

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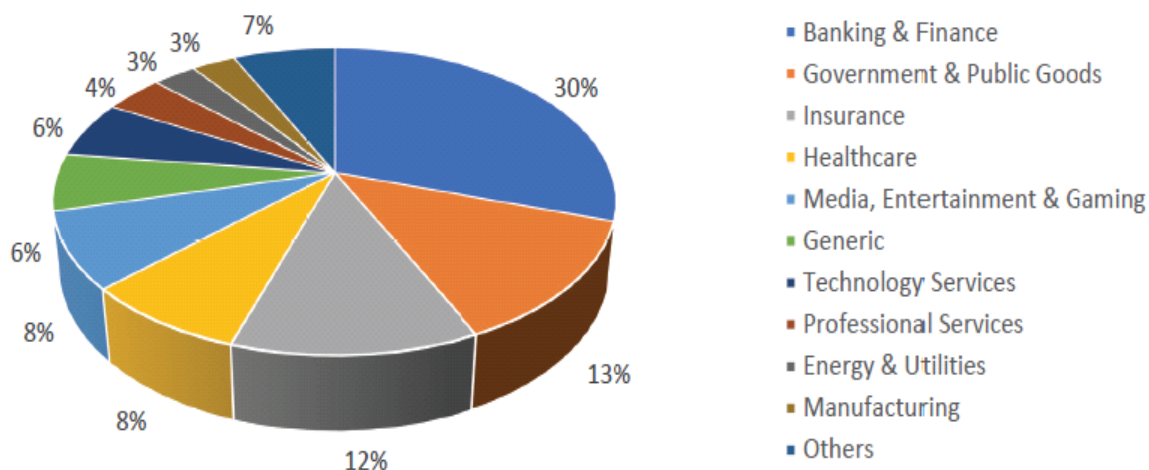
in 2016. In the 2018 Q2 report by Coindesk (2018), the United States is reported to lead with 300 blockchain-related startups and total funding of close to USD 5 billion. Singapore ranks third in the number of blockchain startups with 50 startups after United Kingdom, and fourth in the total funding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

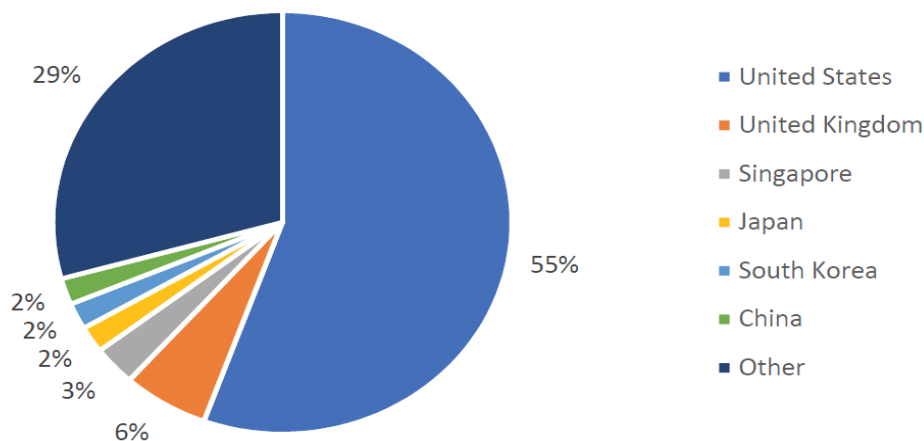
2.2.1 Asia-Pacific

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 form 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 health 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

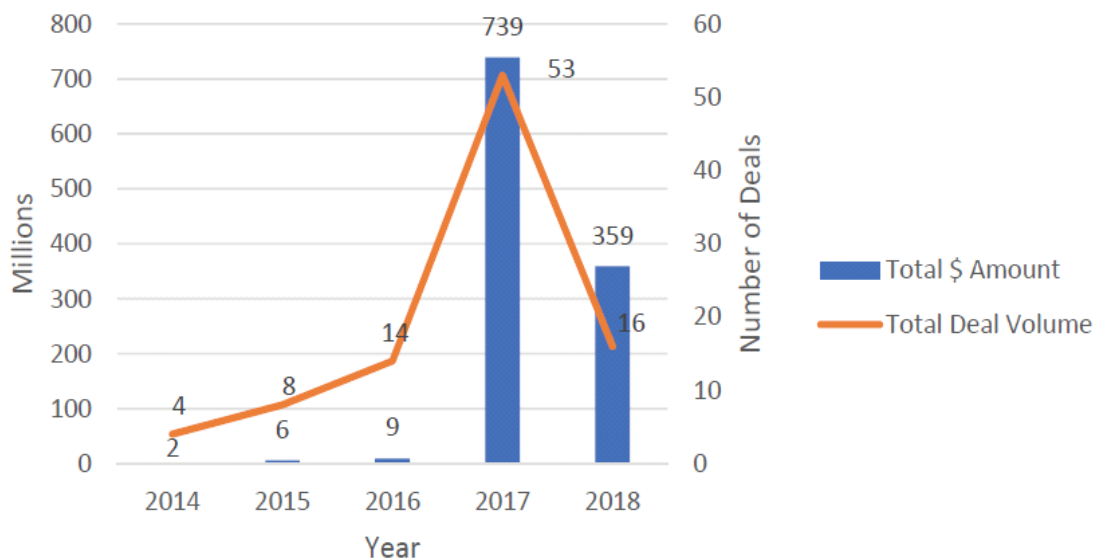
provider Vault Systems and blockchain startup Agile Digital to track the parties accessing medical data and their reasons for such access. Besides providing a platform that facilitates research on health data, the Department uses the blockchain technology to ensure privacy on citizen data. (McLean, 2018).

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 offices 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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