Technology brief: Blockchain—Risks and Opportunities

Almost 10 years ago, an anonymous person or group going by the name of Satoshi Nakamoto published a paper that introduced the world to Bitcoin and its underlying technology, blockchain. Titled "A Peer-to-Peer Electronic Cash System",[1] the paper laid out the advantages of blockchain technology, a new, innovative system that keeps track of ownership of assets and records transactions without a need for a third party or central authority.

This technology was first used to create Bitcoin, the world's first decentralised cryptocurrency. Bitcoin is a form of digital currency used as a medium of exchange for goods and services over which no central authority has control, and which uses cryptography to prevent counterfeit and fraud. Since its launch in 2009, its value has risen from US$0.06 to more than US$17,000 in December 2017, with its market capitalisation standing at around US$125 billion in March 2018. Bitcoin is not the only cryptocurrency being used and traded. In March 2018, there were more than 1,500 cryptocurrencies with a total market capitalisation of US$275 billion.[2] In early January 2018, their value peaked at US$795 billion.

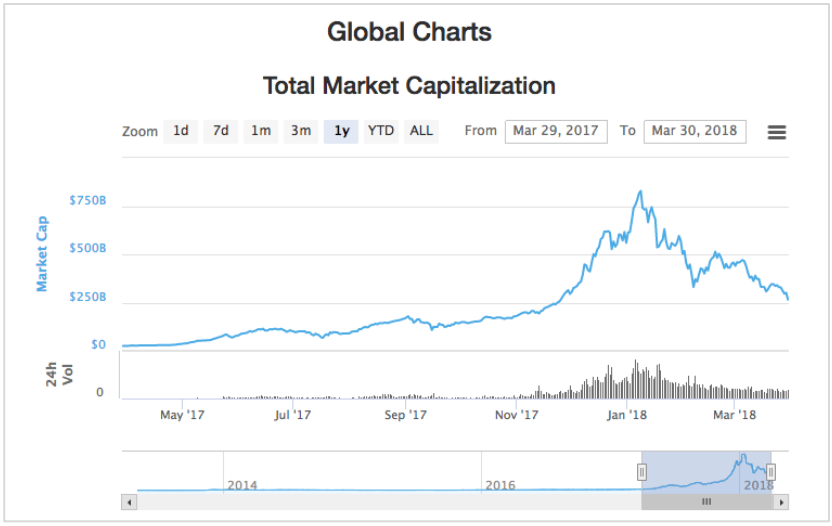

***Figure 1**. Market capitalisation of cryptocurrencies (March 30, 2018)[3]*

[1] Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008, https://bitcoin.org/bitcoin.pdf.
[2] "Global Charts," *CoinMarketCap*, 2018, https://coinmarketcap.com/charts/.
[3] Ibid.

This policy analysis has been written by Lim Wei Chieh and has been funded by the Lee Kuan Yew School of Public Policy (LKY School), National University of Singapore. The case does not reflect the views of the sponsoring organization nor is it intended to suggest correct or incorrect handling of the situation depicted. The case is not intended to serve as a primary source of data and is meant solely for class discussion.

While much of the attention has been focused on cryptocurrencies, it's worth taking a closer look at the underlying blockchain technology, as it offers many opportunities and benefits across various industry sectors and has the potential to transform the way services are delivered in the digital economy.

Indeed, since mid-2015, technologists have begun earnestly exploring this technology and major media outlets have even started proclaiming the power of the blockchain. According to a January 2017 report by the World Economic Forum, 10 percent of the world's GDP will eventually be stored on blockchain technology.[4] Some pundits have even started calling blockchain the greatest invention since the Internet.

While the individual technological components of blockchain had first originated in academic literature as early as the 1980s and 1990s, it was Nakamoto who put them together into a system that holds much promise in solving some of the biggest problems today. Of course, as with all new technology, the opportunity comes with challenges and risks that need to be understood and addressed.

This brief will discuss the underlying concepts and applications of blockchain technology, and the opportunities and risks that are perceivable at the current stage of development.

Blockchains: Why the hype?

To take a simplistic view, economic growth, which is essential for human development,[5] is comprised of the production, consumption, and exchange of goods and services between participants. Producers create tangible or intangible assets that they sell to a consumer through transfers of ownership of the assets. These transactions can occur in a market, which provides a system for participants to trade.

For it to operate properly, a market needs a ledger, which is a system of record of assets and transactions; a contract, which defines the conditions for the transactions; and currencies, which are used as a medium of exchange. Every economic transaction is a transfer of assets, either on or off a ledger, based on the conditions of a contract using a specific monetary currency. In a complex economic set-up with participants that may not know or trust each other, a network of trusted third-party intermediaries is needed to ensure its smooth running. This network will include financial institutions, law firms, and regulatory bodies. It is this system and structure, which facilitates transactions between untrusted parties, that has led to economic growth.

The global economic system, however, is not without problems, and these have given rise to instabilities and inefficiencies. While a detailed discussion of these inefficiencies is beyond the scope of this paper, we can focus on those that could be addressed with blockchain technology. Professors Marco Iansiti and Karim R. Lakhani, in a Harvard Business Review article, noted: "Contracts, transactions, and the records of them are

[4] Don Tapscott and Alex Tapscott, "Realizing the Potential of Blockchain A Multistakeholder Approach to the Stewardship of Blockchain and Cryptocurrencies," 2017, http://www3.weforum.org/docs/WEF_Realizing_Potential_Blockchain.pdf.
[5] Gustav Ranis and Frances Stewart, "Dynamic Links between the Economy and Human Development," 2005, http://www.un.org/esa/desa/.

among the defining structures in our economic, legal, and political systems… And yet these critical tools and the bureaucracies formed to manage them have not kept up with the economy's digital transformation. They're like a rush-hour gridlock trapping a Formula 1 race car. In a digital world, the way we regulate and maintain administrative control has to change. Blockchain promises to solve this problem."[6]

While blockchain technology may not replace the current market structure and system anytime soon, it is worthwhile to consider how it might be able to, in the future, facilitate transactions between untrusted parties without the need for intermediaries or a central authority. This could help accelerate the digital economy, which at present is encumbered by the current market system and needs a massive network of trusted third-party intermediaries, including financial institutions, law firms, regulatory bodies, etc. Bitcoin, as the first use case of blockchain technology, has given us a glimpse of a future with a decentralised global ledger. While the Internet has democratised information, blockchain could, in the future, democratise trust.

What are blockchains all about?

Essentially, a blockchain is an immutable system of record that does not require a third party or central authority. The technology keeps track of who owns what assets, and records the transactions when assets change hands.

To understand blockchain technology, we must first understand the concept of a ledger. Simply put, this is a complete record of transactions. For example, businesses' ledgers record their financial transactions, while bank ledgers track their customers' balances.

Ledgers may be shared among the participants involved in the transactions, making them essentially a shared record of data. Shared ledgers can be maintained as a single ledger of records, or in the form of a distributed ledger, which essentially consists of multiple ledgers or data stores distributed across a network of multiple participants, with all participants holding onto identical copies of the ledger. For all this to work, Distributed Ledger Technology needs to be implemented to record, share and synchronise transactions and data across the network.

Blockchain technology is one such implementation. Each entry in the blockchain "ledger" (or database) consists of a block of data (or batch of transactions) connected to other entries in a digital chain through a reference to the previous entry, with cryptography and algorithms used to maintain the security and integrity of the data assets.[7]

In such a set-up, new transactions initiated by any participant are transmitted to the entire network in a new data block. All participants in the network determine the

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[6] Marco Iansiti and Karim R. Lakhani, "The Truth About Blockchain," *Harvard Business Review*, no. January-February (2017), https://hbr.org/2017/01/the-truth-about-blockchain.

[7] Harish Natarajan, Solvej Karla Krause, and Helen Luskin Gradstein, "Distributed Ledger Technology (DLT) and Blockchain," 2017, http://documents.worldbank.org/curated/en/177911513714062215/Distributed-Ledger-Technology-DLT-and-blockchain.

validity of this new block before adding it to their existing chain of blocks. This relies on a consensus mechanism and is the key innovation behind blockchains, as it enables trustless, distributed consensus.

In the example of Bitcoin, the consensus mechanism facilitates the sending of digital currency from one user to another without the need for trust between the participants, and also removes the need for a trusted third party to effect the transfer. This is achieved through an algorithm known as "proof of work". Special nodes in the network (known as "miners") verify the legitimacy of the transactions, which are put together in a block, by competing to solve a computationally intensive mathematical puzzle (a process known as "mining"). The first node to solve the puzzle announces this to the whole network, forms the new block and adds it to the chain, and receives 12.5 new Bitcoins as a reward. The change in the ledger is thus replicated across the entire network, so that all participants have the exact same copy of the entire ledger. Since the blockchain is a distributed public ledger of blocks of records chained together, a past record cannot be altered without changing all subsequent blocks.

By allowing participants who may not trust each other to transact and share data without a third party or central authority, blockchain technology enables a decentralised business ecosystem that is made up of many participants who can engage in diverse forms of value exchange for any digital asset.[8]

What are the benefits of blockchain technology?

The intent of Bitcoin, the first implementation of blockchain technology, was to create a digital currency that was anonymous and free from government control. This has naturally raised concern among governments and regulators that it can be used to finance illicit activities, such as ransomware attacks that demand payment in Bitcoins.

At the same time, regulators have also come to realise that the system is not as uncontrollable as initially perceived. For example, the underlying architecture of Bitcoin does not provide complete anonymity, as all transactions are recorded in the publicly accessible distributed ledger and linked to specific entities. This is like email addresses, whose actual owners may not be known but can still be tracked down. Law enforcement officials have demonstrated their ability to track down the perpetrators behind illicit transactions.[9] In addition, Bitcoin exchanges that facilitate the conversion of Bitcoins to real-world currency are also subject to relevant regulations on identity verification, money laundering, and terrorism financing.

Despite the poor reputation of Bitcoin, both public sector agencies and private sector companies, recognising the potential of its underlying technology, have been studying and investing in blockchain technologies. A distributed network with decentralised control can help solve real-world industry problems and drive innovation by leveraging on the following benefits:

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[8] Heather Pemberton Levy, "The CIO's Guide to Blockchain," *Smarter with Gartner*, 2016, https://www.gartner.com/smarterwithgartner/the-cios-guide-to-blockchain/.
[9] Natarajan, Krause, and Gradstein, "Distributed Ledger Technology (DLT) and Blockchain."

- Transparency: All network participants share and have access to the same information and transaction history.

- Consistency: Information can be updated only through consensus, as a change in one record requires the modification of all subsequent records.

- Security: The consensus mechanism makes it difficult for hackers to compromise transaction data, as they would have to modify every copy distributed in the network. Encryption can be used to protect sensitive data and prevent fraudulent activities or unauthorised modifications.

- Traceability: As the transaction history is maintained immutably in the blockchain, it provides an audit trail that can help trace the "path" of the asset and verify its authenticity.

- Efficiency: Business-to-business processes can be streamlined and transactions can be completed faster without the need for intermediaries and third parties. A shared ledger can also do away with the need for the reconciliation of transactions.

- Trust: Having a single immutable ledger accessible by all participants means that the data can be trusted, and third parties will no longer be needed to make guarantees.

These attributes can be packaged together to different degrees depending on how much permission, centralisation, or openness is desired.

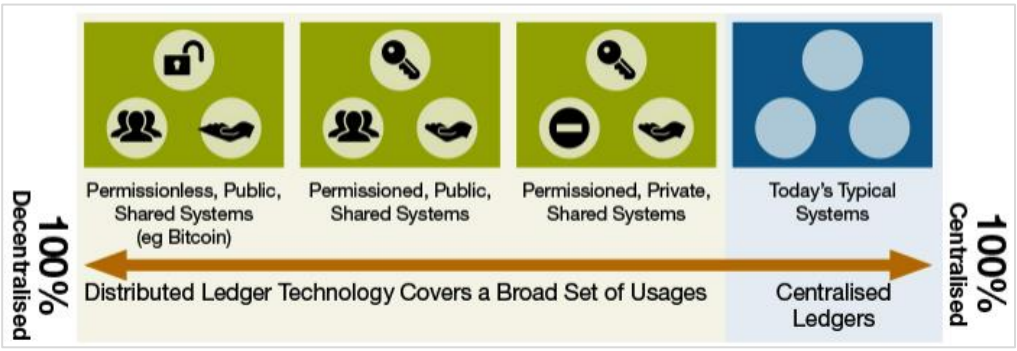

Figure 2. Degrees of centralisation in blockchain technologies[10]

Figure 2 above shows how distributed ledgers can be made permissioned or permissionless (whether participants need permission to make changes to the ledger), and public or private (whether access to the ledger is limited to participants). While the set-up for Bitcoin was left uncontrolled, organisations do not have to implement blockchain technologies in the same way; they don't have to keep it permissionless and public.

[10] Matthew Hancock and Ed Vaizey, "Distributed Ledger Technology: Beyond Block Chain," 2016, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf.

Most of the current implementations of blockchain technology are kept private and permissioned, with networks allowing only trusted participants. Purists, though, would argue that such permissioned systems are not really blockchains, as they restrict who can participate, write transactions or mine blocks and therefore miss out on most of the innovations of Bitcoin. And if participants are trusted, they argue, then the proof of work concept is no longer necessary and we would have missed out on the central innovation of blockchains.[11]

Concerns have also been raised that in permissioned blockchains controlled by a small group, this group can compromise the system. In any blockchain, attempts to alter the ledger requires collusion by a majority of the participants. In an open, permissionless blockchain like Bitcoin, this would necessitate the cooperation of a very large number of users. In a blockchain controlled by a small group, however, such as a group of financial institutions, collusion would be much easier to pull off.

What can blockchain technologies be used for?

Such benefits and the potential of blockchain technologies have prompted many innovators and entrepreneurs to come up with ideas on how the technology can be applied across industry and government. While most of these applications—other than cryptocurrencies—are still at an early stage, we can see how the following examples illustrate the wide range of possible blockchain implementations across both public and private sectors:

- Initial Coin Offering (ICO):

  Start-ups can offer ICOs to raise funds using a crowdfunding approach without the usual challenges of getting investments from venture capital funds or having to meet onerous regulations enforced by financial authorities. Just like in an Initial Public Offering (IPO), an ICO involves a start-up selling stakes in its company to those who want to invest in the new venture.

- Clearing and settlement:

  Blockchain technology can streamline the clearing and settlement of financial transactions and reduce counterparty risks. There is, however, a challenge in achieving decentralisation in a market structure controlled by centralised institutions.

- Tokenisation:

  Tokens are digital representations of a physical assets and can be used to verify the asset's authenticity. Using the immutable property of blockchain technologies, tokenisation can be used in supply chain management, protection of intellectual property, and fraud detection.

[11] Arvind Narayanan and Jeremy Clark, "Bitcoin's Academic Pedigree," *ACM Queue* 15, no. 4 (2017), https://queue.acm.org/detail.cfm?id=3136559.

Carrefour, for example, implemented blockchain technology to demonstrate honesty and transparency by providing consumers with supply chain information on its Auvergne chicken.[12] Each breeder, processor and butcher in the supply chain registers his information in a blockchain, which ensures that neither Carrefour nor any supplier is able to tamper with the records. Consumers can access this information using a QR code on the label to check where a specific chicken was bred, what it ate, and where it was slaughtered.

Everledger, a blockchain start-up, uses similar technology to track diamond ownership to certify the origin of diamonds, and to spot stolen or conflict-zone diamonds.[13] The company believes the same approach can be used for other issues like ivory poaching.

- Smart contracts:

  Smart contracts were first conceptualised by computer scientist Nick Szabo in 1997. In a paper,[14] he described the use of e-commerce protocols to establish contracts between untrusted parties on the Internet. "A smart contract is a set of promises, specified in digital form, including protocols within which the parties perform on these promises," he noted. Using blockchain technology, smart contracts can do away with the need for intermediaries, ensuring that all participants know the contract terms which are then executed automatically when specific conditions are met.

- Proof of ownership:

  Ownership records have traditionally been stored in paper ledgers. These can be tampered with, necessitating the use of notary services to certify the validity of signatures and authenticity of documents. While the use of blockchains may not completely fulfil current legal requirements, they can provide less costly verification.

  In March 2018, Sweden's national land survey agency Lantmäteriet announced that it was rolling out the first real estate sales transaction using blockchain technology in the next few months.[15] It had been building the structure and testing the technology since 2016, and is hoping to increase the speed and efficiency of recording and transferring land titles.

- Social issues:

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[12] Pauline Neerman, "Carrefour Uses Blockchain to Create 'transparent' chicken," *Retail Detail*, 2018, https://www.retaildetail.eu/en/news/food/carrefour-uses-blockchain-create-transparent-chicken.
[13] Gian Volpicelli, "Beyond Bitcoin. Your Life Is Destined for the Blockchain," *WIRED*, 2016, http://www.wired.co.uk/article/future-of-the-blockchain.
[14] Nick Szabo, "First Monday.," *First Monday* 2, no. 9 (1997), http://journals.uic.edu/ojs/index.php/fm/article/view/548/469.
[15] Shefali Anand, "A Pioneer in Real Estate Blockchain Emerges in Europe," *Fortune*, 2018, https://www.wsj.com/articles/a-pioneer-in-real-estate-blockchain-emerges-in-europe-1520337601.

The United Nations is running numerous blockchain experiments ranging from tackling climate change to human trafficking, while Microsoft is working with partners and developers to create a blockchain-based identity system that enables self-owned or self-sovereign identity.[16] Individuals can register a digital identity which is verified through the blockchain to eliminate counterfeiting and theft. The initiative was started to address the problem of human trafficking, especially of those who are most vulnerable—children and people without legal identification, which leaves them "invisible" to society.

A public-private project by Coca-Cola and the U.S. Department of State is also using blockchain technology to combat forced labour in their supply chains by using smart contracts for employee labour agreements. It is hoped that this will provide greater transparency and accountability, reducing the possibility of unfair labour practices.[17]

- Digital voting:

  Blockchain technology can provide a record of votes cast and potentially remove voter fraud. It can also allow voters to cast their votes using a mobile platform instead of having to show up at a polling station. In October 2016, when Colombia held a vote on a peace treaty between the government and rebel group FARC, non-government organisation Democracy Earth Foundation launched a digital voting platform using blockchain technology to let the 90 per cent of 6 million Colombian expatriates who weren't given the right to vote, an opportunity to cast symbolic votes on the plebiscite.[18] The project managed to reach Colombians in 76 countries, allowing them to participate in the vote despite having left the country because of the conflict.

- Internet of Things (IoT):

  In September 2017, a group of companies including Bosch, Cisco and Gemalto launched the Trusted IoT Alliance to create an open-source blockchain standard and trusted ecosystem for IoT technology. The ecosystem came five months after the Alliance members unveiled a protocol binding weak identities (e.g. serial numbers, QR codes, etc.) to strong cryptographic identities using blockchain technology.

- Data privacy:

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[16] Yorke Rhodes III, "What Does Identity Mean in Today's Physical and Digital World?," *Microsoft Azure - Blog*, 2016, https://azure.microsoft.com/en-us/blog/what-does-identity-mean-in-today-s-physical-and-digital-world/.
[17] Joe Liebkind, "Coca-Cola and US State Dept Use Blockchain to Combat Forced Labor," *Investopedia*, 2018, https://www.investopedia.com/news/cocacola-and-us-state-dept-fight-forced-labor/.
[18] "A Digital Referendum for Colombia's Diaspora," *Democracy Earth*, 2016, https://words.democracy.earth/a-digital-referendum-for-colombias-diaspora-aeef071ec014.

The recent fallout over the use of Facebook data by Cambridge Analytica has seen users clamouring for blockchain solutions[19] [20] to allow users to regain control of their personal data and combat Big Tech's unfettered collection, analysis and use of personal data to sell advertisements. Several start-ups are now offering solutions that put the control of personal data into the hands of users.

Is blockchain the silver bullet for the world's problems?

The potential of blockchain to become a disruptive technology has captured the imagination of technologists—and now bankers—and continues to fuel the hype over the possibilities of implementation across all industries. However, while blockchains can potentially help simplify business transactions and make markets more efficient, it is important to recognise that the technology is still evolving—and in some cases, is a solution looking for problems to solve.

After hitting the peak of the Gartner Hype Cycle[21] in August 2016[22], blockchain technology started going down the Trough of Disillusionment in July 2017—a recognition, perhaps, that the technology has been overhyped and that use cases are not proving to be as viable as envisioned. (see **Figure 3**)

[19] Nathaniel Popper, "Tech Thinks It Has a Fix for the Problems It Created: Blockchain," *The New York Times*, April 1, 2018, https://www.nytimes.com/2018/04/01/technology/blockchain-uses.html.
[20] Josh Hall, "How Blockchain Could Help Us Take Back Control of Our Privacy," *The Guardian*, March 21, 2018, https://www.theguardian.com/commentisfree/2018/mar/21/blockchain-privacy-data-protection-cambridge-analytica.
[21] The Gartner Hype Cycle looks at new technologies in terms of maturity and adoption. According to the methodology, there are five key phases in a technology's lifecycle. (1) Innovation Trigger: Early proof-of-concept for a potential technology with unproven commercial viability; (2) Peak of Inflated Expectations: Some success stories along with many failures; (3) Trough of Disillusionment: Technology fails to deliver but surviving providers continue to improve their products; (4) Slope of Enlightenment: Next generation products appear and enterprises start to understand and implement pilot projects; and (5) Plateau of Productivity: Technology proves to be viable and mainstream adoption starts to take off.
[22] "Gartner's 2016 Hype Cycle for Emerging Technologies Identifies Three Key Trends That Organizations Must Track to Gain Competitive Advantage," 2016, https://www.gartner.com/newsroom/id/3412017.

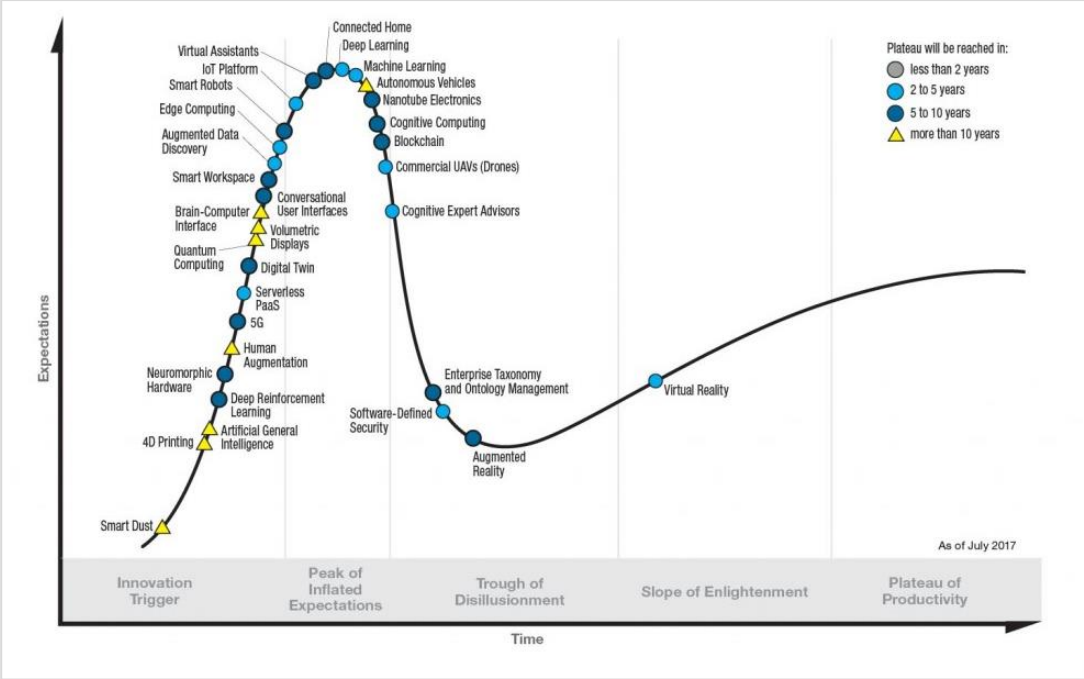

***Figure 3**. Gartner Hype Cycle for emerging technologies, July 2017*[23]

In a March 2017 report on blockchain, Gartner highlighted that "of the several hundred use cases being discussed in the market, none are in full production — even in the financial services industry".[24] It added: "The bottom line is that no enterprise has yet been able to take a POC to scale. This is partly a technology issue, but inhibitors also include multiple business challenges (including legal, risk, accounting, culture and strategy)."[25]

Several models are now available to help organisations determine whether blockchain technology is suitable for their purpose, and whether there will be significant advantages over traditional solutions.[26] The models help them determine if their problems can be fixed without using blockchains, whether participants are already known and trusted, and how critical speed and scalability are for the required solution.

What are the limitations and potential problems?

Blockchain technologies may not always be the best solution for any given problem. These are some of the current limitations of the technology:

[23] Kasey Panetta, "Top Trends in the Gartner Hype Cycle for Emerging Technologies, 2017," *Smarter with Gartner*, 2017, https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/.
[24] David Furlonger and Ray Valdes, "Practical Blockchain: A Gartner Trend Insight Report," *Gartner Research* G00325933, no. March (2017), https://www.gartner.com/document/3628617?ref=solrAll&refval=182700378&qid=a89318613984fd5789d202a1f0d1f680.
[25] Ibid.
[26] Michiel Mulders, "Different Blockchain Decision Models," *Cointelligence*, 2018, https://www.cointelligence.com/content/when-do-you-need-blockchain/.

- Scalability: Due to the way blockchain technologies are designed, significant computational power and energy are needed to verify and confirm each block. The annual electricity consumption of Bitcoin is estimated to be about 60 TWh as of the end of March 2017[27]—equivalent to that of the entire Czech Republic.[28]

- Speed: In the case of Bitcoin, the maximum number of transactions that can take place per second is seven, and there is a delay of at least 10 minutes to confirm each block. As of January 2018, the fastest cryptocurrency is Ripple, which allows 1,500 transactions per second—but this still pales in comparison to the 24,000 credit card transactions that Visa alone can handle per second.[29] Blockchain technology, at least currently, may be unsuitable for situations where speed is of the essence.

- Confidentiality: In the case of public permissionless blockchains, access to transaction information is open. This may not be suitable where transactions need to be kept confidential. Users can opt for a permissioned blockchain, but will then face a possible dilemma—they will not be able to exploit the full benefits of the technology (since participants must be trusted).

There are also legal grey areas[30] that must be considered, including:

- Jurisdiction: Blockchains are not limited by geography and can cross jurisdictional boundaries. This introduces complexity in contractual relationships where there are differences in principles of contract and title in different jurisdictions. In a decentralised environment, even an attempt to apply the relevant rules based on the location of a node in the network may be challenging, as it is difficult to determine its location within the blockchain.

- Liability: In a trading-related blockchain offered by a vendor, customers may face the material risk of systemic issues that affect the settlement of trades. The allocation and attribution of risk and liability between all participants will have to be carefully considered.

- Enforceability: In the case of smart contracts, enforceability issues may arise when there are different levels of acceptance of electronic contracts in different jurisdictions. As disputes may arise from an automatically executed contract, a dispute resolution provision may be needed specifying the mechanism or arbitrator in the event of a dispute. Questions about offers,

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[27] "Bitcoin Energy Consumption Index," *Digiconomist*, 2018, https://digiconomist.net/bitcoin-energy-consumption.
[28] "World Power Consumption | Electricity Consumption," *Enerdata*, 2018, https://yearbook.enerdata.net/electricity/electricity-domestic-consumption-data.html.
[29] Sean Williams, "Which Cryptocurrencies Have the Fastest Transaction Speeds?," *The Motley Fool*, 2018, https://www.fool.com/investing/2018/01/14/which-cryptocurrencies-have-the-fastest-transactio.aspx.
[30] John McKinlay et al., "Blockchain: Background, Challenges and Legal Issues," *DLA Piper Global Law Firm*, 2018, https://www.dlapiper.com/en/uk/insights/publications/2017/06/blockchain-background-challenges-legal-issues/.

acceptance, certainties and consideration as per traditional contracting rules will also need to be addressed.

- Data privacy: Since data stored in a blockchain is immutable and cannot be altered, compliance issues may arise as most existing privacy laws allow individuals to request corrections, updates or deletions of personal data. The transparency of transactions may also conflict with the need to avoid providing competitors with transaction information. Such dilemmas will test the balance between permissioned and permissionless blockchains, and the trade-offs between privacy and transparency.

In a March 2018 study of the Bitcoin blockchain, researchers found 1,600 files (or 1.4 per cent of all files) containing unrelated data including objectionable content such as links to child pornography.[31] The Bitcoin protocol allows arbitrary data to be stored on top of relevant data needed for the original intended purpose, and as the blocks are immutable, once they are accepted into the chain, this arbitrary data can no longer be removed. Any user running a Bitcoin client will have the full blockchain stored on their device, and will thus be in possession of these files. While this is nothing new—images of African leader Nelson Mandela, Valentine's Day messages and Internet memes of pop singer Rick Astley have been found in the blockchain since 2014—it does raise important legal questions, including copyright violations and pornography laws.

And just like any other technology, blockchain implementations are also susceptible to security issues. Numerous Bitcoin heists have been carried out since its introduction, with the biggest taking place in 2014, when a hack on Mt. Gox, a Bitcoin exchange based in Japan, saw hackers taking off with US$460 million in Bitcoins.

Soaring cryptocurrency values have also driven up efforts to hack and create malware to profit from the high prices. According to a February 2018 report by security firm Imperva, 88 per cent of remote code attacks now involve cryptojacking—using malware to hijack devices' processing power to mine for cryptocurrency[32]—and victims have included the U.K. government and electric car company Tesla. This form of attack is proving so lucrative that cybercriminals are now creating cryptocurrency mining malware to kill off competing cryptojacking malware already on a compromised system.[33]

Singapore as a blockchain technology hub

By most accounts, Singapore is a hub of cryptocurrency and blockchain activity, especially since Singapore is home to FinTech Festival, the largest FinTech conference

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[31] Lucinda Shen, "Bitcoin's Blockchain Has '100s of Links' to Child Pornography," *Fortune*, 2018, http://fortune.com/2018/03/20/bitcoin-price-blockchain-child-porn-ban-crime/.
[32] Nicole Lindsey, "Cyber Criminals Profit from Crypto Mining Malware," *CPO Magazine*, 2018, https://www.cpomagazine.com/2018/03/02/cyber-criminals-profit-from-crypto-mining-malware/.
[33] Danny Palmer, "Hacker vs Hacker: This Cryptojacking Malware Kills off Its Rivals to Ensure Maximum Profit," *ZDNet*, 2018, https://www.zdnet.com/article/hacker-vs-hacker-this-cryptojacking-malware-kills-off-its-rivals-to-ensure-maximum-profit/.

in the world.[34] According to a study released in November 2017, Singapore is the leader for ICO activity in Asia and the third largest market globally, behind the U.S. and Switzerland.[35]

As a leading global financial centre, it is imperative for Singapore to stay on top of cryptocurrency and blockchain developments and has been closely watching this space since late 2013. And this is evident at the highest level of government. In his speech at UOB's 80th anniversary dinner in November 2015, Prime Minister Lee Hsien Loong recognized the potential for blockchains for many applications in the financial sector and urged that, "our banks and our regulators MAS must keep up to date and up to scratch with these developments."[36]

Led by the Monetary Authority of Singapore (MAS), various projects have been initiated to test blockchain use cases. In November 2016, MAS launched Project Ubin, which aims to investigate the potential of blockchain technology for clearing and settlement, and is participated by a consortium of more than ten financial institutions and technology service providers.[37] These blockchain prototypes provided Singapore's financial sector with lessons in real-world scenarios, resulting in spin-off projects and even the release of source codes and technical documentations for public access.

Observers recognise that Singapore's success is due in part to the government's strong support of the blockchain ecosystem. By being open to innovation and providing much needed clarity, industry players can move forward with more certainty by operating within appropriate rules of engagement and regulatory frameworks.[38]

From a regulatory perspective, Singapore tends to maintain a light touch in terms of regulating cryptocurrencies. While the Monetary Authority of Singapore (MAS) has issued a statement as far back as September 2013, warning speculators on the risks of trading bitcoin, it has long maintained a stance of non-interference on the acceptance of cryptocurrency.[39] This is unlike large economies like China and India which have sought to clampdown on cryptocurrencies.[40] In a 2017 interview with Bloomberg, MAS Managing Director, Ravi Menon, said he sees "no basis for wanting to regulate cryptocurrencies." But rather, the focus is on the activities surrounding the use of cryptocurrency[41] where there are already existing regulations – money laundering,

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[34] Steven Buchko, "Which City Will Be the Capital of Blockchain Technology?," March 15, 2018, https://coincentral.com/capital-of-blockchain-technology/.
[35] Shiwen Yap, "Singapore Emerges as Third Largest Global ICO Hub," *Deal Street Asia*, November 27, 2017, https://www.dealstreetasia.com/stories/singapore-emerges-asia-ico-hub-86574/.
[36] "Speech at UOB 80th Anniversary Dinner," November 12, 2015, https://www.youtube.com/watch?v=kIKe_xUKJqA.
[37] "Project Ubin: Central Bank Digital Money Using Distributed Ledger Technology," accessed April 27, 2018, http://www.mas.gov.sg/Singapore-Financial-Centre/Smart-Financial-Centre/Project-Ubin.aspx.
[38] Prerna Suri, "Behind Singapore's Meteoric Rise as a Top Blockchain Hub," *Tech In Asia*, April 20, 2018, https://www.techinasia.com/singapore-top-blockchain-hub-world.
[39] Terence Lee, "Singapore Government Decides Not to Interfere with Bitcoin," *TechInAsia*, December 23, 2013, https://www.techinasia.com/singapore-government-decides-interfere-bitcoin.
[40] Suri, "Behind Singapore's Meteoric Rise as a Top Blockchain Hub."
[41] Chanyaporn Chanjaroen, Andrea Tan, and Haslinda Amin, "Singapore Won't Regulate Cryptocurrencies, Central Bank Chief Says," *Bloomberg*, October 25, 2017,

terrorism financing, etc. This reaffirms the agency's statement in March 2014 to regulate cryptocurrency intermediaries for money laundering and terrorism financing risks.[42]

Over the last few years, government agencies have also provided various clarifications and guidance for cryptocurrency. In January 2014, the Inland Revenue Authority of Singapore (IRAS) issued guidance for handling capital gains, earnings and Goods and Services Tax (GST) to cryptocurrency companies and businesses accepting cryptocurrency for payments.[43] In August 2017, MAS clarified that ICOs that fall within the definition of securities under the Securities and Futures Act (Cap. 289)(SFA) will be regulated by the SFA.[44] The central bank subsequently published in November 2017, guidance on the application of securities laws on ICOs.[45]

There is little doubt that Singapore wants to lead the blockchain space in Asia, and especially in ASEAN where Singapore is the chair for 2018. In his opening remarks at the 22nd ASEAN Finance Ministers' Meeting in April, Singapore's Minister of Finance, Mr. Heng Swee Keat stated that, "Distributed Ledger Technology presents us with many opportunities for cheap and secure transactions. This can promote financial inclusion for underserved and underbanked segments in ASEAN."[46]

Beyond the financial sector, various government agencies have started driving blockchain innovations and initiatives in both the public and private sector. In December 2017, SGInnovate[47] announced a 'Deep Tech Nexus' strategy to focus investments in three technology areas for 2018 – artificial intelligence, blockchain and medtech. The plan is to invest in at least 20 early-stage deep tech startups, ranging from less than S$100,000 for pre-seed to more than S$1,00,000 for Series A.[48]

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https://www.bloomberg.com/news/articles/2017-10-24/singapore-won-t-regulate-cryptocurrencies-remains-alert-to-risk.

[42] "MAS to Regulate Virtual Currency Intermediaries for Money Laundering and Terrorist Financing Risks," March 13, 2014, http://www.mas.gov.sg/news-and-publications/media-releases/2014/mas-to-regulate-virtual-currency-intermediaries-for-money-laundering-and-terrorist-financing-risks.aspx.

[43] Jon Southurst, "Singapore Government: This Is How We Intend to Tax Bitcoin," *CoinDesk*, January 9, 2014, https://www.coindesk.com/singapore-government-how-we-intend-tax-bitcoin/.

[44] "MAS Clarifies Regulatory Position on the Offer of Digital Tokens in Singapore," August 1, 2017, http://www.mas.gov.sg/News-and-Publications/Media-Releases/2017/MAS-clarifies-regulatory-position-on-the-offer-of-digital-tokens-in-Singapore.aspx.

[45] Monetary Authority of Singapore, "A Guide to Digital Token Offerings," 2017, http://www.mas.gov.sg/~/media/MAS/Regulations and Financial Stability/Regulations Guidance and Licensing/Securities Futures and Fund Management/Regulations Guidance and Licensing/Guidelines/A Guide to Digital Token Offe.

[46] "Opening Remarks by Mr Heng Swee Keat, Minister for Finance, at the 22nd ASEAN Finance Ministers' Meeting," April 6, 2018, https://www.gov.sg/~/sgpcmedia/media_releases/mof/speech/S-20180406-2/attachment/OPENING REMARKS BY MR HENG SWEE KEAT AT THE 22ND ASEAN FINANCE MINISTERS MEETING AT SHANGRI-LA HOTEL.pdf.

[47] Launched in November 2016, SGInnovate is a private limited company wholly owned by the Singapore Government. SGInnovate supports, develops and invests in the deep tech startup ecosystem.

[48] Priyankar Bhunia, "SGInnovate to Focus on Artificial Intelligence, Blockchain and MedTech and Invest in 20 Deep Tech Startups during 2018," *OpenGov*, December 22, 2017, https://www.opengovasia.com/articles/sginnovate-to-focus-on-artificial-intelligence-blockchain-and-medtech-during-2018.

To encourage greater innovation in blockchain technologies beyond fintech, Singapore's Infocomm Media Development Authority (IMDA) launched a Blockchain Challenge in March 2018.[49] Projects with the potential to improve operational efficiency or transform businesses, government and society can receive prizes of up to S$100,000.

While the focus over the last five years has been in cryptocurrency and the financial sector, we are now starting to see a shift in 2018 towards broader applications of blockchain technology across the wider economy.

Blockchain: What's its future?

In a January 2017 article in the Harvard Business Review, Professors Marco Iansiti and Karim R. Lakhani from Harvard Business School made this observation: "True blockchain-led transformation of business and government, we believe, is still many years away. That's because blockchain is not a 'disruptive' technology, which can attack a traditional business model with a lower-cost solution and overtake incumbent firms quickly. Blockchain is a foundational technology: It has the potential to create new foundations for our economic and social systems. But while the impact will be enormous, it will take decades for blockchain to seep into our economic and social infrastructure."[50]

This is especially since blockchain technology seeks to challenge political, economic, social and legal institutions established over centuries. However, this is a development which cannot be ignored, even as the full extent of blockchain's potential remains to be understood. It will take time for blockchain to mature and find its place in the overall technology landscape.

In the meantime, governments may want to adopt a policy of "permissionless innovation", as described by researcher Adam Thierer at the George Mason University's Mercatus Center. In his book by the same name, Thierer attributes much of the growth of the digital economy to innovators experimenting with new technologies and business models without the "approval" of regulators and policymakers.

That is not to say that governments should simply step aside and allow blockchain developments to run freely without controls; regulators should still assume a leadership role because of the potential impact of these developments on a nation's citizens and economy. Recommendations include:

1. Developing sectoral roadmaps: Government agencies should develop roadmaps for each sector with structured plans to explore fit-for-purpose use cases of

[49] "Launch of Singapore's First Blockchain Challenge to Boost Innovation and Adoption beyond Fintech," *Infocomm Media Development Authority*, March 29, 2018, https://www.imda.gov.sg/about/newsroom/media-releases/2018/launch-of-singapores-first-blockchain-challenge-to-boost-innovation-and-adoption-beyond-fintech.
[50] Iansiti and Lakhani, "The Truth About Blockchain."

blockchains. This will help assess the usefulness of blockchains in addressing challenges faced by each sector, especially in areas of productivity and growth.

2. Going beyond fintech: While most of the current hype and applications of blockchain technology is in the financial sector, governments may want to consider encouraging more experimentation in other industries.

3. Setting up regulatory frameworks: Given that regulation tends to be always playing catch-up with technology, governments need to start looking at what needs to be regulated and how technical and legal frameworks should be implemented in tandem with the adoption and development of blockchain solutions.

4. Developing technology standards: Governments could work closely with industry to develop technology standards, especially in the areas of interoperability and security. Such standards could then be used in the technical codes in regulatory frameworks.

5. Addressing manpower shortages: In any technological boom, be it the Internet, artificial intelligence, big data or cybersecurity, manpower shortages tend to be an impediment to growth. Governments need to start putting in place programmes to develop capability and skills in blockchain technology, such as in institutes of higher learning to grow the future workforce, and in manpower transformation initiatives to meet current demands.

Just as the Internet took decades to mature, revolutionise communication and democratise information, blockchain technologies will likely have to go through a similar adoption and maturity curve before its true potential can be realised. Policymakers, however, should not adopt a wait and see attitude. Work should start now.