A general regression analysis can not be applied to the study as the data on the existence of startup support system and internal cooperation used for the study were nominal scales and only two dependent variables were generated. Also, count data such as the number of programs provided, number of agreements signed, etc. cannot have positive values. It was discrete and showed a skewed distribution. Therefore, a negative binomial regression analysis that used a non-linear model based on a probability distribution function, which was proper to be applied to a count data, was adopted in order to develop the most appropriate model to the characteristics of distribution of dependent variables or count data, and relations between dependent and independent variables.

Figure 1. Research model



5.2.2 Variable measurement

As for dependent variables, a number of startups, result of entrepreneurship of scientists and engineers (researchers) was calculated. The number included startups by individual researchers based on the invention owned by public research institute and ones created directly by the concerned institute.

As for independent variables, the existence of system that supports startups by researchers, and the number of training programs for researchers such as entrepreneurship, technology commercialization, startup, etc. were measured. Also, whether researchers and TLOs were having regular exchanges and the degree of cooperation with external organizations were checked and measured from the network perspective.

As for control variables, the number of research personnel working at research institutes were measured.

The operational definition of variables is summarized as follows.

Table 10. Operational definition of variables

Classification	Variable name	Operational definition
Dependent variable	Number of startups	Number of startups directly created by researchers or institutes based on the technologies they owned
Independent variable	Startup support system	Existence of system that supports startup by researchers based on the technologies they owned
	Startup training program	Number of training programs for researchers with regard to startups
	Cooperation within the organization	Existence of regular exchanges with TLOs
	Cooperation with external organizations	Number of business agreement signed with external organizations
Control variable	Number of research personnel	Number of research staff working at research institutes

Table 11. Elementary statistics

Variable name	N	Mean	Standard deviation	Minimum value	Maximum value
Number of startups	112	0.3392857	1.527841	0	14
Number of research personnel	94	254.234	480.0404	0	3802
Startup support system	109	1.642202	0.4815664	1	2
Startup training program	112	2.053571	3.405981	0	20
Cooperation within the organization	109	1.53211	0.5012726	1	2
Cooperation with external organizations	112	0.5625	1.393558	0	9

Table 12. Result of correlation analysis

Variable name	1	2	3	4	5	6
1. Number of startups	1					
2. Number of research personnel	0.3993	1				
3. Startup support system	-0.2907	-0.2671	1			
4. Startup training program	0.431	0.2796	-0.5804	1		
5. Cooperation within the organization	-0.1936	-0.1343	0.4508	-0.3946	1	
6. Cooperation with external organizations	0.3242	0.1785	-0.4428	0.4776	-0.3083	1

* P<0.01

5.3 Result of analysis

5.3.1 Elementary statistics

A total number of 146 public research institutes in Korea was surveyed and 139 institutes answered the questionnaire. The following table indicates the basic statistics that were obtained by analyzing 112 institutes excluding the ones of which data was difficult to be used due to missing too many data.

5.3.2 Correlation analysis

A correlation analysis is a method of statistics used to analyze close linear relations between two variables and it can evaluate correlation between the measurement levels by analyzing the correlation between the concepts injected. The following table indicates the result of correlation analysis of this study. The results showed correlation between variables were not high as all values were relatively low below 0.5. Hence, it is expected that they would not compromise the purpose of estimation significantly to identify influencing factors.

5.3.3 Result of regression analysis

In this study, a negative binominal regression analysis was conducted in order to verify hypotheses on influencing factors affecting startups of scientists and engineers and the results were as follows.

First, an integration model 4 was developed by combining each factor and three individual models (model 1, 2, and 3) were made to identify each factor in detail.

Other than model 4 (integrated model), model 1, 2, and 3 have the number of startups as dependent variables, and contain the number of researchers as control variables. When control variables are excluded, model 2 and model 3 show explanatory power for startups by including institutional factors and network factors only as independent variable, respectively.

To proof the compatibility of models, the Wald Chi-Squared Test was used and the result found that each model held a sufficient explanatory power.

In order to identify the impact of individual independent variables on startups, startup training program among institutional factors had a positive impact in 10% level of significance and startup support system had no impact in model 2.

In model 3, cooperation with external organization among network factors had a positive impact on startups in 5% level of significance and cooperation within organization showed no statistical significance.

In model 4, only cooperation with external organization was appeared to have a positive impact on startups in 5% level of significance.

Overall, startup training program and cooperation with external organizations were accepted and cooperation within organization was rejected.

Table 13. Result of regression analysis

Variable name		Model 1	Model 2	Model 3	Model 4
Number of research personnel		0.003**	0.001	0.002***	0.002***
		(0.001)	(0.001)	(0.001)	(0.001)
Institutional factors	Startup support system		-18.334		-18.639
			(1981.804)		(1322.604)
	Startup training program		0.150*		0.079
			(0.091)		(0.073)
Network factors	Cooperation within the organization			-0.484	0.390
				(0.792)	(0.765)
	Cooperation with external organizations			0.491**	0.292**
				(0.211)	(0.129)
Constant term		-2.319***	16.562	-2.153*	15.907
		(0.577)	(1981.805)	(1.295)	(1322.604)
Chi2		10.551	33.180	21.339	38.083
N		94.000	91.000	91.000	91.000

* p<0.1, ** p<0.05, *** p<0.01

Table 14. Result of hypothesis testing

	Operational definition	Accepted/rejected
Hypothesis 1	Startup support system will have a positive impact on startups	Rejected
Hypothesis 2	Startup training program will have a positive impact on startup of scientists and engineers.	Partially accepted
Hypothesis 3	Regular exchange between researchers and TLOs will have a positive impact on startup of scientists and engineers.	Rejected
Hypothesis 4	Business cooperation with external organizations will have a positive impact on startup of scientists and engineers.	Accepted

6. Policy recommendations and conclusion

Now is the time that public research institutes that conducted government-funded R&D projects only on a stable basis in the past should play an important role by bringing outstanding outcomes and effectively discovering seeds of technologies they owned, and commercializing and starting a business based on them to increase their social and economic use, and creating a virtuous circle.

Hence, this study intended to identify positive factors triggering entrepreneurship for scientists and engineers, main actors of R&D, by applying both qualitative analysis based on FGIs and quantitative statistical analysis on survey data. The result showed that cooperation between public research institutes and external expert organizations is the most critical determinant for startup of scientists and engineers. Hence, this study suggests following policy recommendations to promote startup of scientists and engineers through cooperation between public research institutes and outside specialized agencies.

First, expanding a cooperative network with outside specialized agencies and share the information focusing on their competencies.

Technology trading agencies, TLOs, RTTCs, and technology valuation agencies are considered as the third actors of utilizing and commercializing the result of R&D by playing the role of messengers that link the creation, use, and commercialization of R&D achievement (Yang Seung-woo et al., 2013). In 2010, the government adopted a system of designating an entity that meets certain standards such as dedicated talents, facilities, etc. among companies specializing in technology commercialization to provide financial support for commercialization activities and a preferential right to participate in technology transfer and commercialization projects to promote technology commercialization of private sector. Companies specializing in commercialization engages in business activities such as collection, analysis, and provision of commercialization-related information, support for the exploration, development, convergence, etc. of technologies to advance commercialization, counseling and consulting for commercialization, and invitation and investment of funds necessary for commercialization. As of July, 2018, 29 companies specializing in commercialization are operating their business in Korea.

With regard to startups of scientists and engineers, cooperation with companies specializing in commercialization is needed. However, it was difficult to gather the information on them including their precise size, main areas of activities, status of startup supporting persons, startup reference, etc. Hence, there is a need to provide detailed information on such private specializing companies so that public research institutes can select a partner that is optimal to the areas concerned, size, and type of tech-based startups that they intend to pursue.

Currently, 29 companies specializing in commercialization is concurrently conducting technology trading or brokering business and there are no ones specializing in startups of scientists and engineers only. Hence, there is a need to promote the designation system to include companies with expertise as companies specializing in commercialization, and develop inducements and other measures to expand the pool.

Second, encourage to conclude business agreements with regard to startups and provide related guidelines.

As of 2015, the share of public research institutes that conclude business agreements with universities and research organizations, companies, patent consulting companies, expert technology trading agencies, etc. at home and abroad for technology transfer and commercialization is a 33.3%, totaling 519 cases (1.9 for average)[2]. The number of business agreement signed is increasing each year as 371, 437, and 357 cases in '12, '13, and '14, respectively.

Most of them are related to technology transfer and they are dealing with demand discovery, marketing, brokering, fees, etc. Business agreements related startups of scientists and engineers are difficult to be concluded without willingness of public research institutes and the number of deals completed is not many as well. Hence, it is natural that the private sector reacts passively to sign such agreements. Under such circumstances, the government needs to encourage both parties to conclude business agreements as a position of middleman to coordinate the process smoothly.

Also, creating an agreement by themselves is difficult as it contains many sensitive terms such as states, licensing fees, post-support, etc. compared to general contracts. Therefore, it would facilitate mutual cooperation if the government provides standard business contract samples and guidelines.

Third, operate a startup related consultative body for regular exchanges on information and opinions with regard to startups.

As seen from the result of FGIs, both public research institutes and companies specializing in commercialization face difficulties in the early stage of mutual cooperation as the public research institutes lack of basic information on companies specializing in commercialization when it comes to which company they should contact, and companies specializing in commercialization do not know the status of startups of scientists and engineers working at public research institutes.

Therefore, there is a need to install a consultative body to improve mutual understanding and share their issues all the time. It would be desirable that the promotion agency of each ministry[3] hold such meetings on a regular basis and play the role of facilitator of cooperation between public institutes and companies specializing in commercialization.

Fourth, creating and expanding startup related projects that both public research institutes and specialized agencies can jointly participate.

Currently, public organizations and specialized agencies are partially participating in support projects related to technology transfer and commercialization. Technology transfer supporting projects are conducted to create a network for technology trading promotion, utilize public R&D outcomes, and contribute to the enhancement of technological competitiveness of small and established companies, and joint TLO support projects are exemplary projects. Commercialization projects support additional development of promising technologies or commercialization of ideas owned by companies to facilitate the process, help them enter into markets

2) MOTIE, "Survey report on technology transfer and commercialization of Korea," 2016

3) Each ministry has a dedicated agency specializing in research management activities such as planning, management, and evaluation of national R&D projects assigned by the government. It plays a role of promotion agency to expand the R&D outcomes and facilitate their commercialization in particular

and create profits stably. Examples of commercialization support projects are commercialization connecting technology development business (R&BD, by MOTIE), and investment-linked public technology commercialization support project (MSIT).

However, there are no projects that directly support startups of scientists and engineers and there is a need to create the concerning support project for the long term. The first step is to officially launch a separate track that supports startups of scientists and engineers with the existing technology transfer and commercialization support projects to promote joint participation of public institutes and specialized agencies.

In line with policies to promote startups of scientists and engineers based on cooperation between public research institutes and private specialized agencies, there is a need to consider startup programs for scientists and engineers. Results of statistical analysis showed its significant effect to startups in part and a necessity of providing startup training was raised several times in FGIs.

Although many organizations provide startup related training programs, there are no ones for researchers working at public research institutes. Similarly, there are training programs that are held on the topic of technology commercialization. However, they are mostly focusing on transfer of technologies with ownership and far from starting a business.

Therefore, scientists and engineers who are interested in starting a business should find and attend such programs provided by other agencies and they are not of a great help as most of them are far from the reality of scientists and engineers.

Hence, the government should create training programs that can help scientists and engineers can start their business based on the technologies they developed in KIRD, an organization that is responsible for government-funded research institutes, and the research institutes by themselves to promote their entrepreneurship.

A limitation of this study is that time series analysis was not made. Variables were extracted from the 2014~2016 DB that was obtained from the planning stage and they were turned out that they contained missing data and incomplete answers of survey respondents. Therefore, the statistical analysis was conducted by using the 2016 DB only. It is impossible to complement the DB of the past. On the contrary, it would be meaningful to follow the trends by conducting a time series analysis, if the DB of 2017 and 2018 can be obtained in the future.

Also, it is possible to carry out an in-depth analysis on government-funded research institutes, technology institute specializing in manufacturing, national and public research institutes, universities, etc. main actors of national R&D projects, by considering their characteristics, if the DB with high completion is secured.

Also, there is a need to study the factors and path of successful startups of scientists and engineers. Of course, it will not be easy and such analysis cannot be carried out right away due to difficulties in obtaining related data and lack of samples. Studies on related fields are necessary to provide guidelines for scientists and engineers who are preparing for startups.

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Science and Technology Trends
Blockchain Industries, Regulations and Policy

Blockchain Industries, Regulations and Policy in Colombia

Diana Rojas-Torres

Abstract
The Colombian blockchain industry is among the most advanced in Latin America. This paper investigates the current stage of blockchain deployment in Colombia. We offer detailed descriptions of a number of projects involving blockchain uses in diverse activities such as logistics, election and voting and international trades. The paper gives special consideration to the regulatory and policy environment for the development of the blockchain industry and market in Colombia.

1. Introduction

The Colombian blockchain industry is among the biggest in Latin America. According to Colombia's stock exchange, the Bolsa de Valores de Colombia (BVC), Colombia has Latin America's second largest number of operations related to Blockchain projects behind Argentina (BVC, 2018).

According to the Central Bank of Colombia, the number of ATMs using cryptocurrencies is growing around the World. Out of 2772 ATMs worldwide, Colombia had 23 ATMs, accounting for 0.83% of the world total (BTC, 2018). Latin America is considered to have a great potential for the adoption of Bitcoin according to the index of the potential bitcoin market of Hileman (Hileman, 2014). Colombia is in the position number 84 in the ranking, Argentina and Venezuela are the countries in Latin America with the greatest possibility of using cryptocurrencies due to the weakness of their national currencies and the public institutions that support them.

Countries where there are cryptocurrency transactions require places to make such a monetary exchange (EX), in order to facilitate the deposit, transfer and exchange of cryptoactives in Colombia there are companies such as Buda, Panda and Bitcoin Suramérica that offer the exchange service in local currency. However, in Colombia there is a lack of regulation and the regulatory agencies have exhibited unfavorable.

For example, in August 2018, the cryptocurrency platform Buda closed its operations in Colombia. Its accounts were blocked because the Financial Superintendence showed a concern that these platforms can be used for money laundering, finaning terrorism and engaging in activities related to the weapons of mass destruction (Revista Dinero, 2018).

In Latin America, Colombia has a market in the development of crypto-active products, being one

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of the leaders in adoption. The transactions in LocalBitcoin were more than US $45 million during 2017 – 2018 (BSL, 2018).

2. The current stage of blockchain deployment

The Ministry of Information and Communications Technologies (MinTIC), proposes that technology can be used in Colombia for the registration of intellectual property, and property or real estate; storage of critical documents; execution of smart contracts; monitoring of investments, expenditures or supply chains, or the promotion of the Internet of Things. According to the Observatory of Digital Economy of the MinTIC, 1% of companies in Colombia have adopted Blockchain technology and 3% are in the implementation stage (Bastardo, 2018).

The MinTIC has carried out various activities to build and strengthen the Blockchain community, for example. Colombia 4.0; digital meeting of orange economy organized in october that brought together more than 72,000 participants and where there was a module dedicated entirely to this technology, where workshops, lectures and training by experts were held (Colombia 4.0, 2018). Other activity is the Digital Government Week (CIO Summit, 2018); a scenario in which IT leaders, the Chief Information Officer (CIO) of the national and territorial public sector, can see progress on issues relevant to their performance, in the event took place the first Blockchain Hackaton in the country, where 4 challenges were identified of public policy that could be addressed through blockchain technology.

Independent events such as Blockchain Summit Latam (BSL), seeks to connect developers and promoters of Blockchain at a Latin American level with regulators and industry leaders to generate community, inform and promote Blockchain technology, and its impact for government, companies, academia and entrepreneurs in the world. The event took place in Bogotá – Colombia and for two days were offered conferences, talks, workshops and the Hackathon with experts in the field with the participation of more than 60 developers.

Groups like Blockchain Colombia, Blockchain Academy Colombia, BogoHack, Blockchain Colombia Foundation among others, seek to generate culture around the use of this technology. The Blockchain Colombia Foundation aims to articulate the ecosystem, starting with culture and education activities. A concrete task is to accompany the good decisions of the national government regarding the use of Blockchain technology. The main actors of the country's Bitcoin ecosystem participate, such as Buda.com Colombia (Sur-BTC), Panda Exchange, BEN (Blockchain Education Network) Colombia, RSK, ViveLab Bogotá, Cajero.co, IntiColombia (Tovar, 2018).

MinTIC of Colombia with ViveLab has two projects under test; the first is related to the first student votes in state schools, the results showed teachers the facility to record votes for elementary students make the digital election process, the logistics of voting and time used by teachers and students were optimized, the time estimated 10 to 20 minutes, when they have several teams available; The elective candidate for each school has a particularly characteristics, it is necessary that the voting platform can be customize, as for the number, names, photographs of candidates, the typology of positions and the database of students qualified to vote (Alcaldía Mayor de Bogotá, 2018).

The second is a prototype called "Blockchain Tierras," developed by the National University of Colombia, through ViveLab Bogotá and with the support of Colciencias and MinTic to The National Land Agency for land allocation or restitution processes. One of the advantages of the system is that employees can have access in real time to databases from anywhere in the country without violating the confidentiality of the files (Agencia Nacional de Tierras, 2018).

The system incorporates biometric facial recognition mechanisms for user input. The first element is the Ethereum Blockchain, used to load information about land and owners, where it can only be consulted by those who manage the private key associated with it. The second is an IPFS network; and the third one is a MongoDB database to store more general data (Di MAtteo, 2018).

Digital plebiscite: An initiative to allow expatriates to participate in the plebiscite for peace 2016, based on Blockchain. The OECD reflected this process, commenting on the impact and future of Blockchain on electoral processes (OECD, 2017).

Buda.com is a Chilean company with operations in Colombia that develops and operates services using Blockchain technology for the financial sector allowing cryptocurrency exchange for Colombia.

The Bank of the Colombia Republic formalized an agreement with software company R3, which allows clients to know and experience the main advances in technology shared records (Distributed Ledger Technology) using Blockchain.

Carvajal Technology and Services is the company in charged of the designed an electronic billing platform that performed and stored invoice information using Blockchain in an encrypted way (Revista Dinero, 2017). The Bancolombia (private bank) and − Carvajal joint an Alliance with the objective to create solutions that provide competitive advantages for companies, by integrating the Electronic Invoice with the services of Factoring and Cash Management with Bancolombia clients (Grupo Bancolombia, 2018).

IBM; the business layer that allows you to créate applications on Blockchain through IBM Cloud, has become a space of research and development that allows develop with many tools total layout applications on Blockchain. An example in Colombia is AOS start up working with insights from “supply chain” and finance proposing an initiative called Banconfio.

For the Minister (enchanrged) Juan Sebastián Rozo; Colombia has a big opportunity to become a reference in the region, taking into account the exchanges with countries like China, England and the United States, countries with high level in the adoption of this type of technology (Bastardo, 2018).

Table 1 presents some major examples of the uses of blockchain in Colombia. We briefly discuss some of them in this section.

2.1 Improving logistics and shipping

Blockchain also provides opportunities to improve logistics and shipping in the country. In June 2017, IBM announced a partnership with the Colombian of logistics solutions provider AOS to develop a system based on blockchain and Internet of Things (IoT) in order to increase efficiency in the logistics business. The solution is based on IBM Blockchain and IBM Watson. It is expected to make the delivery process more transparent by tracking the provenance as well as status of trucks in real time (Keane, 2017).

2.2. Tracking sustainability initiatives

Foreign companies that are developing blockchain solutions for implementing and tracking sustainability initiatives are also teaming up with Colombian companies. A number of these initiatives have been specifically designed to use blockchain’s tranparency and immutability features to ensure that value chain partners are paid farirly and that food products have not been adulterated (Kshetri, 2019).

Dutch startup teamed up with the blockchain firm FairChain Foundation and Bext360 to launch a blockchain-traced coffee product called Token. By June 2018, Blockchain was used to track 60,000 kilograms of coffee exported from Ethiopia to the Netherlands (Vu, 2018). Moyee’s plan is to launch

Token in Colombia in 2019 (Bryman, 2018). Likewise, Nestlé was reported to be working with a mango provider in Colombia (Johnson, 2018).

2.3. Expanding opportunities for voice and empowerment

Blockchain is also being used to expand opportunities for voice and empowerment in political and civic matters (Kshetri and Voas, 2018). For instance, in the 2016 Peace plebiscite that was conducted to ratify the agreement to terminate the existing conflict between the Colombian government and FARC guerillas, the non-profit organization Democracy Earth Foundation used blockchain. The idea was to give Colombian expatriates a voice. A main challenge, however, concerned the lack of maturity in the technology (Ooijen, 2017).

Table 1. Some major examples of the uses of blockchain in Colombia

Sector/activity	Examples of blockchain use
Logistics	Liftit: Liftit is a platform that focuses on the transport provision of logistic and removal services and hiring third-party vehicles. The International Finance Corporation (IFC) will invest US$4 million in the project.
	AoS is working on two projects: a) Banconfio is a financial solution for unbanked people; b) Vehicle tracking solution to optimize loads and deliveries and to handle contractual issues.
Elections and voting	Votes at schools: Prototype made between the High Counseling District ICT, the District Department of Education and the Vivelab of the National University, Three public schools from the district were selected to conduct their votings using blockchain, with the purpose of guaranteeing transparency, democracy and security of the information collected. Democracy Earth Foundation: launched a blockchain-powered digital voting platform Plebiscito Digital (Digital Plebiscite) with an objective to allow Colombian expatriates living abroad to cast votes in the 2016 Peace plebiscite.
Land registry	Blockchain Tierras: is a prototype to The National Land Agency for land allocation or restitution processes.
Agriculture and Sustainbility	Choco4Peace is using blockchain hyperledger technology to improve the production and commercialization of Colombian cocoa in international markets. It aims to support small producers of cocaine that find difficulty to access financing. Blockchain's decentralized feature is expected to be helpful in connecting cocoa retail producers with chocolate manufacturers, socially oriented investors and other key stakeholders, such as sustainable development service providers[1]
Facilitation of international trade	The Danish shipping company Maersk and IBM have jointly developed a blockchain-powered shipping solution TradeLens. TradeLens aims to bring various parties involved in international trade together. Maersk validated its solution with pineapples from Colombia that were transported into the Port of Rotterdam in the Netherlands[2]

1) http://ictupdate.cta.int/2018/09/04/building-lives-with-dignity/
2) https://port.today/maersk-and-ibm-introduce-blockchain-in-shipping/

3. The regulatory and policy environment

The regulatory environment for blockchain applications is rapidly evolving in Colombia. The new President said that he would introduce new policies that would exempt information and communications technology (ICT) companies from paying taxes for the first five years in if such companies generate a certain number of jobs. Observers have noted that this could also apply to blockchain companies (O'Brien K, 2018).

Table 2 presents some key regulations governing cryptocurrencies in Colombia. Colombia still does not have a specific regulatory treatment of cryptocurrencies and so far only public campaigns have been implemented alerting citizens about the risks of cryptocurrencies.

Colombia is one of the world's top adopters of electronic invoicing. The government is planning to make e-invoicing mandatory for all businesses starting January 2019. The requirement of e-invoicing has led to the formation of a number of finance-focused blockchain startups. They plan to use blockchain to create tools that help businesses understand and leverage the data produced by electronic invoicing and make more informed business decisions (Lustig, 2018). The newly elected President assured Blockchain technology would play a fundamental role in guaranteeing the transparency of the bidding processes handled by the State (El Tiempo, 2018).

The Colombian Central Bank was one of the first organizations to collaborate with the blockchain development firm R3 in 2017 to discuss opportunities for partnership. However, government has yet to recognize cryptocurrencies officially. Bitcoin exchange platforms such as LocalBitcoin and Colbitex are operating in regulatory grey área, although some local merchants already accept Bitcoin as payment.

The National Development Plan (2014-2018) defines innovation as an action line to increase value per money promoting innovation in the Colombian market with demand driven approach. The regulation allows governement agencies to contract without competition when the purpose of the contract involves scientific investigation and development projects with innovative solutions. In fact, there is a iniciative called "Colombia compra eficiente"; the objective of the Public Purchase for Innovation is to develop instruments for State Entities to meet their needs through innovative solutions where solutions using Blockchain are expected (CCE, 2018).

Just like in other developing countries such as China, Nigeria and Bangladesh, the use of cryptocurrencies is not legal in Colombia (Wu, 2018). As is the case of other countries financial regulators are concerned about the risks related to the use of cryptocurrencies by terrorists (U.S. Securities and Exchange Commission, 2017). Moreover, tax authorities can not collect taxes when cryptocurrencies are used as a means of payment (Wu, 2018).

Table 2. Some key regulations governing cryptocurrencies in Colombia

Law	Explanation
Bank of Colombia, External Resolution 8, 2010	The Colombian central bank declared that cryptocurrencies were not authorized as a medium of compliance of exchange transactions
2014 – Financial Inclusion Law	It established specialized electronic deposit and payment firms as new channels for the distribution of financial products. That included the possibility of providing these firms access to deposits at the Central Bank

Superintendencia Financiera de Colombia, Circular Letter 29, 2014	It noted that cryptocurrencies have potential risks when they are acquired or traded. It went on saying that cryptocurrencies are not regulated or underpinned for any monetary authority or physical assets, and its acceptance is limited.
Central Bank of Colombia, 2014	It delcared that cryptocurrencies are not legal currencies in Colombia, mainly because the only legal currency in Colombia is the Colombian Peso (COP) (issued by the Colombian central bank (Bank of Colombia, Law 31, Art 6, 1992))
Central Bank of Colombia, External Regulatory Circular Letter DCIN-83, 2016	It noted that Bitcoin is not an asset that could be considered as a currency, because it does not have the support of central banks of other countries. Consequently, it cannot be used to execute currency operations endorsed by the currency system issued by the Colombian central bank's management board. They have established authorized mediums to pay the importation of goods which are currencies allowed by International Monetary Fund (IMF) and the Bank for International Settlements (BIS), COP, and International Credit Card charged in those currencies or COP. It implies that not even all other currencies are considered a medium of payment with legal course in Colombia, however, it does not imply that those currencies are illegal in Colombia; in fact, they are legal medium of payment in Colombia.
Central Bank of Colombia, September 29, 2016	It delcared that cryptocurrencies cannot be used as local currency. It further suggested that cryptocurrencies do not constitute a legal form of payment for operations through the foreign exchange market, such as: a) imports or exports of goods and services. b) Foreing investment. c) external indebtedness. d) guarantees in foreign currency. e) derivates trnsactions.
Superintendencia Financiera de Colombia, Circular Letter 78, 2016	It again explained that the only legal currency in Colombia is the Colombian Peso (COP), issued by the Colombian central bank. Moreover, it indicated that cryptocurrencies have not been recognized as a currency, because cryptocurrencies are not an equivalent asset to the legal currency in Colombia, and they do not have legal tender without limitation for curtailment obligations.
DIAN, Concept 20436, 2017	Document: Mining of virtual currencies is taxed with the income tax. It noted that virtual currencies are not money for legal purposes. However, in the context of the activity of mining is a service provided and generate commissions and it corresponds to income and for those who obtain them as an income is part of its assets and have effects on taxes.
Superintendencia Financiera de Colombia, Circular Letter 52, 2017	It noted that the monetary and account unit is COP issued by the Central Bank. It suggested that electronic currencies - cryptocurrencies or virtual currencies do not have the backing of any Central Bank, so they can not be used as a legal money. It went on saying that cryptocurrencies are not a legal payment method with unlimited liberating power, it is not compulsory to receive cryptocurrencies as payment method.
Law Project 028, 2018	Regulates the use of virtual currencies or cryptocurrencies and forms of transaction with these in Colombia. The law proposes some institutions have authorization to use them. Even raises that those who are not authorized, (natural or legal person) are sanctioned with high fees. Article 14. Transaction taxes. Articles 8, 9, 10 and 11. Limitation of actors that can participate in the market.

4. Concluding comments

Developing countries in particular have the opportunity to create a policy and regulatory environment that enables the scaling up of 4IR technologies that can support NDC implementation (e.g. emissions standards for automated electric vehicles, interconnection standards and net-metering policies for a distributed grid, efficiency standards for Internet of things devices and blockchain systems, and payment-for-performance mechanisms).

The Colombian blockchain industry and market are rapidly evolving. Blockchain technology has a great potential to transform the country's economic, political and social landscapes. Various blockchain projects discussed in this paper suggest that this technology can play a key role in facilitating international trades.

There is a lot of room for improvement on the regulatory and policy fronts. As is the case of India (Kshetri, 2018) tough cryptocurrency regulations can affect the broader blockchain environment negatively. This is because blockchain start-ups often fund their projects by issuing new cryptocurrencies. If start-ups are banned from utilizing this new fundraising tool, it can affect the blockchain ecosystem unfavorably.

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Science and Technology Trends
Blockchain Industries, Regulations and Policy

Blockchain Industry, Regulations and Policy in Estonia

Risto Hansen

1. Introduction − blockchain trends in Estonia, the leading country in the blockchain industry

While named 'the most advanced digital society in the world' by Wired (Hammersley, 2017), Estonia is a true pathfinder in e-governance solutions. The Baltic state has built an efficient, secure and transparent ecosystem, saving its population, as well as the public system, both time and money. About two decades ago, when the information society was starting to develop in Estonia, no digital data on Estonian citizens was being collected. The general population did not have access to the Internet or even devices enabling access to it. It took a great deal of courage from the Estonian state to invest in information technology (IT) solutions and take the first innovative steps down the information technology road, steps which have now transformed Estonia into one of the world's most developed digital societies.

However, being a digital society also means exposing oneself to cyber threats. After Estonia's experience with the 2007 cyber-attacks (e.g. Ottis, 2018), scalable blockchain technology was developed to ensure the integrity of data stored in government repositories and to protect this data against insider threats. With KSI Blockchain, deployed in the Estonian government networks, history cannot be rewritten by anybody and the authenticity of electronic data can be mathematically proven. It means that no-one − not hackers, not system administrators, and not even the government itself − can manipulate the data and get away with it.

With the fourth industrial revolution, the importance of fostering blockchain industries is becoming more apparent. Solid investments in cyber security infrastructure have helped Estonia develop extensive expertise in this area, becoming one of the most recognised and valued sources of international cybersecurity expertise. Today, Estonia is host to the NATO Cooperative Cyber Defence Centre of Excellence and the EU-LISA (the European Union IT agency), showcasing the strategic focus of the country's innovation, research and development within the spheres of cyber security and cyber defence and domestic and international cyber defence exercises and trainings. Also offering reliable day-to-day management of the related infrastructure, hosting large, critically valued, EU databases.

Technology changes rapidly, this is also true in the blockchain industry. It is important to understand the nature, benefits and use-cases of blockchain technology as much as to consider its misconceptions

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and future challenges, impacting wider implementation and development within the industry.

2. Understanding the background of blockchain in Estonia

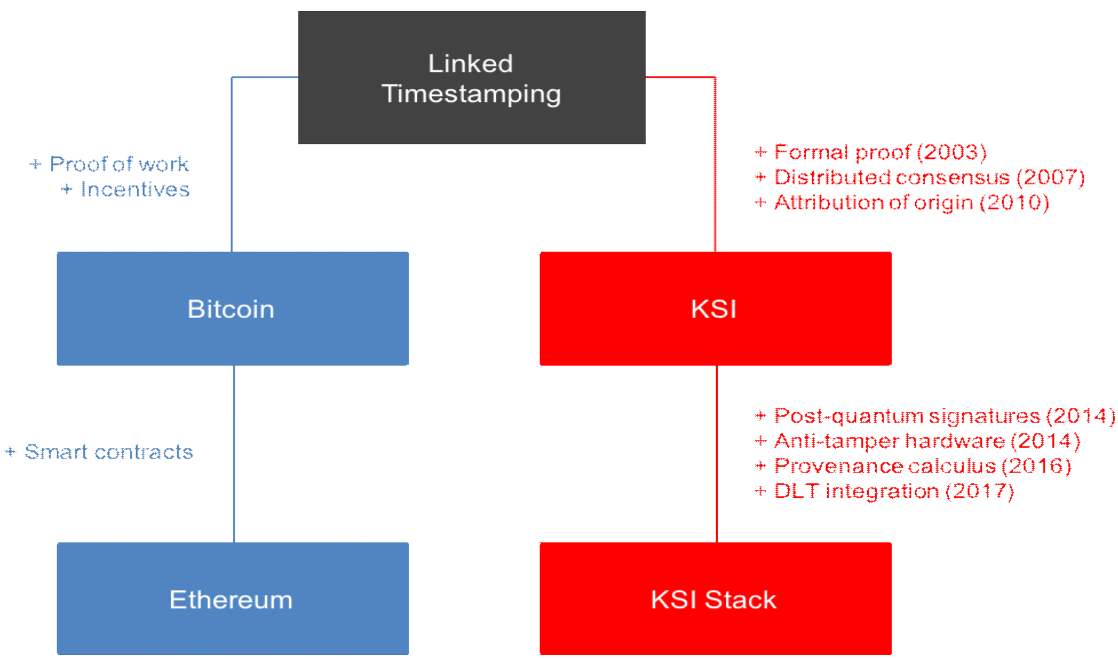
After taking the first steps toward becoming an e-state, Estonia realised that the risk of cyber-attacks will always be part of the information society – a risk that must be taken seriously. After analysing different options, Estonia found a solution for this: blockchain technology – a mathematically ensured cyber security solution for identifying the use and misuse of digital data and intelligent devices, providing transparency and reliability to all organisations and institutions related to and working with digital data or intelligent devices in the public or private sector.

Although blockchain has only become 'hot' technology in recent years, Estonia is leading the way in the blockchain revolution – the state has been testing the technology since 2008, i.e. even before the release of the Bitcoin whitepaper which first coined the term "blockchain" (Nakamoto, 2008). Since 2012, blockchain has been employed in Estonia's data registries, such as the national health, judicial, legislative, security and commercial code systems, with plans to extend its use to other spheres such as personalised medicine, cyber security and data embassies.

2.1. From timestamping to the blockchain

While the academic pedigree of bitcoin often goes unknown, the cryptography behind those individual components has been well known since the 1990s (Haber & Stornetta, 1991) and Guardtime's cryptographers have been very active participants in that history.

Figure 1. Blockchain Technology Family Tree



Source: Guardtime (2018a)

One of the core concepts behind bitcoin is called 'linked timestamping' and Professor Ahto Buldas and Märt Saarepera (PhD) of Guardtime were the first cryptographers to give a formal security proof in 2003, i.e. defining what properties are needed for hash-functions and data structures in order to build a formally verifiable security proof (Buldas & Saarepera, 2004).

Formal verification might sound arcane but if you want to build a house you had better make sure the foundations are solid − and formal methods and verification are the basis of everything that Guardtime does today.

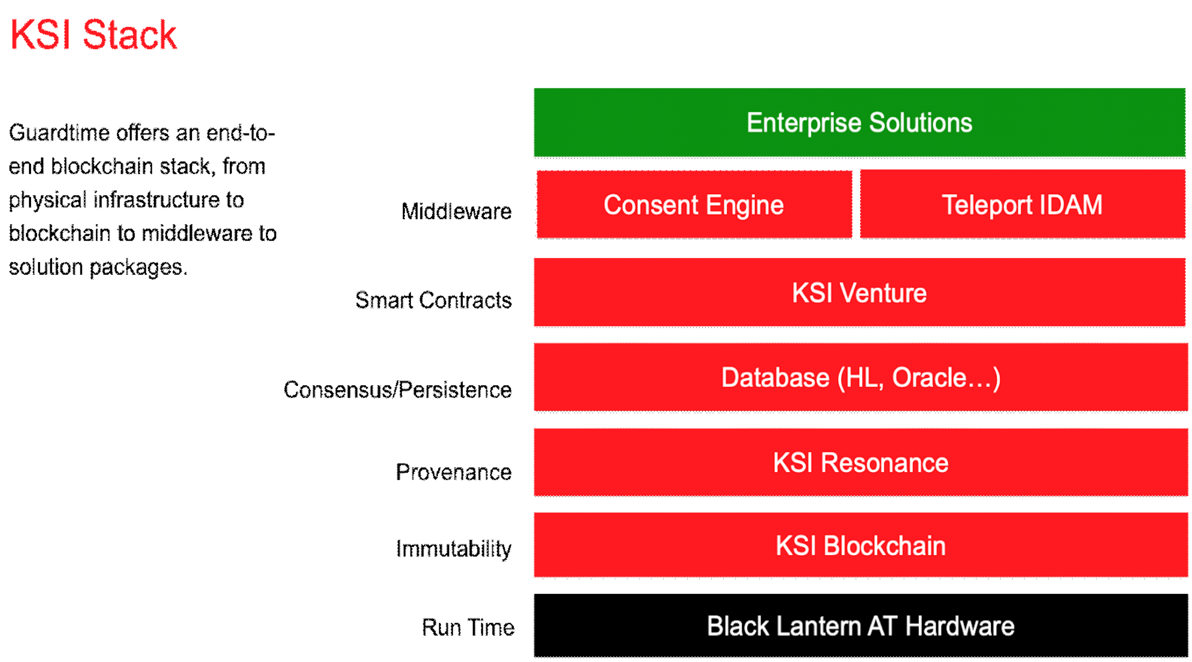
The Estonian blockchain company Guardtime was launched in 2007 with the goal of creating a formally verifiable security system for the Estonian Government, i.e. eliminating third parties, trusted insiders or cryptographic keys in the verification of the integrity of government records, networks and systems.

Cryptography, like mathematics, starts off with assumptions (axioms) and derives conclusions from those assumptions. The goal was to eliminate humans from the list of assumptions needed to make assertions about the time and integrity of digital records, such as documents in a government registry, configuration files in a network router, or software running inside an IOT device, etc.

The challenge was not cryptography but engineering, building a scalable and reliable service for the government that would continue to function even under constant cyber-attack.

As a result, the system was successful and went into production in April 2008 and over the last decade, Guardtime has continued to innovate, adding more and more functionality to the platform. Guardtime has added post-quantum signatures to replace RSA, Anti-Tamper hardware (Black Lantern), a provenance calculus designed to track and trace digital information as it crosses organisational boundaries and many other new features (Guardtime, 2018a).

Figure 2. Guardtime's KSI ® Technology Stack



Source: Guardtime (2018)

The result is a stack of technologies, designed in the spirit of the Unix philosophy – abstraction and encapsulation of functionality into layers, each of which does one thing well.

Ultimately blockchains are just tools used to solve customer problems. Guardtime's mission is to leverage these tools, work with partners and build the highest-quality enterprise solutions possible.

2.2. Estonian KSI Blockchain Technology

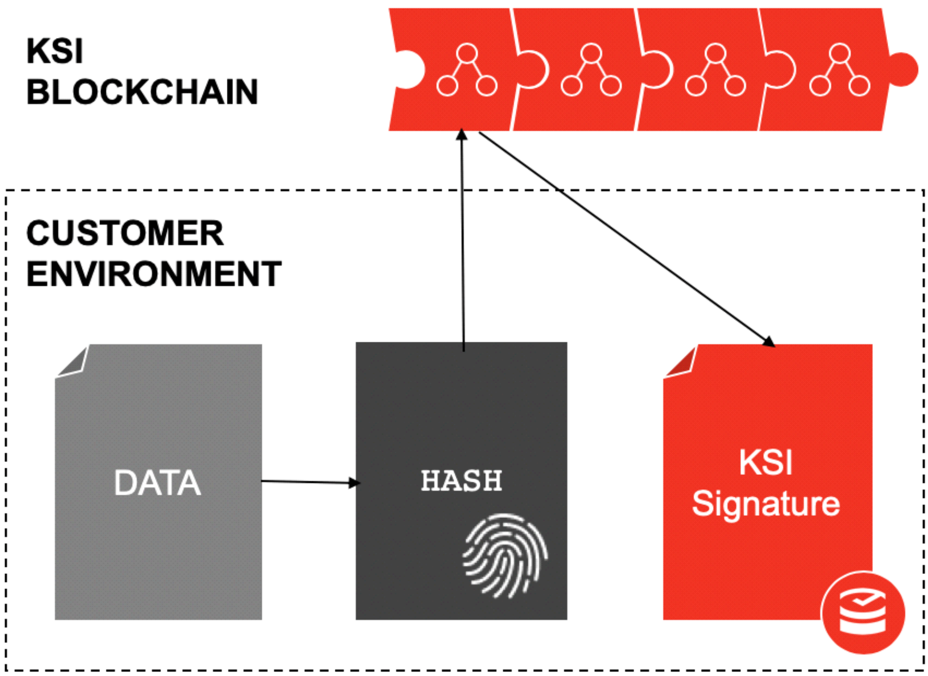
KSI Blockchain technology, developed by Guardtime, is designed in Estonia and used globally to ensure networks, systems and data are free from compromise, all while retaining 100% data privacy. Today, KSI blockchain is available in several countries, while scaling 1012 items of data every second globally.

By its nature, it is a mathematically assured cybersecurity solution for detecting the use and misuse of digital data and devices. The KSI Blockchain is a globally distributed network infrastructure and method for issuing and verifying KSI signatures.

Unlike traditional digital signature approaches, e.g. Public Key Infrastructure (PKI), which depend on asymmetric key cryptography, KSI uses hash-function cryptography only, allowing verification to rely only on the security of hash functions and the availability of a public ledger – commonly referred to as a blockchain (Guardtime, 2018). A blockchain is a distributed public record of events; an append-only record of events where each new event is cryptographically linked to the previous. New entries are created using a distributed consensus protocol (ibid).

A user interacts with the KSI system by submitting a hash-value of the data to be signed into the KSI infrastructure and is then returned a signature which provides cryptographic proof of the time of signature, the integrity of the signed data, as well as attribution of origin, i.e. which entity generated the signature.

Figure 3. KSI Blockchain and Customer Environment



Source: Guardtime (2018)

The benefits of the KSI include (Guardtime Federal, 2018):

- Massive Scale. KSI signatures can be generated at exabyte-scale. Even if an exabyte (1,000 petabytes) of data is generated around the planet every second, every data record (a trillion records assuming 1MB average size) can be signed using KSI with negligible computational, storage and network overheads.

- Portability. The properties of the signed data can be verified even after that data has crossed geographic or organisational boundaries and service providers.

- Data Privacy. KSI does not ingest any customer data; data never leaves the customer premises. Instead, the system is based on one-way cryptographic hash functions that result in hash values uniquely representing the data. These are irreversible, such that one cannot start with the hash value and reconstruct the data − data privacy is guaranteed at all times.

- Independent Verification. The properties of the signed data can be verified without reliance or need for a trusted authority.

3. Blockchain in Estonia Today

While using KSI blockchain with many registries, today Estonia uses a variety of innovative solutions that have been developed for the Estonian government. Siim Sikkut, Estonian Government CIO, Ministry of Economic Affairs − has brought out that the goal of Estonia using blockchain is to increase citizens' trust in public services by ensuring data integrity (Si-soo, 2018). Therefore, the government is continuing to carry out various experiments with blockchain to test how much it can support the existing system of the Estonian e-state and expand its implementation.

3.1. Various use-cases

For example, in Estonia blockchain technology helps to detect who looks at a person's digital health data, who changes it and when. In order to keep health information completely secure and, at the same time, accessible to authorised individuals, the electronic ID-card system is used.

The Estonian e-Health Record[1)] uses blockchain technology to ensure data integrity and mitigate internal threats to the data. The main value that blockchain provides is immutability of the logged activities, ensuring that neither adversaries nor insiders could tamper with the data nor cover up the tracks of malicious activities. As a result, every occurrence of data use and misuse is detectable and major damages to a person's health can be prevented (such as a prescription for the wrong medicine or an incorrect dose).

Another example of Estonian blockchain integration is the Estonian National Gazette[2)], where maintaining data integrity is extremely vital. Since 1 June 2010, the electronic National Gazette has been the one and only publication where laws and regulations are published. The whole of Estonia relies on the information provided by the National Gazette. There is no paper copy to turn to if something is wrong in the portal. What you can see in the National Gazette is what the law has been and currently is in Estonia. To protect such an important database, the Estonian Centre of Registers and Information Systems uses various security measures, one of them being the KSI Blockchain.

1) See: The Patient Portal: https://www.digilugu.ee/login?locale=en
2) See: State Gazette: https://www.rik.ee/en/international/state-gazette

Besides these examples, the Estonian KSI Blockchain technology protects a number of other Estonian e-services, such as the e-Prescription database, e-Law and e-Court systems, e-Police data, e-Banking, the e-Business Register and the e-Land Registry. For example, it can help to see when information about a company in the Estonian e-Business Register was changed and why; or to detect who changed data about a real estate property in the Estonian e-Land register; or statements documented in the e-Court system, as well as when and how these were changed.

3.2. Deploying blockchain in Estonia

In order to deploy blockchain in Estonia's state information systems, the Estonian Information Systems Authority (RIA), as an internal service provider for the government, guarantees access to the blockchain network for state agencies via the X-Road infrastructure (e-estonia.com, 2018). The Estonian state agencies deploy blockchain technology by themselves, using the Software Development Kits (SDKs) and prebuilt tools, i.e. for log and database integration.

However, according to Mehis Sihvart, Director of the Centre of Registers and Information Systems (RIK), it still often comes as a surprise to hear that most of the government registers in Estonia today are operated electronically (Sihvart, 2017). While the key question here is to guarantee integrity and safety, the Estonian government and RIK have found blockchain to be a tried, tested and suitable technological method for guaranteeing the integrity of government data.

Sihvart explains that RIK, which is currently managing and administrating over 70 information systems and registers in Estonia, started implementing blockchain first for its Register of Wills/Succession Registry in 2012. According to the initial idea, RIK takes will information from the database and anchors it to the blockchain so that no one can remove or change the will in the registry. The information sent to the blockchain is encrypted while RIK validates the data against the blockchain, and therefore knows the data has not been removed or tampered with. According to Sihvart, this gives a good level of security when managing this as well as other government registers (ibid).

In fact, the same KSI Blockchain technology described above is used globally in many sectors. A few notable defence and commercial implementations include Verizon, Ericsson, Lockheed Martin, Maersk, DARPA, Ericsson, EY, etc (Guardtime, 2018b).

4. Myths and Legends About Blockchain in Estonia

There are several myths and misconceptions related to blockchain in Estonia, which must be corrected. Let us review them.

First, it is often misunderstood that the data of the Estonian population is stored on the blockchain and that the main database structure in Estonia is based on the blockchain platform. This is untrue, as there is no personal data on the blockchain − there is no need for it. The only digital fingerprints, i.e. hashes, of data are put to the blockchain for integrity assurance.

Another misconception concerns IDs based on the blockchain. It has been brought out that Estonia has been operating a universal national digital identity scheme using blockchain, but this fact is incorrect. The blockchain is not used for IDs. Instead, Estonia has a national PKI infrastructure for that − blockchain is used within registries/systems for integrity purposes. However − R&D on quantum immune, blockchain backed IDs − is ongoing and therefore we might not know the possibilities that are to come in the future.

The third blockchain myth in Estonia is the statement that the X-Road is a blockchain based technology or it utilises blockchain internally. Actually, the X-Road is not a blockchain and it does not use blockchain today. The X-Road is the secure data-exchange layer which is used to connect the registries and services in Estonia. However, blockchain service (for integrity assurance) is one of the services available on the Estonian X-Road. The X-Road itself is just a transport layer which facilitates blockchain access.

These kinds of misconceptions include several other false ideas, such as the statement that bitcoin and blockchain consume an exorbitant amount of energy or that one bitcoin transaction uses as much energy as one's house in a week. However − this all applies to public blockchain technology (Proof of Work (PoW) based) only, while PoW is needed when participants are anonymous. As Estonia uses permissioned blockchain technology, participants are known and there is no need for PoW.

5. Global Use-Cases of KSI Technology

It is important to understand and to continue developing and implementing blockchain technology solutions into the financial sector or state institutions and in other fields of businesses in order to introduce their potential and benefits more widely. Different fields around the world are expected to combine their solutions with blockchain technology, and here Estonia can certainly share its experience. In the section below, a number of successful use-cases of KSI technology are examined.

5.1. PRIViLEDGE

Although based on cryptographic techniques at their core, the currently deployed blockchain and distributed ledger technologies (DLTs) have privacy challenges. Indeed, the very idea of a public ledger that stores a verifiable record of transactions at first appears inherently incompatible with the privacy requirements of many potential applications, which use sensitive data, such as trade secrets and personal information. New cryptographic techniques and protocols are therefore needed to protect the data, facilitate these applications, and make DLTs deliver on their promises (Priviledge, 2018).

PRIViLEDGE, as a consortium of 10 EU organisations, realises cryptographic protocols supporting privacy, anonymity, and efficient decentralised consensus for DLTs. Within this EU-funded project, several key European players in cryptographic research and from the fintech and blockchain domains, including Guardtime, unite to push the limits of cryptographic protocols for privacy and security. Results from PRIViLEDGE are demonstrated through four ledger-based solutions: verifiable online voting, contract validation and execution for insurance, a university diploma record ledger, and an update mechanism for stake-based ledgers (ibid). The selected use cases are diverse and represent the principal application domains of DLT while ensuring a wide reach and impact of the techniques developed in PRIViLEDGE beyond the immediate scope of the project.

5.2. SOFIE

Another example here is the SOFIE project, which aims to develop a blockchain driven federated platform for enabling information exchange of numerous Internet of Things (IoT) and data silos (Sofie, 2018). The goal of this EU-project is to enable the creation of business platforms, based on existing IoT platforms and distributed ledgers, without needing to negotiate with any gatekeepers.

The wide applicability of the approach of the SOFIE project is tested through four pilots. Within that, Guardtime is implementing an energy pilot, which will demonstrate how the SOFIE federated framework can be used for providing reliable data feeds and exchange power consumption information among energy grid participants, in order to allow flexible services based on smart meter data (ibid).

5.3. Insurwave

The blockchain is now also applied to the world's first platform for marine insurance in commercial use. In spring 2018, Guardtime, EY and other partners announced the blockchain platform Insurwave, which helps global businesses to transform the management of risk and the way of working with brokers and (re)insurers across the organisations (Guardtime, 2018c).

Insurwave leverages blockchain and distributed ledger technologies while supporting more than half a million automated ledger transactions and helping manage risk for more than 1,000 commercial vessels in its first year. By connecting participants in a secure, private network with an accurate, immutable audit trail and services to execute processes, the platform establishes a first of its kind digital insurance value chain (ibid).

6. Future challenges

With rapid changes in technology the blockchain industry will remain in constant development and must respond to the demands coming from the surrounding environment. Among other aspects, new standards for digital identity and blockchain, as well as novel technologies, such as artificial intelligence (AI), will need to be considered.

6.1. New quantum-immune blockchain standard for digital identity

In May 2015, Guardtime announced BLT, the authentication and signature protocol meant to replace RSA as the standard for digital identity (Guardtime, 2018d). In contrast to RSA's reliance on quantum-vulnerable asymmetric key cryptography, BLT is based on Guardtime's quantum-secure KSI technology, which uses hash function cryptography only.

Mike Gault, CEO of Guardtime explained then (ibid) that the RSA has been dominating the digital signature scheme since the 1970s, but it is outdated and cannot scale for the explosion of data or devices we are seeing with the Internet of Things, mobile and machine-to-machine technologies. Most importantly, on the advent of quantum computers, RSA could be rendered completely useless. No practical and scalable alternative for the market existed, until BLT, which provides a scalable, secure alternative to RSA − practical for authenticating not only data in motion, but also for data at rest in the cloud or as part of the infrastructure.

As KSI blockchain technology employs one-way hash functions to generate digital signatures that can prove the time, integrity and attribution of origin for electronic data, BLT extends this approach to provide human and machine identity management, with a level of non-repudiation consistent with existing digital signature schemes.

Through this methodology, BLT offers simplified revocation management: there is no need to check the certificate validity when verifying signatures, eliminating the need for complicated Certificate Revocation Lists (CRLs). It also benefits via long-term validity: there is no need for periodic re-timestamping of the signatures due to expiring keys − the time and integrity of the signature can be proven mathematically, without reliance on trusted parties or the security of the keys.

Unlike RSA, BLT signatures cannot be generated offline, removing the potential for unlimited liability in the case of private key theft. Also, BLT's hash functions cannot be broken using quantum algorithms.

Matt Johnson, CTO of Guardtime has stated (ibid) that, apart from robust security, e-commerce and/or device registration applications, BLT greatly improves the strength of any signing and authentication process.

As a result, BLT collapses security issues and removes traditional trust anchors with this new signature scheme. It's clean, efficient and beautifully simple, demonstrating the power of KSI to transform the world's security landscape.

6.2. "Kratt law" to legalise Artificial Intelligence (AI) in Estonia

Another future challenge within the blockchain industry is strongly related to the fact that countries around the world are facing the challenge of understanding the rise of AI, which is increasingly affecting the daily lives of people all over the world. This raises the question: which country will be the first in developing a comprehensive legal framework that ensures that the technology can be developed in an ethical and sustainable way?

Marten Kaevats, National Digital Advisor for The Government Office of Estonia, has stated that while Estonia is known for its "firsts" − as the first country to declare internet access as a human right, the first country to hold a nationwide election online, the first country in Europe to both legalise ride sharing and delivery bots, and the first country to offer e-Residency − Estonia should be the first to develop this legal framework also (Kaevats, 2017).

The work to understand AI in Estonia started in November 2016, with the self-driving vehicles task force, together with the Estonian Ministry of Economic Affairs and Communications and the Government Office. However, it quickly became clear that their scope was too limited, as working on traffic regulations is simply not enough given the far-reaching implications of the technology. As a result, the task force suggested four different options regarding how to regulate AI in a user-friendly way.

According to Kaevats (ibid), within this process, the Estonian government authorities have acknowledged that the biggest obstacle for mass implementation of AI is our current cyber capabilities, particularly regarding, firstly, the integrity of these systems and, secondly, their security. Similar to life and death decisions made by self-driving cars, it is important to be sure that the decision-making algorithm has not been tampered with.

Today, Estonia has recognised the complexity, scope and possibilities of these issues and aims to contribute to the global discussion with positive case studies with an emphasis on ethics and cyber measures. The immense possibilities of AI cannot be enabled if there are no right values and right regulations.

However, from a governmental perspective, it is also crucial to consider the practical enforcement side of implementing these kinds of measures as well. Therefore, the Estonian government is working together with Guardtime to ensure measures of anti-tampering and data integrity within these AI algorithms.

7. Conclusions

Successful countries need to be ready to experiment. Building e-Estonia − one of the most advanced e-societies in the world − has involved continuous experimentation and learning from mistakes.

Increasing levels of cybercrime and politically motivated attacks on data, as well as electronic services, show that cyber security is more important than ever for the private and public sector, and citizens alike. Estonia's preparedness to handle cyber crises has significantly increased over the past decade. The country has created intrusion detection and protection systems, practiced cooperation with both public and private institutions, significantly contributed to the awareness of users, and is participating in intensive international cooperation.

After its experience with the 2007 cyber-attacks, Estonia has implemented blockchain technology to ensure data and system integrity and combat insider risk and has become a powerhouse of cybersecurity expertise. Estonia uses Guardtime's KSI Blockchain technology, which is purpose-built for mass-scale integrity verification. Based on original academic research, it predates even Bitcoin and has been used in production for more than 10 years. Contrary to the common understanding that blockchain is used to store transactions, the KSI Blockchain only ingests cryptographic hash values, therefore, it is 100% privacy preserving and complies with all regulations.

KSI Blockchain technology was created in Estonia but has now taken off on a global scale. Guardtime can be considered the world's largest commercial blockchain technology provider, with implementations in the public sector, defence, healthcare, and many more.

Estonia is ready to share its experiences and lessons openly with the whole world. Through rapid reforms, creating new solutions and being a role model to the world, it is inevitable that sometimes things go wrong. However, it is important to stick to one's principles, learn from one's mistakes and to talk openly about them. A key feature of a true expert is having the courage to talk about their mistakes – this is exactly how Estonia has managed to build such a successful digital society.

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The Indian Blockchain Landscape: Regulations and Policy Measures

Nir Kshetri

1. Introduction

Blockchain is considered to be a technology that has the potential to bring major political, social and economic benefits to developing economies such as India (Kshetri, 2017a). According to the National Association of Software and Services Companies (NASSCOM), blockchain-led increase in productivity and cost reduction can create value of up to US$5 billion in the Indian economy by 2023 (IANS, 2018). The research company ResearchAndMarkets.com's study indicated that the banking and financial services sector is expected to the leading sector to benefit from this technology (Business Wire, 2018).

According to PwC, there were only 23 blockchain firms in India before 2016. In 2016, 32 additional blockchain firms were established (Karnik, 2017). As of 2018, India was estimated to have more than 100 blockchain and cryptocurrency startups (Krishna, 2018).

The benefits of this technology are especially important to disadvantaged groups such as low-income population and small and medium-sized enterprises (SMEs). Prior research has demonstrated the importance of blockchain in fighting poverty and reducing financial exclusion in developing economies (Kshetri, 2017a, b, c). Blockchain is also expected to help the Indian government's initiative to develop the healthcare sector to provide healthcare services to low-income population (Business Wire, 2018).

The Indian blockchain landscape reveals a number of encouraging signs. The policy think tank of the Indian Government, the National Institution for Transforming India (NITI) Aayog, which is headed by the Prime Minister, is exploring the use of blockchain to address key problems facing the country such as land registry, health records and distribution of fertilizer subsidy. Other focus areas include tacking fraudulent drugs and improving agriculture supply chain (The News Minute, 2018).

India's history of cryptocurrency is comparable to that of other similar economies. Bitcoin transactions were being conducted in India as early as in 2012. By 2013, some businesses started to accept payments in bitcoin (The Mission Podcasts, 2018).

At the same time the country's blockchain Industry has run into many roadblocks and challenges. Blockchain startups have faced an uncertain regulatory and policy climate in the country. In April 2018, India's central banking institution, the Reserve Bank of India (RBI) initiated a crackdown on cryptocurrencies (Iver and Anand, 2018). The lack of blockchain use cases has also been reported to hamper the growth of this industry (Krishna, 2018).

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2. The Indian blockchain ecosystem: Opportunities for economic development and social welfare

2.1 Foreign companies and non-profit organizations enriching the blockchain ecosystem

Foreign multinational companies and non-profit organizations are playing a key role in the Indian blockchain ecosystem. A notable example is IBM. IBM's India research labs is involved in some of the IBM's blockchain-related work (Mahalingam, 2016).

Some Indian companies are also a part of sophisticated supply chain systems developed by IBM. For instance, in February 2017, it was reported that with support from Dubai Customs and Dubai Trade, IBM was working with many participants to design a blockchain solution to track the shipment of fruit from India to Dubai via a cargo ship. In Dubai, the fruit would be processed to produce juice, which is then exported to Spain by an airplane.

The participants included a telecommunications company, a letter of credit (LoC) issuing bank, a responding bank, a freight company and an airline. The plan after the completion of the supply chain and trade finance proof-of-concept (PoC) would be to integrate the system with Watson's artificial intelligence (AI). To move the transactions to blockchain, the UAE-based telecommunications company Du would track relevant data (e.g., temperature, humidity, etc. when the fruits are being transported) via Internet of Things (IoT)-enabled devices. Data reported via Du's IoT devices are validated by Watson AI.

It was reported to be among IBM's most visible blockchain projects (Del Castillo, 2017a). The PoC involved several key steps. Emirates NBD Bank would issue the LoC. The Spanish bank, Santander would receive the letters. The freight company Aramex would ship the fruits to Dubai. An airline carrier would transport the juice. The POC is powered by smart contracts.

Indian companies have also teamed with foreign companies to develop blockchain-based solutions for the Indian market. In 2016, the Indian bank ICICI collaborated with Dubai's Emirates NBD bank in a blockchain pilot (Das, 2016a). Two pilot transactions were conducted. The first was an international trade finance transaction. It enabled all parties to access data in real-time. In the pilot project, an Indian firm imported goods from a Dubai-based supplier (Das, 2016a). The second project involved remittance transaction. Money was transferred from ICICI bank to an Emirates NBD branch. Blockchain reduced the time taken by cross-border remittances from two days to a few minutes (Das, 2016b).

Foreign non-profit organizations are also exploring to develop blockchain-based solutions for the Indian market. It was reported that Gates Foundation was exploring blockchain's potential to expand financial inclusion in order to reach 200 million unbanked Indians (Cointelegraph, 2016).

2.2 State level initiatives

Table 1 provides an overview of some of the initiatives at the state level that would affect the development of the Indian blockchain ecosystem.

Andhra Pradesh

The most advanced stage in the deployment of blockchain-based solutions can be observed in the state of Andhra Pradesh (AP). Policy measures have been taken to develop a rich ecosystem and infrastructure in which blockchain applications can grow. Blockchain has been the main focus area of the FinTech Valley Vizag. It was established in 2016 in the Visakhapatnam city.

The AP government has teamed up with the local company Covalent Fund to establish a blockchain stack called Velugu Core. It will make the government data freely accessible through open application program interface (API). This means that software developers can freely access to the protocols and tools, which can be used to build applications. For instance, apps can be built using this stack to provide information about all former owners of a property as well as transaction details (Rungasamy, 2018). Covalent Fund will also focus on the creation of manpower and expansion of the access to funds (Patnaik, 2018). The AP state also announced a plan to establish a Blockchain University with an investment of US$10 million (Rao, 2018).

The AP government signed an MoU with ConsenSys to provide technical advisory to the government (Khatri, 2018). ConsenSys will help the state to prioritize pilot blockchain use cases. Another MoU was signed with the Malaysian cryptocurrency company Belfrics Global to establish an institution in Vizag with the Gitam University. The MoU also involves developing blockchain applications for government operations (Sinha, 2018). The state also announced a collaboration with the cybersecurity firm WISeKey to implement a project to securely store citizen data on a blockchain (cryptocoinsnews.com, 2017).

In October 2017, the AP government collaborated with a Swedish start-up, ChromaWay, to create a blockchain-based land registry system for the planned city of Amaravati (LawFuel, 2017). Local blockchain startup Zebi Data is doing most of the implementation activities.

Telangana

In July 2017, the state of Telangana announced a plan to sign MoUs with a number of blockchain companies. The state is especially interested in implementing the technology to improve government services (Press Trust of India, 2018). Telangana started a land registry pilot project in the capital city of Hyderabad. It was reported in September 2017 that a complete rollout of the program in Hyderabad and nearby areas would take place within a year (BlockChain News, 2017).

The Telangana government noted that migration of land records into a blockchain platform would be undertaken on a phased basis. Only transactions that have been validated would be moved to blockchain (thehindu.com, 2018). For instance, lands that have been collateral for mortgage and other types of loan can be moved more easily onto blockchain. Banks and financial institutions engage in a comprehensive appraisal of such properties (Panchapagesan, 2018).

Public private partnership (PPP) projects have also been initiated. The Telangana state and Tech Mahindra signed an MoU to create a Blockchain District in the capital city of Hyderabad. The goal is to create a blockchain ecosystem. The government will provide appropriate regulatory and legal framework (Krishnakumar, 2018). Tech Mahindra will provide the technology and platform for the incubators in the Blockchain District (Anupam, 2018).

According to Tech Mahindra, companies in a number sectors such as pharmacology, retail, fashion, and architecture will be developing blockchain-based solutions in the District (Express News Service, 2018). In addition to Tech Mahindra, local blockchain startups Eleven 01 and Nucleus Visions are also founding companies. These companies will provide services such as mentoring, market reach, and technical insights to the startups.

Maharashtra

In October 2018, the state of Maharashtra concluded a blockchain pilot study. Four PoC projects were tested: organ transplants, rationing (administration of ration cards issued by the state government to households that are eligible to purchase subsidized food products), land records, and digital certification of government records (Burr, 2018).

Table 1: State level initiatives in blockchain-related areas

State	Some key focus areas of blockchain deployment	Remarks
Andhra Pradesh	Government services, land registry, establishment of a Blockchain University	Has collaborated with a number of foreign blockchain companies such as ConsenSys, WISeKey, ChromaWay, and Belfrics Global and local companies such as Zebi Data and Covalent Fund to develop the local blockchain ecosystem.
Telangana	Government services, land registry, PPP to create a Blockchain District in the capital city of Hyderabad.	July 2017: announced a plan to sign MoUs with a number of companies to implement blockchain to improve government services.
Maharashtra	Organ transplants, rationing, land records, and digital certification of government records.	Zebi Data is reported to be working with the state.
Uttar Pradesh	Land record registration	July 2018: announced plans to start blockchain projects to manage land-related data within six months

Uttar Pradesh

Uttar Pradesh was reported to be exploring blockchain for land record registration (Acuna, 2018). In July 2018, the state's government announced that it will start using blockchain to manage land-related data by the end of the year (businesstoday.in, 2018).

2.3 International collaboration and cooperation

The Indian blockchain industry and market are likely to benefit from international collaboration and cooperation at various levels. Some Indian companies such as the IT consultancy firm Wipro have joined the non-profit organization Enterprise Ethereum Alliance (EEA) (Del Castillo, 2017b). The AP government is also a member of the EEA (Blockchain News, 2018). The EEA has been taking major initiatives to develop blockchain standards (Graham, 2018). As of mid-2018, it had over 500 members that included well-known companies such as Accenture, BP, Credit Suisse, and Microsoft as well as developers and academics (Allison, 2018). The EEA released Enterprise Ethereum Client Specification 1.0 (EEAS) in May 2018, which is available as a public download (Kot, 2018). This is expected to increase interoperability for companies using Ethereum-based solutions (Bitcoin Exchange Guide News Team, 2018).

India and other BRICS countries have signed an MOU, which aims to provide a deeper understanding of the use of blockchain in order to improve banks' operational efficiency. Major financial institutions of the five countries: Banco Nacional de Desenvolvimento Economico e Social (Brazil), China Development Bank (China), the Export-Import Bank of India (India) State Corporation Bank for Development and Foreign Economic Affairs (Russia), and the Development Bank of Southern Africa (South Africa) will conduct joint research under this initiative (Alexandre, 2018).

2.4 Controlling corruption and frauds

India ranked 81st in Transparency International's 2017 Corruption Perceptions Index (Transparency International, 2018). According to a 2017 survey conducted across 11 states in the country, 45% Indians had paid bribes in the past year (Banerjee, 2017).

According to Global Financial Integrity's (GFI) 2015 report, fraudulent misinvoicing of trade transactions accounted for 83.4% of all illicit financial flows (IFF) from developing countries (Kar and Spaniers, 2015). An estimate suggested that during 1988-2012, US$186 billion worth of IFF went out from India through such process (Nguyen, 2014).

Due primarily to frauds, bad loans account for about 20% of bank loans in India (Suberg, 2017). Loan frauds in the country amounts to about US$2 billion annually, which results in high interest rates. This is an indicator of low trust (Pitti, 2018). Financial institutions such as the State Bank of India (SBI) have been trying for some time to develop blockchain-based solutions to promote information sharing in order to reduce bad loans and fraud. They want to launch a blockchain platform for handling digitized loan and trade finance documents (Suberg, 2017).

Pervasiveness of frauds in the insurance sector has also been a concern. One estimate suggested that false claims in the Indian healthcare insurance industry account for 10-15% of total claims. The industry is estimated to lose about 6 billion (about US$90 million) on false claims annually. Major fraud categories include misrepresented services, services that were not provided and services that were provided to so called 'rented' patients (Bardhan, 2007). An upshot is that a large proportion of the Indian population lacks insurance. In India, about 86% of the rural population and 82% the urban population lack health insurance (Bansal, 2016).

Frauds are rampant in the microfinance sector too. It was reported that during 2010-2012, in India's Kerala state, president and secretary of the Adoor Sree Narayana Dharma Paripalana Union received loans amounting 76.5 million (about US$1.15 million) from Bank of India on behalf of about 5,000 families representing 256 micro units. The members of the units had no knowledge of the loans (The New Indian Express, 2015). The families faced debt collection proceedings. Such frauds can be prevented using blockchain in microfinance (Kshetri, 2017a).

Blockchain-led transparency may help reduce these undesirable practices. For instance, banks are not willing to lend money in places where fraudulent invoices are common, or where manufacturers and their customers might have inconsistent and error-ridden records. A blockchain system reduces those concerns because these records must be authenticated before being added to the books, and because they can't be changed (Kshetri, 2017c).

2.5 Land registry

Across the world, land registries are inefficient and unreliable (Kshetri, 2018). One estimate suggests that over 20 million rural families in India do not own land and millions more lacked legal ownership to the land where they have built houses and worked (Hanstad, 2013). Landlessness is arguably a more powerful predictor of poverty in India than caste or illiteracy (Hanstad, 2013).

A study conducted by the civil society organization Daksh indicated that property-related disputes in India account for a 66% of all civil cases and cost the country 0.5% of the GDP (Haridas, 2018). About US$700 million is paid annually in bribes related to land registrars in the country (Bhattacharya, 2018).

There are some encouraging initiatives to address this problem. In 2017, the Telangana and AP states announced plans to use blockchain for land registry. Maharashtra and Uttar Pradesh are at various levels of preparedness to develop such systems (Table 1). The state of Goa was also reported to be exploring blockchain for land record registration (Acuna, 2018).

Blockchain can lead to important cost saving opportunities. Before the implementation of blockchain, farmers needed to pay at least Rs 5,000 (about US$68) to prepare registration papers. With blockchain farmers can get system-generated digital documents for free. The digital document with a QR code can be sent directly to the land registrar (Bhattacharya, 2018).

In blockchain-based land registries, it is possible to do all or most of the processing using smart phones (Shin, 2016). India's high and rapidly growing smartphone penetration should facilitate this initiative. There were 299 million smartphone users in 2017, which is expected to increase to 442 million by 2022 (The Economic Times, 2018). A high cellphone penetration rate has been a key enabling factor for the deployment of blockchain in land registry in AP. According to the AP Capital Region Development Authority (CRDA) digital literacy in the state is high. At least one person in most families in the state can use cellphones and Internet (Bhattacharya, 2018).

Currently after a land transaction is finalized, the officer in charge of the collection of land revenues (tehsildar) needs to submit a land demarcation in order to the register the deed. The process takes between one month to three months. Often bribes need to be paid to prepare the document (Ramnani, 2018). With blockchain, properties can transferred in a day without paying the bribes.

2.6 Voting and election systems

Blockchain is likely to have a dramatic impact on voting and election systems. Especially blockchain may reduce two of the concerns that are most prevalent in voting today: (1) voter access, and (2) voter fraud (Kshetri and Voas, 2018a).

Blockchain applications for shareholder voting and corporate governance are also being explored. Shareholders in India face challenges in physically attending shareholder meetings. In order to conduct some special business items, a postal ballot is held (Venkat et al., 2014). Blockchain-enabled e-voting (BEV) is expected to enhance transparency in corporate governance (BussinessLine, 2018). The National Stock Exchange (NSE) was reported to be conducting tests to use blockchain for e-voting for companies. NSE-listed companies would tokenize voting rights (NSE, 2018). Mumbai-based blockchain startup Elemential will develop the platform.

Aadhaar card and electronic know your customer (eKYC) is likely to provide the foundation for BEV (Varshney, 2018). Note that eKYC is a paperless process to verify the Identity and address of a person based on the Aadhaar authentication (Emudhra, 2018).

2.7 Access to finance

In order to make financing more efficient and increase access to finance for SMEs, the government and the private sector have taken initiatives that are at various stages of exploration. Among the first such measures Yes Bank teamed up with IBM for a blockchain project to digitize vendor financing for its client, the consumer electrical equipment manufacturing company, Bajaj Electricals. The fintech startup Cateina Technologies developed a blockchain-based smart contract (Kasteleln, 2017).

When Bajaj Electricals processes invoices, the details are transferred to Yes Bank on blockchain. After bill discounting (bank lending against receivables), the funds are automatically disbursed to the vendors of Bajaj Electricals when the conditions in the smart contract are fulfilled. Following the implementation of blockchain, the process cycle for bill discounting reduced from four-five days to almost real time (Gupta, 2017). As of February 2017, Bajaj Electricals was doing transactions with one supplier on the blockchain system (Gupta, 2017).

As of mid-2018, fourteen Indian banks had signed up to use the services of the blockchain platform India Trade Connect consortium, which was developed by the local software firm Infosys. The platform facilitates the issuance of loans that are backed by trade transactions (Satila and Anthony, 2018). The banks account for about half of India's internal trade. The solution is expected to speed up processes for approving new loans.

It was reported that the traditional trade finance process within India involves processing a large number of documents, which can take up to 22 days. According to Yes Bank, blockchain is expected to reduce the time to less than a day (Satila and Anthony, 2018).

Blockchain may help the government's efforts to address key problems in receivable financing. The RBI licensed three entities RXIL, A.TReDS, and M1xhange to provide receivable financing to micro and small businesses. These three platforms wanted to share information in order to prevent fraud but keep the data private. Blockchain can help achieve this.

Using blockchain, it is possible to create a cryptographic representation of the invoice, known as a hash. A hash provides an indecipherable text, which does not reveal information about the invoice. It is nearly impossible to convert a hash back to the original data. If a trader submits the same invoice to more than one trade finance platforms, the hash will match, which would raise a red flag. The New York-based software company providing blockchain solutions to financial institutions and central banks, MonetaGo also hashes some of the elements of the invoice in order to prevent the trader from making some modification in the invoice. It will produce an amber flag if an invoice has a high degree of similarity with another invoice already submitted to a different platform. The invoice will not be rejected but the trader may be asked to explain more.

2.8 Strengthening cybersecurity and protecting privacy

According to the Unique Identification Authority of India (UIDAI), 1.19 billion people were enrolled in the Aadhaar system. In January 2018, all sensitive patient data for Aadhaar were hacked. India hopes that blockchain will properly secure the electronic health records (EHRs) and other sensitive data (Bryzek, 2018).

Blockchain is touted as a technology that can possibly provide a robust and strong cybersecurity solution and high level of privacy protection (Schutzer, 2016). Its proponents argue that this technology is secure by design (Kshetri, 2017d).

2.9 Healthcare

According to the World Health Organization (WHO), about 20% of the drugs manufactured in India is fake or of lower standard (Venkatasubramanian, 2018). India has been hit by a number of fake drug scandals. Counterfeit medicines were suspected to lead to the deaths hundreds of infants at a pediatric hospital in Kashmir. Likewise, a random test in a government lab found that one widely used antibiotic had lacked any active ingredient (Haris, 2014).

Blockchain could transform the healthcare sector. The NITI has taken initiatives to use blockchain-based solutions to fight against counterfeit drugs. The Aayog has teamed up with the U.S. technology company Oracle and a local hospital chain for this purpose. Oracle's blockchain solutions will be used in Apollo Hospitals' pharmaceutical supply chain to create immutable records for each transaction (Rana, 2018).

Likewise, 500,000 people die every day in India due to the non-availability of organs. In most cases, patients are unable to find donors due to the lack of proper communication channels (atositchallenge.net, 2016). It was reported that doctors who were part of a criminal gang that the police had arrested in early 2018 paid US$1000 for the kidneys and then sold for about US$38,000 (Robinson, 2008). It is argued that blockchain would play a key role in a critical supply chain such as those involving organs (Digiatal Oil & Gas, 2018). It provides transparent, real-time, secure and auditable records of transactions involving organs.

3. The regulatory and policy environment

In recent years, there have been a number of high-profile initiatives, which have signaled an interest in blockchain. In October 2018, Prime Minister Narendra Modi announced that blockchain is one of the priority areas for a new technology center opened in the Maharashtra state. The center is a part of the World Economic Forum Centre for the Fourth Industrial Revolution (Dumont, 2018).

NITI Aayog is reported to be working on building the country's largest blockchain network: IndiaChain. The goals are to reduce frauds, facilitate contract enforcement, increase transparency of transactions, and enhance agricultural productivity. The plan is to link IndiaChain with government digital identification databases such as IndiaStack (Sen and Murali, 2017). Note that IndiaStack (http://indiastack.org/about/) is a set of APIs developed around Aadhaar that allows government agencies and businesses to build products and services.

In October 2018, the Internet and Mobile Association of India (IAMAI) formed "Blockchain Committee." The Committee's members include the country's big business and cryptocurrency companies. The Committee is expected to work with government agencies, related industries and startups to strengthen a blockchain ecosystem (ET Bureau, 2018).

We discussed various state level initiatives in the last section. As noted earlier, PPP projects have also been initiated in some states.

Table 2. Some regulatory developments related to cryptocurrencies

Time	Regulatory entity involved	Actions
December 2013	RBI	Cautioned the users, holders and traders of cryptocurrencies about "the potential financial, operational, legal, customer protection and security related risks that they are exposing themselves to" (RBI, 2018).
December 2013	Enforcement Directorate (ED) (part of the Department of Revenue, Ministry of Finance).	The Bitcoin exchange BuysellBit.co.in in Ahmedabad was raided. It was found that BuysellBit.co.in violated the Foreign Exchange Management Act (FEMA) (DNA, 2013). BuysellBit.co.in suspended its operations (Mishra, 2013).
February 2017	RBI	Noted that it has not given any "licence / authorisation to any entity / company to operate such schemes or deal with Bitcoin or any virtual currency" (RBI, 2016).
December 2017	RBI	In light of the significant and rapid growth of cryptocurrency values and ICO activities, RBI again cautioned the public against cryptocurrencies. It pointed out to the press releases of December 2013 and February 2017 (RBI, 2017).
December 2017	Central Board of Direct Taxes (CBDT), Department of Revenue, Ministry of Finance	Conducted surveys of nine cryptocurrency exchanges to assess the possibility of tax evasion (ET Bureau, 2017).
April 2018	RBI	A decree declared that all RBI regulated bodies (e.g., banks) were prohibited to have business relationships with entities dealing with cryptocurrencies. Those with existing relationships with such entities were required to end within three months.

Despite the above mentioned positive trends, blockchain companies face a challenging regulatory and political environment. From the beginning, the Indian cryptocurrency market faced tough regulations. The system of capital controls prohibited Indians from using local bank accounts to buy and sell cryptocurrencies on international exchanges (Mundy, 2018).

Table 2 presents key regulatory developments related to cryptocurrencies in India. In December 2013, the RBI cautioned the users, holders and traders of cryptocurrencies about "the potential financial, operational, legal, customer protection and security related risks that they are exposing themselves to" (RBI, 2018a).

In the late 2017, the RBI issued reports cautioning users of the risk of bitcoin. The country's income tax officials then started investigations into transactions at a number of illegal bitcoin exchanges (Antony and Chasudhary, 2018).

In the early 2018, in his annual budget speech, the Indian finance minister noted: "The Government does not consider crypto-currencies legal tender or coin and will take all measures to eliminate use of these crypto-assets in financing illegitimate activities or as part of the payment system" (Venkateswaran, 2018).

Among the most damaging regulatory policies, in April 2018, the RBI initiated the most significant crackdown on cryptocurrencies (Iyer and Anand, 2018). At that time about 10% of the world's bitcoin transactions took place in India (Anand, 2018a).

The RBI's decree issued on April 5, 2018 declared that all RBI regulated bodies (e.g., banks) were prohibited to have business relationships with entities dealing with cryptocurrencies. Those with existing relationships with such entities were required to end within three months (RBI, 2018b). It did not, however, affect peer-to-peer options to buy and sell cryptocurrencies (Khatwani, 2018).

4. Key challenges facing the Indian blockchain industry and market

In theory distributed networks facilitate decentralized and democratic processes since no single entity owns or controls such networks. In practice, such processes are hindered by many factors.

The usual digital divide puts those without computers and relevant skills at a disadvantage. Cognitive entry barriers may be more severe due to the complexity of blockchain technologies (Atzori, 2015).

At the most basic level, India's high illiteracy rate has direct consequences upon the populations' capability to benefit from technologies such as blockchain. According to the World Bank, India's adult literacy rate was 69.3% in 2011 (https://data.worldbank.org/indicator/SE.ADT.LITR.ZS).

There has been the lack of deep expertise on blockchain-related applications in the country. The head of the ConsenSys Ventures noted that blockchain knowledge in India "was at a very shallow level" (Kaushik, 2018).

A slow bureaucracy has hampered the development and implementation of blockchain systems. As of August 2018, most blockchain projects in the AP and Telangana states had just completed the PoC phase or were developing PoCs (Murali 2018). It was noted that some of the government departments were not motivated to move beyond the PoC stage (Murali, 2018).

The experiences of government blockchain projects in various Indian states have shown that the migration and integration of legacy IT and database management systems into a blockchain-based system would be a difficult task

(Murali, 2018). A major barrier is that different systems from which data need to be transferred to the blockchain system use different data formats and models (Kumar, 2018).

Analysts warned that tougher cryptocurrency regulations discussed in the previous section would have a significant negative effect on the broader blockchain environment (Mundy, 2018). For instance, blockchain projects are often funded by new cryptocurrencies. These are issued through initial coin offering (ICOs). Ban on cryptocurrencies thus would restrict the funding for innovative blockchain projects. It was reported that many blockchain startups were unable to implement projects they had started due to the government's ban on cryptocurrencies and ICOs (Team Inc42, 2018). The tougher regulatory measures would force blockchain startups and developers to relocate in other countries to access funding (Pitti, 2018).

This regulatory uncertainty made the blockchain industry and market less attractive for blockchain startups and developers. A large number of Indian blockchain developer were reported to move to jurisdictions with more friendly regulatory regimes such as Thailand, Estonia and Switzerland (Gunjan, 2018). Out of the country's 2 million software developers, only 5,000 were estimated to have blockchain skills (Agarwal, 2018). Some speculate that about 80% of these developers may pursue job opportunities outside the country (Agarwal, 2018).

Blockchain companies exhibited a similar trend. Zebpay, one of the country's oldest and largest virtual cryptocurrency exchanges closed its operations in India in September 2018. By October 2018, it had opened new offices in Malta and Singapore. Zebpay's new exchange in Malta noted that it would provide services to residents of about 20 countries, which did not include India (Anand, 2018b).

5. Discussion and implications

Blockchain adoption is a slow process that may take many years to exploit the full benefits. For instance, it is expected to take three to four years for the Indian banks to make full utilization of blockchain for trade financing (Bloomberg, 2018).

India has some of the most sophisticated uses of blockchain in some areas. For instance, one of the most advanced applications of blockchain to store property records known to date can be found in the AP state of India. In some cases, the poor quality of the existing land records in the state has posed a major challenge to this initiative (Panchapagesan, 2018). The farmers in the AP have expressed suspicion and distrust toward the blockchain-based land record system Especially the stages before the land records are moved to blockchain are viewed to be fraud prone (Bhattacharya, 2018).

The lack of land ownership remains among the major barriers to entrepreneurship and economic development in India (Kshetri, 2016). Blockchain can reduce friction and conflict, as well as the costs associated with property registration and transfer (Kshetri and Voas, 2018b). In addition, blockchain-based land registry can provide incentives and pressures for small informal businesses to formalize. This is important because informal businesses often tend to avoid attention and like to keep their activities secret. Digitization of their economic activities, however, forces them to be more transparent (Kshetri, 2019). Overall blockchain deployment would boost entrepreneurial activities in the country.

Economic sectors that are already digitized can be more easily moved to blockchain. In the land registry projects in the AP state, the land records were already digitized before (Bhattacharya, 2018). The costs of moving land records onto the blockchain system have also been low because of the involvement of the local firm, Zebi Data. For the first, 83,000 records, it took just a few weeks and cost about Rs 5 (about US$0.07) per record to move to blockchain (Bhattacharya, 2018). Zebi Data is also working with other states including Maharashtra and Telangana.

India lacks some of the key prerequisites to succeed in implementing blcockahin in some other areas. For instance, regarding the BEV it is worth noting that shareholders of Estonian technology company LVH Group can use blockchain to make corporate governance-related voting decisions. They can log in using their verified national online ID and vote at LVH’s annual general meeting (AGM) (Waterman, 2017). Estonia's e-residency platform is used to authenticate e-resident shareholders (Aasmae, 2016). India’s Aadhar system is not as advanced as Estonia's e-residency platform.

In developing countries, foreign and local blockchain companies have different, but complementary roles to play in the development of the local blockchain ecosystem. Regarding established foreign blockchain firms’ entry in developing economies, it is worth noting that they are likely to offer more sophisticated applications and services compared to local companies. For instance, Swedish blockchain startup, ChromaWay partnered with the AP state. ChromaWay had gained significant experience and expertise working with Sweden’s land registry authority, Lantmäteriet and other projects (Bhattacharya, 2018). Local blockchain companies such as Zebi Data, on the other hand, are more effective in providing solutions suitable for local needs at a lower price.

6. Concluding comments

In this article, we examined the current state of the blockchain industry and market in India. Blockchain undoubtedly has tremendous potential to play a major role in addressing a number of economic, social, and political challenges facing India. This technology is likely to help move the Indian economy into a higher gear.

A number of initiatives have been taken by the government and the private sector to promote the development of the blockchain industry and market. PPPs have also been used as mechanisms to promote blockchain development. Political and regulatory uncertainty around cryptocurrencies, however, has been a concern. Probably the most damaging regulatory actions is that in 2018, the RBI cut off cryptocurrency exchanges from the formal financial system. The lack of friendly regulation has also led to brain drain of blockchain developers. Some crypto companies have relocated their operations from India to other jurisdictions that have more friendly regulations.

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An Analysis and Diagnosis of the Korean Blockchain Ecosystem

Sung-jun Kim

1. Introduction

The core values of the 4th Industrial Revolution lie in hyper-connectivity and superintelligence. Today, Blockchain is being highlighted as the core foundational technology that is expected to take a leading role in the 4th Industrial Revolution, as it not only is a core technology of hyper-connectivity, but also strengthens superintelligence. In 2016, more than half of the global experts and business executives who participated in the World Economic Forum predicted that blockchain-based platforms will account for about 10% of global GDP by 2025. Also in the same year, global experts at the World Knowledge Forum forecasted that blockchain, when commercialized, will not only result in a reduction of financial transaction costs, but also play an irreplaceable role in platforms of various sectors. In light of this, blockchain-related institutions are currently seeking to develop platforms using various means, such as establishing partnerships with fintech and IT enterprises, or through investments. Significantly, the institutions are currently undergoing service development and demonstration projects in various fields of industry through convergence with ICT. Governments and central agencies of key countries are establishing policies at the national level and announcing studies to invigorate blockchain technology. Since 2018, the Korean government has expanded its investment into blockchain R&D by allocating new funds, and is conducting a thorough review on the legislation and regulations that may be hindering the invigoration of blockchain.

Blockchain is a distributed ledger technology through which all participants in the network can verify, record and store transaction information. In other words, all records and management authorities are recorded and managed through a P2P network in blocks[1], without having to go through trusted agent institutions. Blocks with new transaction information are inter-connected every 10 minutes, and information in the blockchain is practically impossible to forge or falsify, as the blocks are validated every time they are newly connected.

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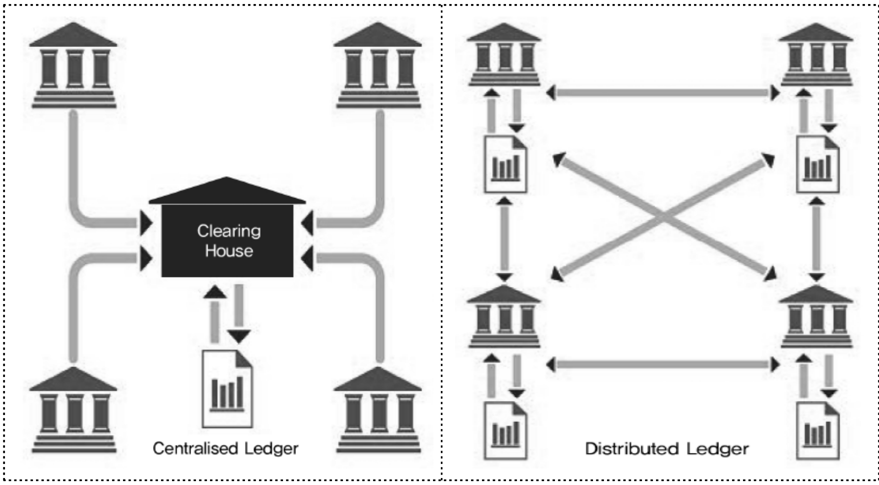
1) Block: A sequentially interconnected packet of data which stores content such as transaction records, or content encrypted in forms of letters or digits



* Source: Application of Blockchain in Financial Industry and Policy Tasks (Suh et al, 2017)

Thanks to these attributes, blockchain is rapidly spreading into not only the financial but also other sectors, promoting the actualization of the 4th Industrial Revolution.

Benefits of the adoption of blockchain include reduced transaction cost, safe and convenient utilization of data, and autonomous cooperation between IoT devices. First, blockchain allows agents of the economy such as the individual or the corporation to engage in transactions without having to rely on trusted third-party agents such as the government or public administrations. Also, the blockchain enables data to be stored safely thanks to the difficulty in forgery or falsification, and to be shared conveniently through access configuration. Based on smart contracts, another technology that is becoming popular in Korea, blockchain supports real-time autonomous cooperation among IoT devices without human intervention. Blockchain will bring changes to the overall industrial ecosystem, and is expected to create immense economic ripple effects and new industrial innovations in terms of productivity enhancement, competitiveness and effectiveness.

Table 1. Examples of Future Blockchain-based Services

Type	Examples	Description
Reduced Transaction Cost	Blockchain-based Logistics Service	All documents regarding containers such as logistics contracts or shipping are shared using blockchain technology to reduce management costs
Utilization of Data	Blockchain-based Genome Data Distribution	Safe sharing of sensitive genome data with research institutions using blockchain
Autonomous Cooperation Among IoT Devices	P2P Electricity Trading among neighbors	Real-time matching and automatic electricity trade between prosumers and consumers through blockchain based electricity trading platform

*Source: Blockchain Technology Development Strategy (Ministry of Science and ICT, 2018)

Table 2. Characteristics and Applications of the Blockchain by Generation

Type	[Introductory Stage] 1st Generation (2009~2014)	[Proliferation Stage] 2nd Generation (2015~Now)	[Maturing Stage] 3rd Generation (Future)
Main Characteristics	Virtual Currency Assets Transaction	Smart Contract (Automatization of Business) Decentralized Application	Expandability Interoperability Among Blockchains Supporting IoT
Representative Cases	Bitcoin	Ethereum Hyperledger	Various platforms being developed

*Source: Blockchain Technology Development Strategy (Ministry of Science and ICT, 2018)

2. Current Status of Blockchain Technology Development and Application in Korea

2.1. Blockchain Paradigm

While in its early stages of development blockchain technology was used as a means of payment, it is now expected to become recognized as a foundational technology leading the innovation of industry and society by overcoming technological limitations and being applied in various transactions and contracts. Blockchain technology's development and application can be broadly broken down into three stages, each with their own technological characteristics.

The 1st generation (2009-2014) refers to the period when over 1,600 types of virtual currencies using blockchain entered the market, shortly after the emergence of Bitcoin in 2009 based on the sharing of a distributed ledger. The main attributes of the 2nd generation blockchain (2015~now) are the emergence of smart contracts which allow automatic fulfillment of contracts based on predetermined conditions, and private blockchain which can be used by enterprises in certain tasks. And so the application of the technology is spreading in various fields, such as sharing of electronic documents and e-commerce. But for blockchain technology to enter other industries, the issue of expandability and interoperability should be dealt with. With the advent of the "3rd generation blockchain" the government is actively engaging in the proliferation of blockchain technology by supporting the development of core technologies and actualization of the platform and announcing plans to establish a performance assessment system, to assist Korean enterprises in developing competitive blockchain platforms. Through these supportive measures being pursued by the government, blockchain technology is expected to overcome the existing centralized structure and be applied in various fields which require trust, including public services, contracts and verification (Ministry of Science and ICT, 2018).

2.2 Fields and Cases of Application of Blockchain Technology

Blockchain technology is currently being used on transactions and payments, contracts, information recording, and platforms. In the field of transactions and payments, the technology is being used in e-commerce, overseas remittance, deferred payment and microfinance, thanks to the advantages it offers in terms of cost reduction and higher transaction effectiveness by enabling transactions without the need to go through agents or trusted organizations. In the field of contracts, it is also being used in content copyright usage-related contracts and transaction protection services, allowing transaction assurance and conclusion of a contract at the same time by inputting a program into transaction data. For information recording, blockchain is being used in public services, medical information management, supply chain management and copyright protection services thanks to the stronger information security and reliability the technology enables. Finally, in terms of platforms, the technology is being used for data protection security and sharing through linkage with IoT platforms. In Korea, blockchain technology is actively used in transactions and payments, information recording, and platforms.

2.2.1 Transaction and Payment

As blockchain transactions take place without having to go through agents or trusted institutions, transaction cost is reduced and efficiency is enhanced, which has led to its active adoption in transaction and payment industries. In particular, cases of investment in the technology and alliance with fin-tech startups are rapidly increasing, with major banks at the center. For example, KB Kookmin Bank established a non-face-to-face identification storage system (2016.4), while KB Kookmin Card adopted a convenient personal authentication system using blockchain technology, becoming the first Korean financial company to adopt the technology (2016.8). Shinhan Bank initiated a cooperative project with 'Streami,' a foreign exchange remittance service developer (2016.7), and launched 'Shinhan Gold Assurance Service'in August 2016, issuing proof of purchase and warranty when gold transactions were made based on blockchain technology. NH Nonghyup Bank mounted a FIDO (Fast Identity Online) based biometric verification solution which can replace the existing public certificate system on its financial platform (2016.8), and in October of the same year, the bank widened its application to on-line services by combining blockchain technology with original fingerprint certification to enhance protection. In June 2015, KEB Hana Bank collaborated with fintech enterprises including Sentbe through the bank's fintech startup incubation center '1Q Lab' to establish a blockchain-based overseas remittance service, and conducted a project on domestic deferred payment and authentication, for which technological verification was completed (2016.11). Woori Bank cooperated with US remittance company 'MoneyGram' to launch a service in February 2017 that allows 24H overseas remittance to more than 200 countries around the world. The Industrial Bank of Korea commenced the development of a blockchain-based financial service in March 2016 by working in cooperation with 'Korbit,' a fintech company, and concluded an MOU on mutual cooperation four months later with 'BitPesa,' a Kenyan Bitcoin-related startup which provides a Bitcoin transfer service between Europe and Africa. In September 2016, Korea Exchange cooperated with 'Blocko,' a blockchain-specialist company, to develop 'KSM (KRX Startup Market) System' for over-the-counter trading, and joined 'Hyperledger,' a global cooperative organization focused on the development of blockchain technology on April 2017 (Min, 2018).

The application of blockchain in fields other than the financial sector has also been increasing. First, Nowon-gu District Office developed a blockchain platform on which 'No-Won,' an exclusive virtual district currency, can be used, to enhance the usability and invigorate the usage of the currency. The currency is provided as compensation to individuals or organizations engaging in volunteer work, donations or recycling of resources. No-won can be used as fiat money in 122 affiliates (21 public affiliates and 101 private affiliates) through scanning a QR code with a mobile app or using a card, and also can be traded (or given as a gift) between users.

Next, the Korea Electric Power Corporation established its 'power trading platform' which matches ideal prosumers and consumers in real-time to enable prosumers[2] to sell self-generated power to neighbors with high electricity demand, with the corporation serving as the middleman. The transaction is made using ‘energy points,’ which can be used to pay electricity bills, reimbursed for cash, or used at electric vehicle charging stations.

Kyobo Life Insurance Co. currently provides an automated actual medical expense reimbursement system which simplifies the insurance claiming process to minimize renunciations of insurance claims by policyholders. Through the system, the entire process from claiming to provision is recorded on the blockchain, and the policyholder reimbursement process is automatically carried out once the medical expenses are paid by the policyholders. That is, the claim is automatically submitted to the company when the policyholder notifies the hospital that he/she wishes to file an automatic claim, and selects medical records to send to the insurance company using a smartphone application. The pilot system was launched in December 2016 at three hospitals in the metropolitan area for certain policyholders of Kyobo Life Insurance, and will be expanded to medium and large hospitals around the country in the near future (Moon, 2018).

2.2.2 Information Recording

Blockchain technology is also used in various fields of information recording to enhance the effectiveness of information use, thanks to its stronger information security and reliability. Several countries are currently using blockchain technology in public service areas such as electronic citizenship issuance, real estate records, voting and public data records based on security and reliability. The technology is also used in the medical sector to collect medical data of patients, verify and share health records in real time, and improve the protection of medical data. Other blockchain technology applications include distributed database-based data sharing, copyright protection of artworks distributed on-line, and safe messenger services which use encrypted keys to deliver messages, audio and images.

Recently, KT developed a ‘Blockchain-based Next-generation Electronic Document Management System’to meet domestic demand for an electronic document storage system (2017.11). ‘KT Blockchain’ can store any data of any enterprise regardless of its size or format, and is parallelized in real-time to allow high-speed encryption.

A significant change in the public administration services sector brought about by blockchain is the application of the technology to electronic voting. Several local administrations in Gyeonggi-do have sought to adopt a blockchain-based electronic voting system to increase referendum turnout and better reflect the opinions of the majority in policymaking. In February 2017, a blockchain-based electronic voting method was used in the public contest for helpful suggestions for the administration, in which residents from 815 communities participated (Jang, 2017). Also, Korea Securities Depository is currently developing a PoC[3] electronic voting system to assure stockholder convenience and prevent forgery and falsification of data during the drafting and registration of stockholder lists or the exercise of stockholder voting rights (Moon, 2018).

In the logistics sector, SK C&C developed a ‘blockchain logistics service’ for domestic and overseas shipping companies in May 2017. In contrast to the conventional method in which all logistics data are recorded and stored in central

2) Electricity Prosumer: Someone who produces electricity through solar generation panels installed on rooftops of houses or stores
3) PoC (Proof of Concept): A small project carried out to resolve technological uncertainties prior to adopting technologies which did not exist in the market before.

servers, the blockchain logistics service allows for shared data management by all parties concerned including shipowners, land carriers and consignors through the P2P network. Not only the locations of containers, but also management information such as temperature or humidity are automatically collected and shared to all parties concerned in real time, while blocking any possibility of intervention. The system helps maintain the content of the data and reduces the burden of having to verify and re-register the cargo when the means of shipping is changed from land to sea or vice versa, and therefore is expected to enhance the efficiency of logistics-related works, resulting in shorter time consumption and cost reduction (Kim, 2018).

2.2.3 Platform

Blockchain technology is widely used through linkage with platforms of various sectors. Korea Electrical Safety Corporation developed a blockchain-based electrical fire ignition point analysis system which utilizes data acquired from the IoT platform to identify the source of fire in disputes among landlords, insurance companies and tenants (2017.11). Through the system, information on the occurrence of arcs, which are flames or sparks that occur on wiring due to electrical discharge, is generated by sensors installed on panel boards of each floor of the building and recorded on the blockchain every five minutes. Through the mechanism, objective evidence required to identify the cause of a fire is collected. The Korea Electrical Safety Corporation formed a consortium with other companies including SK Telecom to launch pilot projects in 10 locations including buildings, traditional markets, temples and cattle sheds, and is planning to expand the project all over the country.

The medical sector is currently developing a data management platform and app service through which personal medical information can be filed into digital documents and be recorded, saved and shared. Today, medical records of patients are handwritten or stored and managed by individual hospitals, and therefore are prone to tampering, and cause inconveniences and unnecessary medical expense. However, once the system is launched, a doctor can record medical information of patients, which will automatically be encrypted and saved on the blockchain platform, giving access and right to sell the record only to the patient through decryption keys. Also, a smartphone app will be launched to enable the patient to manage his/her medical information him/herself. In August 2018, MEDIBLOC published a teaser page on YakOlLim, a service which allows patients to own and manage prescription information, and is conducting beta test (Han, 2018).

In the energy sector, blockchain is used as a ledger which records the credit (virtual currency) provided as a compensation for energy conservation by collecting data on usage conditions such as temperature, humidity, illuminance and percentage of occupants, and on power consumption, to calculate the estimated conservation and actual conservation. This platform may also prove to be helpful in not only enhancing existing carbon mileage projects conducted by local administrations, but also carbon credit trading. The amount of energy conserved for a month or a year, and calculation of earnings is shared transparently and in real time on the platform, allowing the user to check his/her performance and give feedback accordingly. Currently, Australia is testing power trading using blockchain, and the U.K. and Germany are also providing a blockchain-based electricity and gas usage management system. The Korean government also announced plans to replace 5% of the maximum power consumption with negawatt by 2030. E-GenPartners, a Korean company, was selected as the developer for ‘blockchain-based energy service platform for small buildings’ as a part of the integrated convergent security product development project launched by

Korea Internet & Security Agency (KISA) (Woo, 2018). Once the development is completed, blockchain-based information trade will be enabled, allowing anyone to produce and sell energy.

3. Policy Trends and Limitations of the Blockchain in Korea

3.1. Policy Trends of Blockchain in Korea

Korean blockchain companies are still in the course of confirming the technological feasibility of their projects, and have not yet made their way into the market. This may seem reasonable, considering that the technology itself is still in its early stages of development, and that those currently in the race for platform development are restricted to developer groups such as the Ethereum foundation, specialized companies, and multinational corporations. But if Korean companies are to gain technological competence and dominate the global market, the government should be responsive and provide strategies for the formation of the blockchain ecosystem.

The Ministry of Science and ICT recently announced the 'Blockchain Technology Development Strategy' (2018.6) to establish early markets and support private-led growth of the technology by securing global competence, in order to facilitate the development of blockchain, the core technology of the 4th Industrial Revolution.

The strategy aims to promote the adoption of blockchain in public sector areas to bring efficiency to public services and attract private investment, through which the early blockchain market will be formed. To this end, beginning in 2019 the government will select up to two pilot projects with significant effects in terms of simplification of work process or cost reduction, and provide multiple-year funding to commercialize the services. Also, private-led nationwide projects to build public awareness of the utility of the blockchain technology will be initiated. The government aims to discover projects which can strengthen the blockchain utilization capacity of the private and public sector, draw out the demand for blockchains throughout the industry, and significantly reduce unnecessary social costs. Blockchain technology will be applied in 8 leading industries of innovation including intelligent hyperconnection, smart factories, smart farms, fintech, newly developed energy, smart cities, drones and futuristic vehicles, on a preferential basis, to kickstart private-led innovation.

To gain technological competitiveness in the global market, the Korean government will assist domestic enterprises in self-developing competitive blockchain platforms by supporting the development of core technologies and the actualization of the platforms, and establish a performance assessment framework. Currently, Korea's blockchain development capacity is about 2.4 years behind the US. The government aims to reduce this gap and achieve 90% of the total output produced by the country with the most advanced technological capacities by providing a technological development roadmap and updating it every year. In detail, the government plans to adopt a competitive approach - that is, to have several companies compete in a project for two years, after which the final candidate for the project will be selected - in its support for the development of blockchain platforms in each sector, including finance, logistics and the medical industry. The government will also establish a 'blockchain technology support center' and provide a reliability assessment service and testbed to strengthen the competitiveness of private enterprises.

Table 2. Key Contents of Blockchain Reliability and Performance Assessment

Type	Main Contents
Verification of Elementary Technologies	○ Works to verify elementary technologies essential for the realization of blockchain - (Consensus Algorithm) Reviews malicious node tolerance and performance of consensus algorithms such as PoW or PoS - (Encryption Technology) Reviews conformance of encryption technology applied to blockchain * Applies latest encryption technologies including homomorphic encryption, multi-signature, secure multiparty computation and zero-knowledge protocol
Evaluation of Blockchain Platform	○ Conducts assessment on the reliability of blockchain platform to assure public administrations and private enterprises that it is safe to adopt and utilize the technology - Observes the relationship between the reliability attributes by selectively applying the attributes in regard to the type and domain of the blockchain platform * China conducted demonstrative evaluations on the reliability of blockchain, led by the China Academy of Information and Communications Technology (CAICT) (2017.6~2017.9)
Decentralized App Testing	○ Tests the reliability and quality of DApp and identifies risks of realization of Smart contracts that are applied in DApp * IBM announced that 94.6% of tested Ethereum-based smart contracts were found to be vulnerable (2018.2)

*Source: Blockchain Technology Development Strategy (Ministry of Science and ICT, 2018)

Standardization activities will also be reinforced to help Korea take the lead in the global blockchain market. The standardization of blockchain is still in its early stages, and is currently being led by ISO·ITU-T (Official Standardization) and W3C·IEEE (De Facto Standardization). Korea is also currently operating a specialized committee under the National Radio Research Agency and Korea ITU Committee to manage matters related to ISO·ITU-T, and is planning to upgrade its blockchain standardization roadmap and link it with the R&D roadmap to utilize the outcome as a long-term plan for achieving global leadership in the early stage of the industry's development. The government is also planning to expand support for expert actions regarding official standardization, de facto standardization and consortium standardization, and to promote national-level standardization to facilitate consultation among stakeholders and secure inter-compatibility in adopting blockchain in major sectors.

Finally, the government is planning to promote the development of a professional workforce, incubate specialized companies and make improvements to the legal framework to establish the basis for the invigoration of the industry. The government will begin by fostering a professional workforce of 10,000 to meet the demands of the industry, and expedite the establishment of the blockchain ecosystem by providing start-up assistance, increasing investment and making institutional reforms until 2022. Beginning next year, 1,000 blockchain professionals will be educated at a facility where details on blockchain technology and services are taught and discussions take place. As well, blockchain research centers will be established at universities and will receive KRW 800 million in funding every year for up to six years to foster master and doctoral level blockchain experts. Special lectures and curricula on blockchain will be provided at KAIST and GIST, the two national institutes on science and technology, and on-line open access lectures will be provided for students and office workers who wish to learn about the technology. A cloud-based blockchain platform service (BaaS)[4] will be provided to foster specialized companies with competitiveness in the global market and to expand the number of blockchain companies from 30 to 100 by 2022. In the area of legal reforms, a 'Regulatory Reform Panel' will be launched to identify regulations and institutions that are hurdles to the development of blockchain technology and services and to make changes, and blockchain technology will be added to the list of technologies for which R&D expenses can be used as tax credits (Ministry of Science and ICT, 2018).

3.2. Limitations of Blockchain

As mentioned above, blockchain is a technology through which all participants connected through a network jointly verify, record and store transaction data. The application of the technology ensures integrity and reliability, as transaction records cannot be forged or falsified without having to go through official third parties such as Korea Financial Telecommunications & Clearings Institute or Korea Securities Depository. In particular, blockchains based on a distributed network infrastructure using security technologies such as hash, digital signature and encryption allow the actualization of various application services. As a result, services using blockchain technology are emerging not only in the financial sector but also in diverse other industries such as distribution, logistics and the medical industry. In particular, pilot services are beginning to emerge in real estate contracts, food distribution records, and import/export documents with the help of smart contracts.

However, the distributed ledger technology, one of the most distinct and strongest features of blockchain, may in fact serve as a problem. Since transaction records cannot be modified, those with access can freely observe the records at any time, resulting in unregulated transfers and financing which may potentially cause problems. Also, experts note that the technology may act as a burden to middleware, database, security, analysis and the financial sector, as transactions are continuously recorded onto the peer-to-peer (P2P) transaction agent platform. This means that for the blockchain technology to be applied in various fields and used in a stable manner, perfecting the technology is more crucial than making improvements on the administrative side, such as by enhancing the related legal framework.

In its prenatal stages, it is expected that the blockchain technology will require more time to be actualized as stable services in the industrial field. In fact, the first actual applications and pilot projects only took place 2-3 years ago. And due to the immaturity of the technology, various problems occur during its application. For instance, if a user uploads images as a part of a transaction record, data usage may rapidly increase and cause a network overload, and the costs required may also skyrocket as bigger data have to be copied to each node.

Another significant issue is the security; while data in blockchains are known to be practically impossible to forge or falsify as all information distributed throughout the P2P network is recorded and managed in units of Blocks without having to grant any middlemen the recording and storage authority. However, the emergence of supercomputers has overturned the existing information security system, as they were found to be able to break the distributed ledger algorithm. While it takes up to eight months for more than

4) BaaS (Blockchain as a Service): Service which provides a cloud-based distributed virtual network to test the blockchain service development environment

1,600 high performance computers connected in parallel to factorize a 129-digit number, experts argue that with a quantum computer it only takes a few hours, and thus blockchains can also be penetrated in a short amount of time. At a recent workshop, a professor at Chongqing University in China claimed that the destruction of the blockchain will pose a great threat to the security of all internet and applications based on hierarchical systems using public keys, and that new encryption systems using quantum computers should be adopted to ensure the security of the network space.

As blockchain is a core technology with great applicability in various sectors, there are also many tasks and issues to resolve. As suggested above, development should be focused on perfecting the technology, while at the same time administrative issues such as legislations should also be resolved in line with the speed of technological development. A good example would be the existing Korean laws and regulations on networks for commercial use; they were mainly established based on a centralized computer environment. As regulations such as the Electronic Financial Transaction Act or Regulations on the Supervision of Electronic Financial Transaction were devised based on a centralized computing environment, it is difficult to apply these regulations to the blockchain.

4. Conclusion

A swift response to the evolving paradigm and changing environment of blockchain is crucial for the stable invigoration and proliferation of blockchain technology. In this article, applications of the technology in sectors including transaction and payment, contracts, information recording and platforms were observed. In the early stages of blockchain, various service models for transaction and payment were developed, with the financial sector at the center. And as the technological development was invigorated and relevant policies were established in several countries, the technology found its way into industries other than the financial sector. In particular, technologies and service models required for the application of blockchain technology in the information recording sector such as electronic voting and logistics information management have been developed in earnest. Furthermore, platforms on which service models could be mounted were being developed, with several being in the pilot project stages.

However, domestic blockchain businesses still remained at the stages of confirmation and verification of technological potential, and were still far from actual market expansion. Recently, the Korean government announced strategies to establish the basis for the invigoration of the industry by securing technological competence through means such as forming early markets, supporting the self-development of blockchain platforms and establishing a performance evaluation system, and fostering professionals and specialized enterprises. The Korean government's initiative is expected to trigger efforts to strengthen the blockchain competency of the Korean market and narrow the gap with leading countries. However, to take a step further in order to hold technological dominance in the global market and prepare for preemptive responses, it is necessary to focus on current key issues such as data authentication process efficiency or stronger protection against quantum computing. Needs in the area of technological enhancement should be clearly defined, and a staged approach for problem-solving should take place. Active responses should be pursued by the Blockchain Technology Support Center, which was proposed by the government, informed by a swift understanding of the technological, administrative and legal issues of each applicable sector. Korean experts in the field predict that commercialization of the technology will take place in earnest beginning in 2020, and for this reason the government should actively work to develop its response to the fast-changing global market.

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Science and Technology Trends
Blockchain Industries, Regulations and Policy

Blockchain Industries, Regulations and Policies in Singapore

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1. Introduction

When Satoshi Nakamoto launched in 2008 the peer-to-peer electronic cash Bitcoin, little did he expect the underlying blockchain technology he invented would explode into other industrial applications around the world a decade later. Blockchain is a growing list of records or blocks, which are linked using cryptography. It contains a secure history of data exchanges, utilizes a peer-to-peer network to time stamp and verify each exchange, and can be managed autonomously without a central authority (Lafaille, 2018). Using an open distributed ledger, Blockchain can record transactions between two parties efficiently and in a verifiable and permanent way. The ledger itself can be programmed to trigger transactions automatically (Iansiti and Lakhani, 2017).

With blockchain, contracts can be embedded in digital code and stored in transparent, shared databases, where they are protected from modification and deletion. Every payment, process, agreement and task would have a digital record and signature that can be identified, verified, stored and shared. Middlemen such as banks and brokers might not be needed anymore to facilitate these contracts. Individuals, institutions, devices and computer applications can freely transact with one another seamlessly. A major aspect of blockchain is decentralization, which protects it against unauthorized censorship or modification. Copies of the ledger are stored in multiple sites due to peer-to-peer network, rendering it almost impossible to track down every single site for modification or deletion. Since many different, independent nodes keep track of the ledger, updating it in an untrustworthy way will not work because all the other nodes will not reconcile with that transaction and will not add it to the ledger (Lafaille, 2018).

The global blockchain technology market was valued at USD 604.5 million in 2016 with compound annual growth rate (CAGR) of 37.2 percent to reach USD 7.7 billion by 2024 (Grand View Research, 2016). According to CB Insights (2017), the United States and Europe have dominated the blockchain innovation, representing one-half and one-fifth of the annual blockchain global deal share, respectively, in 2016. This dominance is however being challenged by Asia, which has increased its deal share remarkably from 8.5 percent in 2013 to 22.7 percent

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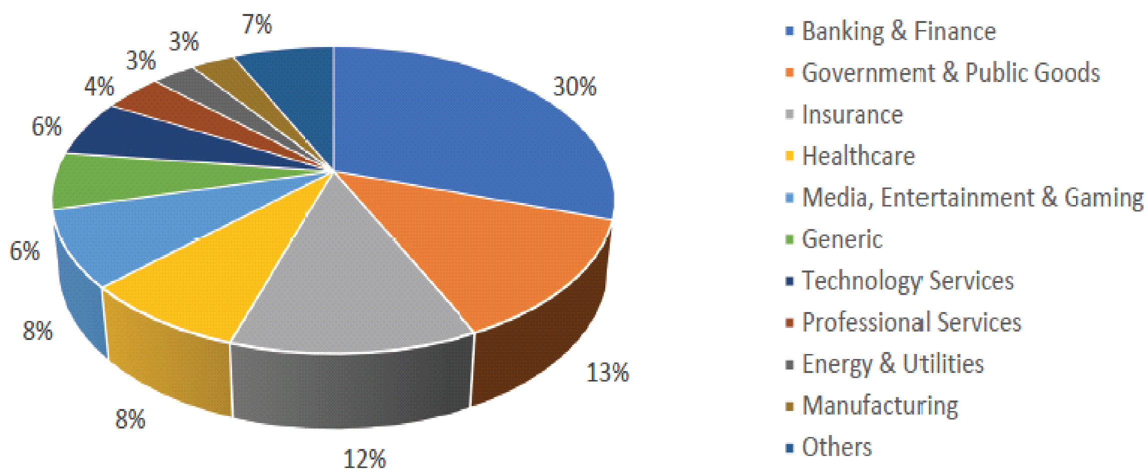
in 2016. In the 2018 Q2 report by Coindesk (2018), the United States is reported to lead with 300 blockchain-related startups and total funding of close to USD 5 billion. Singapore ranks third in the number of blockchain startups with 50 startups after United Kingdom, and fourth in the total funding with more than USD 0.5 billion after China and Switzerland.

Singapore's innovation with blockchain technology has been driven in part by the government's digital strategy to build a smart nation that aims to improve the wellbeing of its society and create opportunities for its business community. In the banking and finance industry, the central banking and financial regulator, Monetary Authority of Singapore (MAS), has spearheaded industry growth by working with financial institutions and technology partners to explore blockchain applications for clearing and settling payments and securities, among other initiatives. To enhance the resilience of the country's power systems and energy markets, the sector regulatory agency, Energy Market Authority (EMA), actively funds the application of new technologies such as blockchain among academic researchers and industry innovators. To provide better care for patients in the healthcare industry, the Ministry of Health (MOH) announced in 2017 that all public and private healthcare service providers would be required by law to capture patient records into the National Electronic Health Record (NEHR) to ensure patient data portability and seamless care. Although blockchain adoption is still early in healthcare, NEHR is largely seen as paving the way for blockchain applications to enable healthcare data integrity and security.

As blockchain continues to disrupt industries and countries, it is important for policymakers to understand the threats and opportunities presented by the technology. This article aims to review the current trends of blockchain developments and their drivers across various industries in Singapore and its Asia-Pacific environment. It also examines how the Singapore government interacts with the industry and academia to formulate regulations to mitigate the risks and inform policies to harness the potential of blockchain innovations. It concludes with implications for policymakers in innovation promotion, consumer and investor protection, as well as human capital and market development.

Figure 1. Identified DLT use cases



Source: Adapted from Global Blockchain Benchmarking Study world (Hileman and Rauchs, 2017)

2. Blockchain Development Trends and Drivers

Based on a study by the University of Cambridge on over 200 organizations from 49 countries in their use cases of distributed ledger technology (DLT) —an alternative term for blockchain— banking and financial services emerged top at 30 percent (Hileman and Rauchs, 2017). Healthcare has use case share of 8 percent, and energy and utility has 3 percent. The findings indicated increasing use of blockchain in non-monetary cases such as identity, supply chain and intellectual property, as depicted in Figure 1.

The World Bank, on the other hand, has identified sectors such as manufacturing, clean energy and government financial management systems in which DLT can be adopted (World Bank, 2018). In Singapore, the industries that saw rising blockchain adoption are banking and finance, healthcare and energy. As this article focuses on Singapore, the authors will examine these industries.

2.1 Banking and Finance

2.1.1 Asia-Pacific

The Asia-Pacific region has seen strong blockchain adoption in the banking and finance industry, driven by social, technological, economic and political factors. With the increasing population of migrant workers sending money back to their home country, there is high demand for financial services that are efficient, convenient and affordable (Cognizant, 2017). Blockchain reduces cross-border settlement costs significantly. Maybank Singapore, for example, aims to leverage blockchain technology to allow close to 20,000 migrants to transact without banking access (Suberg, 2017a).

Market analysts have forecast that by 2020, 50 percent of the world's middle class could be in Asia-Pacific, leading to a larger market for financial services in the region (Cognizant, 2017). To capitalize on the economic opportunities, blockchain startups have emerged across multiple banking segments. Many existing banking and financial institutions are also experimenting with blockchain in their respective domain.

Japan, currently an 80 percent cash-driven country, has explored blockchain to reduce its dependency on cash. SBI Ripple Asia, a joint venture between Japan's SBI Holdings and US blockchain specialist Ripple, has developed the blockchain-based money transfer application MoneyTap and works with over 60 Japanese banks to enable low-cost, fast and secure money transfer (Arnold, 2018). In June 2018, China's Alibaba launched Alipay, a mobile payment solution, which uses GCash Blockchain system, with Standard Chartered as its banking partner, to provide a quicker and cheaper method for people to send money from Hong Kong to the Philippines (Arnold, 2018).

Blockchain developments in the Asia-Pacific region have also been fuelled by forward-looking governments recognizing the potential to improve transparency and efficiency of regulatory compliance-related processes such as know-your-customer (KYC) and anti-money-laundering (AML) (Cognizant, 2017). Regulators in Australia and Hong Kong have established regulatory sandboxes to ease testing and piloting of blockchain projects (Cummings, 2017). Japan and South Korea have regulated cryptocurrency environments, with strict policies for security, internal management and anti-money laundering. The Korean government has announced plans to invest USD 880 million in blockchain technology to improve the efficiency of the government operations (Startup Radar, 2018). Among the developing economies, China has been a forerunner in testing a sovereign blockchain digital currency to foster a flexible regulatory environment (Wu, 2016).

Figure 2 presents the global Bitcoin and blockchain deal share during the period from 2012 to 2017. It is apparent that Singapore, Japan, South Korea and China have been dominant players in Asia-Pacific, occupying 9 percent of the pie.

2.1.2 Singapore

MAS has adopted a proactive approach toward blockchain. MAS and the Association of Banks in Singapore (ABS) have successfully developed software protocols of various models for decentralized inter-bank payment and settlements, using DLT (MAS, 2017a, 2017b).

The Singapore Exchange (SGX) and MAS have developed Delivery versus Payment (DvP) capabilities to settle tokenized assets across different blockchain platforms to simplify post-trade processes, shorten settlement cycles and reduce settlement risks (Ramchandani, 2018). DvP is a settlement procedure where securities and monies are exchanged at the same time, and was developed with technology partners Anquan, Deloitte and Nasdaq.

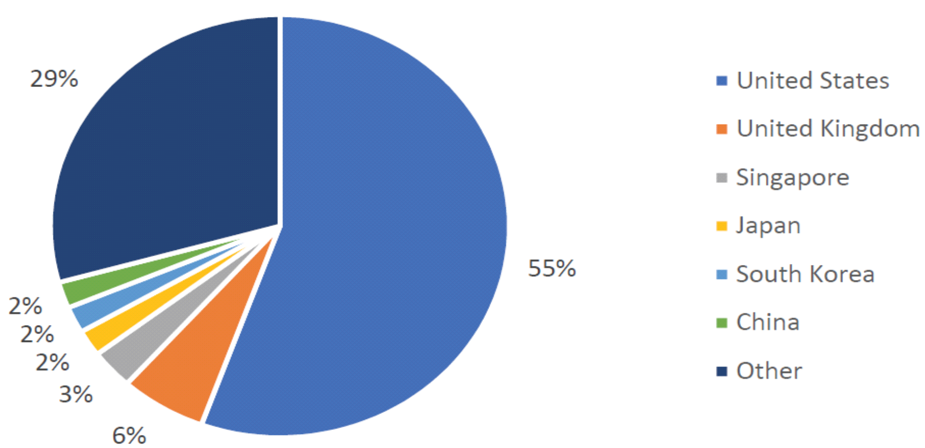
2.2 Energy

2.2.1 Asia-Pacific

In many countries, energy production and distribution has been monopolized since the turn of the century by large utility companies that are either government owned or privately held. With recent technological innovation in alternative energy sources, individuals are increasingly empowered to produce energy (e.g. solar energy) and use it themselves as prosumers. For the excess energy generated, the prosumers may sell it to consumers that are connected on a local utility grid (microgrid). For the sales and purchase to take place between prosumers and consumers, energy can be transacted as a digital asset. Blockchain technology has the potential to facilitate the decentralized mode of peer-to-peer energy trading.

Investment in the global energy and clean technology (cleantech) market has reached USD 739 million with 53 deals in 2017 and USD 359 million with 16 deals in 2018 Q1, as shown in Figure 3 (Besnainou, 2018). In 2017, USD 330 million of blockchain investment was made in core energy with more than half of the use cases in peer-to-peer and retail electricity trading, and a quarter in green mining. As early adopters, the Asia-Pacific region is projected to be the fastest-growing market for blockchain in energy and cleantech, and to be the largest market globally by 2023 (MarketsandMarkets, 2018).

Figure 2. Bitcoin and blockchain global deal share 2012-2017



Source: Adapted from CB Insights (2017)

Over 90 percent of blockchain financing in energy and cleantech in 2017 and 2018 Q1 were in the firm of coin or token offerings. By 2018 Q1, European companies have raised over USD 723 million, followed by those in Asia-Pacific and North America that raised more than $251 million and USD 140 million, respectively (Besnainou, 2018).

In Asia-Pacific, Australia seized the largest share of blockchain in the energy market, on the back of strong government support to fuel blockchain adoption as part of its Smart Cities and Suburbs Program. An example is a collaborative project to pilot the use of blockchain-powered distributed energy and water systems in the Perth, involving academic, infrastructure and technology partners, and private investors (McLean, 2017). In Japan, Kansai Electric Power Co (Kepco), has partnered with Mitsubishi UFJ Bank, IT service management company Nihon Unisys and the University of Tokyo to conduct research on blockchain applications in distributed electricity supply. The research explored the sale of excess energy produced by solar power suppliers to consumers (Suberg, 2018).

2.2.2 Singapore

In October 2018, the national electricity and gas provider, Singapore Power (SP), launched blockchain-powered trading of renewable energy certificates (REC) at the ASEAN Energy Business Forum. With blockchain, SP is able to ensure security, integrity and traceability of production, consumption and transaction, thereby enabling local and international enterprises to achieve their energy sustainability goals (CCN, 2018). Solar developers such as Cleantech Solar Asia and LYS Energy Solutions have placed their solar assets on the marketplace for the sale of RECs, while local property developer City Developments Limited and local bank DBS Bank have signed on as REC buyers (SP, 2018).

2.3 Healthcare

2.3.1 Asia-Pacific

Blockchain technology has the potential to revolutionize the healthcare industry by enabling health information exchanges (HIE) to become more efficient, disintermediated and secure in managing electronic medical records. A Deloitte analysis on blockchain in healthcare gives several use cases: Precision Medicine Initiative, Patient Care and Outcomes Research (PCOR), and the Nationwide Interoperability Roadmap (Deloitte, 2016). Table 1 summarizes the key HIE pain points that present opportunities for blockchain applications.

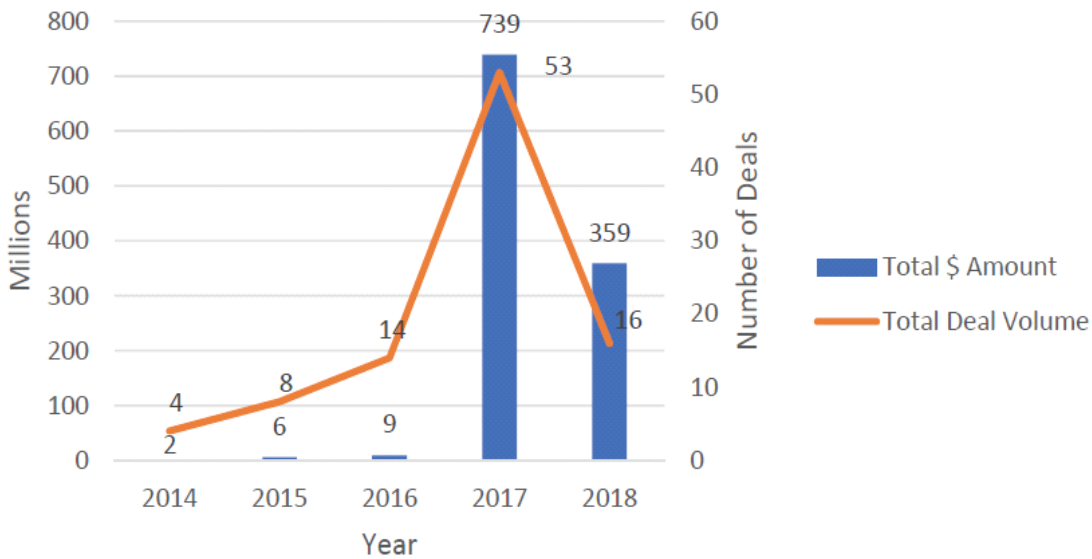
The healthcare blockchain market is projected to grow at a CAGR of 72.8 percent USD 829 million by 2023 from USD 53.9 million in 2018. The major drivers for the adoption of DLT are rising incidents of healthcare data breaches, threat of counterfeit drugs and the transparency of DLT. It is predicted that the Asia-Pacific market will grow at the highest rate over the next five years, driven primarily by the general improvement of healthcare infrastructure, growing adoption of Electronic Health Record (EHR) systems, and the need to prevent counterfeit drugs from entering the supply chain (MarketWatch, 2018).

In the Indian state of Rajasthan, blockchain has been adopted to maintain EHR (including heath summary, reports, vital statistics and prescriptions) to ensure data integrity and security, and patient privacy, which has helped to reduce costs and increase operational efficiency (Raval, 2018). In the Chinese city of Changzhou, the local Chinese government has partnered with Alibaba to launch blockchain applications through Ali Health. The blockchain technology provides interoperability for managing patient data, ensures strict access controls and provides convenience to both patients and healthcare stakeholders (Suberg, 2017b). In 2018, the Australian Department of Health collaborated with secure cloud provider Vault Systems and blockchain startup Agile Digital to track the parties accessing medical data and their reasons for such access. Besides providing a platform that facilitates research on health data, the Department uses the blockchain technology to ensure privacy on citizen data. (McLean, 2018).

2.3.2 Singapore

In 2017, Singapore spent 1.5 percent of its GDP on healthcare. It has also committed USD 19 billion from 2016 to 2020 to R&D (Fintechnews, 2017). With the continuous rise in annual healthcare spending, it is predicted to reach USD 13 billion dollars by 2020, (MOH, n.d.). Faced with the issue of rapidly ageing population, Singapore is constantly looking for new, innovative solutions to keep up with the rising demand for good quality healthcare. Due to its business-friendly laws and economic stability, the country has attracted noteworthy blockchain startups to the healthcare sector. There is a corresponding increase in blockchain investments in the sector.

Figure 3. Investment in energy and industry market



Source: Adapted from Cleantech (Besnainou, 2018)

Table 1. HIE Pain Points and Blockchain Opportunities

HIE Pain Points	Blockchain Opportunities
Establishing a trust network depends on the HIE as an intermediary to establish point-to-point sharing.	Disintermediation of trust likely would not require an HIE operator as the DLT ledger is accessible by all participants without complex brokered trust.
Inconsistent rules and permissions prevent access of right patient data at the right time by the right health organization.	Smart contracts create a consistent, rule-based method to allow permissioned health organizations to access patient data.
Varying Data Standards reduce interoperability because records are not compatible between systems.	Shared data enables near real-time updates across the network to all parties.

Source: Adapted from Deloitte (2016)

3. Overview of Singapore's Policies

For the past decade, Singapore has been ranked among the top three on the Global Competitiveness Index out of 140 countries by the World Economic Forum. Ranking second in 2018, the country leads in the areas of transport infrastructure, connectivity, services and product market. With its business-friendly policies, Singapore is also home to many well-funded blockchain startups that have the potential to become leaders in their respective markets. (Hynes, 2018). From our review of Singapore's policies on blockchain innovations, it is evident that the government has actively adopted the Triple Helix model (Etzkowitz, 2007), which underscores the importance of interactions among three spheres—government, university and industry—in advancing the development of national innovation system (Cheah, Ho and Lim, 2016). This section will focus on the government and university spheres of the Triple Helix to understand how public policies are formulated in active consultation and experimentation with the academic and business communities, with particular emphasis on the banking and finance, energy, as well as healthcare sectors. These policies are instrumental in building a national innovation system comprising infrastructure, resources and capabilities to create and capture value from blockchain innovations, as part of the smart nation strategy to enhance the nation's competitive advantage. Section 4 will examine the industry sphere of the Triple Helix to discuss its role in blockchain adoption and the resulting impact from the interaction dynamics of the three spheres.

3.1 Banking and Finance

Singapore's central bank MAS plays the dual role of regulating financial services and promoting the country's role as an international financial center. As one of the most forward looking regulators, MAS pioneered the adoption of blockchain innovations to transform its banking and finance industry.

In 2016, MAS started Project Ubin, a collaborative multi-phase project with the private sector, to explore the creation of digital money using DLT for payments and securities clearing and settlement (Luu, 2017). The first phase from November 2016 to March 2017 focused on domestic inter-bank payments using a central bank-issued Singapore dollar (SGD) equivalent. This phase involved a DLT company R3, a consortium of financial institutions (Bank of America Merrill Lynch, Credit Suisse, DBS Bank, The Hongkong and Shanghai Banking Corporation Limited, J.P. Morgan, Mitsubishi UFJ Financial Group, OCBC Bank and UOB Bank), SGX and technology provider BCS Information Systems. The insights of the first phase were published by Deloitte in the report "Project Ubin: SGD on Distributed Ledger," detailing DLT features that are the most appropriate for settlement systems and design considerations used for the prototype (MAS, 2017a).

MAS launched the second phase in July 2017 with ABS to study the implications of implementing DLT for real-time gross settlement (RTGS) and balancing decentralization Liquidity Saving Mechanisms (LSM) with banking transaction privacy. After 13 weeks, the second phase was concluded and its findings reported by consulting firm Accenture. The second phase demonstrated that RTGS can be decentralized by three DLT platforms (Corda by R3, Hyperledger Fabric by IBM and Quorum by JP Morgan) without compromising privacy, thereby removing the need for a central infrastructure operator for interbank payments and establishing the framework for future innovation. In November 2017, the second phase report together with the source codes were made available to the public, encouraging central banks, financial institutions, along with academic and research institutions to use them for research and innovation

(MAS, 2017b).

Regarding blockchain as "fundamental" technology, MAS has classified digital assets into three groups: payment tokens, utility tokens, and securities. While there are no plans to regulate utility tokens, a payment service law for payment tokens will be introduced by end of 2019 (Aw, 2018). While cryptocurrencies are not considered legal tender in Singapore, cryptocurrency exchanges and trading are legal. Singapore's tax authority treats Bitcoins as "goods" and so applies Goods and Services Tax on them (ComplyAdvantage, 2018).

Unlike China or the United States, Singapore is moving quickly to establish a reliable legal framework for digital assets, which will help companies to invest confidently in the nation-state. China's crackdown on one of the world's most promising new technologies has driven companies like imToken, Bitmain and Huobi to open regional headquarters in Singapore (Say, 2018). To attract blockchain-based decentralized exchanges to the country, MAS has proposed changes to existing regulations in consultation with the public in May 2018. The current single-tier recognized market operators (RMO) regulatory framework is limited in meeting demand for new business models based on such emerging technologies. MAS suggests a three-tier structure to facilitate market access for small-scale exchange platforms. A new Tier 3 category targets market operators that are significantly smaller than established exchanges to allow them to implement blockchain and P2P technology to deploy services in a supervised environment (MAS, 2018a). To combat the perennial challenges of money laundering and terrorism financing, MAS issued a detailed guide on the application of securities law in relation to offers or issues of digital currencies in Singapore in their "A Guide to Digital Token Offerings" (MAS, 2017c). To protect public interest, all virtual-currency intermediaries in Singapore such as exchange operators are required to comply with requirements to combat money laundering and terrorism financing.

In April 2017, the National University of Singapore (NUS) School of Computing announced its collaboration with the IBM Center for Blockchain Innovation (ICBI) to develop a module on blockchain and DLT (Mizrahi, 2017). The module focuses on the fundamentals of DLT, its use cases including banking and digital currencies using the financial technology software Hyperledger Fabric. The collaboration aims to prepare a future workforce that is blockchain savvy to support the country's vision of Smart Financial Center and Smart Nation (Mizrahi, 2017).

3.2 Energy

In Singapore, EMA plays the roles of a power system operator (supplying electricity to homes, offices and industries), industry developer (developing energy industry through innovations) and industry regulator (regulating electricity and gas industries in Singapore to promote fair competition among businesses while protecting consumers' interests). To foster innovation with emerging technologies such as blockchain, EMA has announced grant calls in May 2017 for local firms to develop solutions to optimize energy generation, transmission and consumption. To enhance the resilience of the country's power system and energy markets, EMA has also awarded SGD15 million grant in September 2018 to fund seven public-private projects expecting completion by 2021. Among the seven projects, three applied blockchain to enhance market resilience.

The first project was led by The Experimental Power Grid Center, in collaboration with the National University of Singapore (NUS), the Nanyang Technological University (NTU), French renewable energy producer Beebryte Pte Ltd and Singapore-based power generator and electricity retailer PacificLight Energy Pte Ltd. The project aims to increase market resilience by enhancing energy market operations and trading through DLT. A decentralized, secure and tamper-proof ledger of all transactions will be created to facilitate peer-to-peer trading and payment. By removing middlemen, it is expected to reduce customer costs by up to 20 percent (EMA, 2018).

To establish technical standards for global commercialization of blockchain-based micro-grid for commercial buildings, NTU led the second project in partnership with Taiwan's National Chiao Tung University, China's Guangdong Institute of Technology, Switzerland-based Ethereum Foundation, energy and water solution provider Sembcorp Industries Pte Ltd, SP, and deep learning R&D center NVIDIA Technology Center Asia Pacific.

Together with SP and solar energy solution provider SolarGy Pte Ltd, NTU researchers led the third project to study the feasibility of open ledger technology based on blockchain to record multi-party transactions in a verifiable and permanent manner, with the view to enhancing the efficiency and scalability of the electricity market operations.

To develop professional competences in blockchain and power engineering capabilities, EMA has collaborated with the Public Service Division and SkillsFuture Singapore in 2018 to design a training program with sign-on incentives of SGD 5,000 for graduates of local polytechnics and vocational institutes. By providing facilitated learning and on-the-job training, the structured program aims to deepen their knowledge and expertise in the energy sector (EMA 2018).

Apart from encouraging technological innovation, EMA has taken steps to liberalize the energy market. Since 2001, it has progressively offered industrial and commercial consumers the options to purchase electricity from other electricity retailers than the national power supplier SP at regulated tariff. By November 2018, the open electricity market was extended to consumers across the country. This has paved the way for more energy innovations to be introduced to the market.

3.3 Healthcare

MOH is Singapore's ministry responsible for the formulation of policies and programs for the development and regulation of healthcare products and services. All healthcare facilities such as hospitals, medical centers, community health centers, nursing homes, clinics (including dental clinics), and clinical laboratories are required to apply for licences under the Private Hospitals & Medical Clinics (PHMC) Act (MOH, n.d.). While the current PHMC Act has no provisions for blockchain technology, healthcare providers and research institutes in Singapore are experimenting with DLT.

SGInnovate, a deep tech venture capital owned by the Singapore government, has been investing heavily in medtech as part of its Deep Tech Nexus strategy, that aims to add tangible value to the country's deep tech startup ecosystem in two key areas—Human Capital and Investment Capital (Bhunia, 2018). In particular, the organization focuses on blockchain, artificial intelligence (AI) and robotics in healthcare, resources and transportation in partnership with blockchain and AI players such as IBM and Singularity Net (Crunchbase, n.d.; SGInnovate, 2017).

SGInnovate has partnered with Kingsland University School of Blockchain and Ngee Ann Polytechnic (NP) in Singapore, to launch the country's first certified blockchain developer program. The partnership would combine the technical expertise from Kingsland University and educational practice by NP to develop the human capital needed to support blockchain innovations.

4. Case Studies

By 2018 Q2, 57 blockchain-related projects have raised over USD 570 million in Singapore via ICOs. Industry partners have been pivotal in this journey. Using a case study approach, this section discusses the role and impact of industry in blockchain innovations across banking and finance, energy and healthcare sectors.

4.1 Banking and Finance

Drawing upon the findings of Project Ubin, MAS and SGX have successfully developed in 2018 Delivery versus Payment (DvP) capabilities for the settlement of tokenized assets across different blockchain platforms. The prototypes developed with technology partners Anquan, Deloitte and Nasdaq have simplified post-trade processes, shortened settlement cycles, increased operational efficiency and reduced settlement risks (MAS, 2018b).

MAS also launched a regulatory sandbox in 2016 to allow participating firms to experiment and work on fintech projects in a controlled environment, that is separate from production, without posing much risk to consumers or investors. In November 2018, MAS released a consultation paper on the creation of Sandbox Express, which are pre-defined sandboxes. It aims to enable firms to conduct regulated activities and experiments more quickly without the need to go through existing sandbox application and approval process. The Sandbox Express is suitable for activities where the risks are generally low, or well understood and could be reasonably contained within the specific pre-defined sandbox, such as insurance brokering, recognized market operators and remittance businesses. Each pre-defined sandbox will have its boundaries, expectations and regulatory reliefs pre-determined (MAS, 2018c). In the precursor sandbox, MAS and the applicant jointly define the boundaries within which the experiment would take place, and then MAS will determine the specific legal and regulatory requirements it is prepared to relax for the experiment (Menon, 2016).

Acting both as a promoter and a regulator, MAS not only assesses the risks of changing technology scenarios, but also helps Singapore promote fintech startups and lead in blockchain globally. This illustrates the importance of a partnership between the public and private sectors.

The forward-looking regulations have succeeded in attracting both blockchain startups and investors. Signum Capital, a Singapore-based firm that consults in blockchain-enabled companies has invested in a few fintech blockchain startups, such as TenX and Republic Protocol. TenX provides a cryptocurrency payment platform in the form of a wallet, physical debit card, bank account and ATM access. The company aims to make cryptocurrencies instantly spendable. The TenX wallet allows a user to receive and send cryptocurrencies (Bitcoin, Ethereum, Litecoin). Upon pairing the wallet with a TenX card, users will be able to spend their cryptocurrency at in-store purchases, online shopping and cash withdrawal at ATMs. The card is still under development. TenX investors include Signum Capital, Fenbushi Capital and ICH with support from DBS Blockchain Hack, Citi and PayPal Incubator (Business Wire, 2018a). TenX has raised USD 81 million in funding: USD 80 million through initial coin offering (ICO) in June 2017 and a seed investment of USD 1 million in January 2017 (Tech in Asia, n.d.). Fenbushi Capital had invested in TenX in the seed round of investments. In the latest ICO round held in June 2017, Chain Capital has also invested in TenX (Crunchbase, n.d.).

Republic Protocol, a Singapore-based startup, has developed RenEx, an open-source decentralized dark pool exchange that facilitates cross-chain atomic trades on a hidden order book. It is carried out over

Ethereum and Bitcoin networks. A dark pool is a type of private exchange in which financial assets and instruments are traded and matched by an engine running on a hidden order book. It is common on Wall Street and operated by institutional investors such as JP Morgan Chase and Goldman Sachs (Business Wire, 2018b). RenEx offers hidden order books, where orders are private until execution, for large amounts of tokens. It also offers cross-chain asset trading and a way to place large trades with minimal market impact and price slippage. Its investors include Huobi, Polychain Capital, FBG Capital, HyperChain Capital, Signal Ventures and Signum Capital (ICORATING, n.d.; Tech in Asia, 2018). Republic Protocol has raised USD 34.8 million in January 2017 and USD 30.5 million in February 2018 through ICO (Tech in Asia, 2018).

These two cases highlight the importance of supportive public policy and munificent funding by private investors to develop blockchain ideas into marketable solutions.

4.2 Energy

Similar to MAS, EMA has launched a regulatory sandbox to encourage innovations in the energy sector. The sandbox enables EMA as the industry regulator to assess the impact of new products and services by innovating companies including startups, before formulating the appropriate regulations (EMA, 2018).

One such startup is Electrify, a Singapore-based electricity marketplace that allows consumers to buy energy from a range of energy retailers using blockchain. The blockchain model is expected to reduce costs for Electrify and its consumers with smart contracts. Smart contracts remove the legal, accounting and administrative costs which can account to as much as 30 percent of the retail cost of electricity in traditional transactions (Cai, 2018). Electrify is funded by two investors, Wendell Davis and Jun Hasegawa, who have invested USD 30 million in an ICO round in March 2018 (Crunchbase, 2018). Electrify has also partnered with Tepco Frontier Partners, a subsidiary of Japan's largest utility company Tepco, to explore commercialization in Japan, potentially serving a third of Japan's electricity consumption (Abudheen, 2018). Electrify has helped companies buy around 500,000 kWh of electricity, saving Singapore businesses more than USD 200,000 per year.

The case of Electrify brings into focus the importance of public agency support, as well as access to savvy angel investors, established industry player and international markets.

4.3 Healthcare

In April 2018, MOH has launched a regulatory sandbox called the licensing experimentation and adaptation program that aims to provide a controlled environment to pilot new and innovative healthcare models. To date, MOH has invited telemedicine and mobile medicine providers to participate in the sandbox. The ministry also collaborates closely with SGInnovate that works with researchers and startups in healthcare technology to bring their ideas from the laboratories to the clinics and hospitals.

In April 2018, SGInnovate made its first investment in a Singapore-based blockchain and healthcare analytics startup MediLOT Technologies. Building on blockchain, AI and database management system technologies, MediLOT not only enables patients and doctors to have full access to health data for more effective diagnosis and treatments, but also allows researchers and commercial companies to conduct research and create greater quality of care for the patients (Sregantan, 2018).

MediLOT was cofounded by Prof Ooi Beng Chin (NUS), Dr. Ngiam Kee Yuan (National University Health System), Prof Zhang Mei Hui (Beijing

Institute of Technology) and Zhang Jiangwei (NUS). The startup has also received funding from Signum Capital and is backed by Blocks, QCP Capital and NUS. The cofounders have spent five years on research to develop its technology, and recently partnered with a number of hospitals, such as Tan Tock Seng Hospital (TTHS) and National University Hospital (NUH), Singapore (Block Asia, 2018).

MediLOT's solutions provide personalized healthcare to patients, who get easy and efficient access to their health records that are secured in MediLOT's databases, Patients can earn LOT tokens by allowing their data to be used for research. These tokens can be used to access applications or health reports or redeem items at partner pharmacies. MediLOT offers solutions to organizations that allow them to harness big data which can enable the development of new sustainable business models (Cheah and Wang, 2017; Cheah, Ho and Li, 2018). They can request for health data remotely and have easy access to large, valuable datasets with transparent and fair pricing.

This case emphasizes the significance of having access to R&D talent, university and hospital resources, as well as public and private investors.

5. Implications and Conclusion

We presented the Triple Helix interactions that are inherent in the Singapore government's ecosystem-based approach to encourage and regulate blockchain innovations across three industries– banking and finance, energy and healthcare. From our discussion of the findings, it is apparent that there are several implications that policymakers should consider in developing the multiple dimensions of the blockchain innovation ecosystem.

First, regulatory sandboxes are important in encouraging researchers, innovators and entrepreneurs to come forward to experiment with their blockchain innovations while minimizing risks and maximizing learning opportunities. The speed with which regulatory frameworks have been proposed based on sandbox findings and consultation with the public (e.g. single-tier vs three-tier RMO structure suggested by MAS) has attracted international startups, market operators and investors to the country. The transparency and clarity of policy (e.g. guide to digital token offerings to fight financial crimes) has instilled confidence in service providers, investors and consumers in adopting innovations.

Second, access to financial resources is crucial for any emerging technology that is still unproven and risky. Private investors are less likely to fund the development of early-stage technologies as they are fraught with uncertainties and the likelihood of failures is high. Public funding is therefore essential at this stage for proof-of-concept projects (e.g. EMA's SGD 15-million grant award for energy innovation and SGInnovate's investment in MediLOT) to advance technological development. When the projects have validated their technological feasibility and demonstrated market viability, the availability of angel investors (e.g. individual investors for Electrify) and private institutional investors (e.g. Signum Capital for TenX and Republic Protocol) is crucial for the projects to progress to the next stage of product and market development. In Singapore, incentives have been provided by the government to attract investors to set up their officers and launch their technology funds in the country. For example, Golden Gate Ventures (GGV), a Singapore-based venture capital firm has launched LuneX Ventures, a USD 10 million fund that will invest in cryptocurrency and blockchain startups globally (Cheok, 2018).

Third, studies have shown that successful innovation and ventures require strong support in the ecosystem (Cheah et al., 2016; Cheah and Yu, 2016). Support can come in various forms from infrastructural facilities to non-government institutions. University and public research centers (e.g. The Experimental Power Grid Center, NUS, NTU) can provide access to computing resources and simulation facilities for technology development, prototyping and testing of use scenarios for product development. Hospitals (e.g. NUH, TTSH) can also grant access to their laboratory equipment and medical databases (e.g. NEHR) for research, experimentation and product validation (Cheah, 2016). Non-government institutions including associations (e.g. ABS in banking and finance) that represent and champion the interests of their banking and financial institution members in emerging technologies such as blockchain have also contributed to rapid growth in the number of blockchain startups, innovators and investors.

Finally, human capital is a critical resource in the ecosystem. Institutes of higher learning play an essential role in developing human capital to create and transfer knowledge and capability. The NUS School of Computing introduced in 2018 a new module on blockchain and DLT to equip undergraduates with knowledge on cryptocurrencies and DLT applications. At a national level, the country started a national movement called SkillsFuture Singapore in 2014 to build skills alongside the industry transformation initiatives that have taken place as part of its five-year research, innovation and enterprise (RIE2020) plan from 2016 to 2020.

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