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Permissionless and permissioned blockchain diffusion

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ABSTRACT

This paper explores the barriers and drivers of diffusion associated with permissionless and permissioned blockchains, seeking to establish whether they are the same or different and whether barriers and drivers change over time. The study was undertaken in two stages: (i) interviews in 2016 that examine the barriers and drivers of diffusion; followed by (ii) a case study in 2019 of the Italian wine industry's permissioned blockchain. The results show that diffusion is reaching a final stage for permissionless blockchains but is lagging behind for permissioned blockchains due to the different barriers and drivers of diffusion.

The implications from this study are that: (i) drivers and barriers for different types of technological innovation may be different and change over time; (ii) initial barriers may be surmounted and become features of the underlying technology; (iii) barriers may become drivers of a technology; (iv) drivers of one type of technology may spill-over to become drivers for another type; (v) diffusion may be measured by both the number of adoptions and the number of participants in that technology; (vi) off-chain processes may become a major barrier for permissioned blockchains; and finally (vii) self-interest may be the key driver of technological innovation.

1. Introduction

Blockchains are the distributed ledger technology outlined in the Nakamoto White Paper of 2008 (Nakamoto, 2008) whereby participants can transact with each other directly in a secure, immutable and chronological way without the need for any intermediaries (Iansiti & Lakhani, 2017; Swan, 2015; Tönnissen & Teuteberg, 2020). Blockchains *per se* are chains of digital information, distributed across multiple computers (called nodes), located anywhere in the world. A blockchain records and validates each 'block' of information in real time, creating an immutable, chronological, transparent transaction history (Kemp, 2015). The data cannot be censored, deleted or edited and can be viewed by anyone who downloads the software making all transactions open and transparent. Blockchains are able to store and encrypt all kinds of data, from cryptocurrencies to high-value chattels, and facilitate the use of smart-contracts (Cohen, 2017; Dierksmeier & Seele, 2018; Smith, 2017). If blockchains diffuse widely there could be disruptive implications for businesses and the whole of society (Aste, Tasca, & Di Matteo, 2017).

The first application of a blockchain was in 2009. This involved the Bitcoin cryptocurrency, and since then two types of blockchains have diffused - permissionless and permissioned - as outlined in this paper. These two types of blockchain are uniquely different from each other in both their conceptual underpinnings and also their adoption in practice (Behnke & Janssen, 2020). Permissionless blockchains have become the domain of cryptocurrencies and financial markets. In contrast, permissioned blockchains have entered the domain of businesses and institutional practices.

This paper addresses a number of research gaps identified in the literature such as that of Janssen, Weerakkody, Ismagilova, Sivarajah & Irani (2020) and Frizzo-Barker, Chow-White, Adams, Mentanko & Ha (2020) who call for more research into blockchain adoption. Hughes et al. (2019) note that diffusion of blockchain studies are especially needed. Further, although Bumblauskas, Mann, Dugan, and Rittmer (2020) partly address these calls by examining a US proof-of-concept blockchain, this paper examines a blockchain that is already in use. Queiroz and Wamba (2019) ask for research into the use of blockchains in supply chains outside the US and India; this paper addresses their call by examining a supply chain in Italy. Further, Kapoor, Dwivedi & Williams (2014) ask for research methods other than surveys and questionnaires and Frizzo-Barker et al. (2020) demand more qualitative research, both of which are addressed in this paper by using interviews

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and case study research methods. We address these research gaps by analysing the drivers and barriers of blockchain diffusion over time and undertake a case study of the Italian wine industry (see also Di Vaio & Varriale, 2020, who also examine Italy). In addition, this study addresses Kapoor et al.'s (2014) concerns that studies of more than one innovation are needed; we examine two distinct types of innovation, permissionless and permissioned blockchains, and we further investigate the benefits and challenges of blockchain diffusion as two innovations instead of just one (see Frizzo-Barker et al., 2020; Kamble, Gunasekaran, & Sharma, 2020). We also answer Kapoor et al.'s (2014) challenge regarding diffusion by identifying new attributes of diffusion.

With respect to the diffusion of technological innovations in general, the prior literature notes that a major barrier is the initial lack of knowledge and expertise of the innovation, suggesting a need for training and clarification of the perceived benefits. There are also scalability issues, and for blockchains this reflects how many transactions the blockchain technology can process (Frizzo-Barker et al., 2020). The literature also raises concerns over interoperability and compatibility with other systems (Dunne, Helliar, Lymer, & Mousa, 2013). The cost of implementing a new technology and the switching costs of transitioning from one platform to another have also been raised in the literature with regard to blockchains (Frizzo-Barker et al., 2020; Kapoor et al., 2014). Other barriers that relate specifically to the adoption of blockchain technologies include resource wastage because of the computing power required to run them as well as the electricity that is needed by the miners who solve the algorithms (Hanson, Reeson, & Staples, 2017; Kamble et al., 2020). Regulation and governance may also be barriers (Caiazza, 2016; Thakur, Doja, Dwivedi, Ahmad, & Khadanga, 2020), especially in light of adverse publicity around criminal activity and money laundering.

Drivers of diffusion of blockchains include transactional efficiency and disintermediation (Casey & Vigna, 2018; Queiroz & Wamba, 2019; Ying, Jia, & Du, 2018) as well as the immutability and integrity of data (Frizzo-Barker et al., 2020; Kamble et al., 2020) and protection against hacking. Another two drivers of blockchain adoption are the provenance and traceability of goods in the supply chain and a further benefit is the use of smart contracts. However, in discussing the barriers and drivers of diffusion the prior literature does not distinguish between different types of blockchain technology. In addition, the majority of research is cross-sectional and fails to consider whether the barriers and drivers change over time.

This paper seeks to answer two research questions:

1 What are the barriers and drivers of diffusion of permissionless and permissioned blockchains, and are they the same?
2 To what extent do the barriers and drivers of diffusion change over time?

In order to address these questions a qualitative research method was used (Yin, 2009) that involved interviews conducted in 2016 and a case study undertaken in 2019. Drawing on this data, as well as developments over the last 10 years, we analyse the barriers and drivers of diffusion over time and compare and contrast the differences between permissionless and permissioned blockchains.

This paper is now structured as follows. The next section elaborates on diffusion theory followed by an outline of blockchain developments in the literature (see Di Vaio & Varriale, 2020) over the last 10 years. The qualitative research methods adopted in this study using interviews and a case study are reported next, followed by the research findings. The implications for practitioners, businesses and academics is outlined next. Finally, the conclusion, with the limitations of the study and future research avenues are suggested with final concluding comments.

2. Theoretical approach: diffusion of blockchains

The literature articulates that a number of theories can be used to study the adoption and acceptance of new technologies, such as the often-used technology acceptance model or the diffusion of innovation (Dwivedi, Kapoor, Williams, & Williams, 2013; Weerakkody, El-Haddadeh, Al-Sobhi, Shareef, & Dwivedi, 2013). Diffusion theory explains how a technological innovation, such as blockchain, spreads or results in rejection (Abrahamson & Rosenkopf, 1997; Caiazza, 2016; Dunne et al., 2013; Rogers, 2003; Sahlin & Wedlin, 2008). According to Rogers (2003): 5), the diffusion of innovative technologies is: *"the process by which an innovation is communicated through certain channels over time among members of a social system"*. The diffusion process goes through stages of adoption (Bjornenak, 1997; Orr, 2003) with Brancheau and Wetherbe (1990) describing four stages in the diffusion process: (i) knowledge; (ii) persuasion; (iii) decision; and (iv) implementation with Rogers (2003) adding a fifth stage of confirmation. However, Nam, Leeb & Leea (2019) note that relatively few studies regard diffusion as a stage-based process. Our paper contributes by adopting this approach.

If successful, the stages of diffusion are sequenced from the leaders who make the initial discovery, to translation into practice by early adopters, disseminated through networks by fast-followers, to widespread implementation by a critical mass of stakeholders (Rogers, 2003). Woodside, Augustine Jnr, and Giberson (2017) outline the five groups involved in the diffusion process as the innovators (leaders), early adopters, early majority, late majority and laggards. With regard to blockchain diffusion, Woodside et al. (2017) note that around 2.5 % are innovators, 13.5 % are early adopters, 34 % are the early majority and late majority each; 16 % are laggards.

Most studies focus on the adoption of a technology either by individuals or by individual organizations (Dwivedi et al., 2013; Weerakkody et al., 2013), rather than by an industry or business sector (Dunne et al., 2013; Grover, et al., 2019). This paper uses diffusion theory as a lens to examine blockchain diffusion across industries (permissioned blockchains) and also in the financial markets (permissionless blockchains).

In the traditional diffusion process the initial uncertainty over the innovation (Brancheau & Wetherbe, 1990) needs to be overcome by the leaders and early adopters, and collaboration and networking may be needed to jump start the diffusion process and persuade others (the majority) to follow suit (Abrahamson & Rosenkopf, 1997; Dunne et al., 2013). Dwivedi et al. (2013) note that increasing awareness of the technology results in more use of the technology and hence increases the adoption rate. Brancheau and Wetherbe (1990) document that the rate of adoption of a technology is usually measured by the number of participants that adopt an innovation, and that as more and more people communicate their positive evaluations of a technology, there may be a contagion effect as the number of adopters increases rapidly. This may have implications for our paper with regard to permissionless blockchains, resulting in a speculative bubble in the financial markets if contagion takes hold.

However, our paper is not only interested in individuals' acceptance of blockchains, but also that of industries. Grover, Kar, and Janssen (2019) argue that different industries can have different levels of technological diffusion, with some cross-fertilization. They nonetheless posit that blockchain implementation is still at an early stage of diffusion, although specific industries are beginning to develop specific blockchain applications. As Grover et al. (2019) demonstrate, the manufacturing sector is still at the initial knowledge stage of blockchain diffusion, public administration is at the persuasion, or second stage of diffusion, transportation and utilities have reached the decision stage of diffusion, the services industry is at Stage 4, implementation, but the finance sector is the most advanced having reached the final stage of diffusion, that of confirmation. It can therefore be argued that the finance industry is the innovator, the service sector is the early adopter, transport and utilities are the early majority, public administration the late majority adopter and manufacturing the laggard.

As well as voluntary adoption of an innovation, regulators or governments may coerce diffusion (Dunne et al., 2013); or mimetic isomorphism may play a role (DiMaggio & Powell, 1983). As Dunne et al. (2013) note, successful diffusion occurs when the emphasis changes from the technical aspects of an innovation to a focus on increased functionality.

To examine the diffusion process, the paper first distinguishes permissionless blockchains from permissioned ones. As shown in sections 3.1 and 3.2 the diffusion process for each of these has been very different, driven by distinct inherent features. Permissionless blockchains are the basis of the cryptocurrency markets and may diffuse across both individuals and institutions. Permissioned blockchains are the remit of organizations where diffusion is the domain of businesses rather than individuals. Thus, a groundswell of enthusiastic individuals can drive adoption and acceptance of permissionless blockchains, but businesses would need to understand the business case for adoption (Dunne et al., 2013) of permissioned blockchains.

3. Literature review

3.1. Permissionless blockchains and their diffusion trajectory

The first blockchain development was permissionless and hosted the Bitcoin cryptocurrency, a non-fiat currency, offering a disintermediation mechanism to safeguard trust between transacting parties, decentralizing and distributing transparent ledgers of transaction data. In permissionless blockchains the hashing together of blocks of transactions depends on the work of many anonymous miners competing to solve, through trial and error, a complex mathematical algorithm for that block of transactions (see Lanzanis, 2015; Ram, Maroun, & Garnett, 2016). Once a miner has solved the algorithm the other miners check the solution through a consensus process. When a block of information is authenticated, it leaves an indelible mark on the blockchain through the hashing process with encrypted transactions ensuring the integrity of the data. Notably, a collusion of miners may subvert the process if they act together in concert (see Tuwiner, 2017 and Wong, 2017) but, overall, blockchains are open and transparent to everyone. Access is granted through public 'keys' and personal transaction information is gained using private keys (Carson, Romanelli, Walsh, & Zhumaev, 2018).

The launch of the Bitcoin in 2009 following the Nakamoto White Paper of 2008 was the first stage of permissionless blockchain diffusion, the knowledge stage. As Fig. 1 shows, the launch of Bitcoin had a slow take-up and it was two years later, in 2011, that the Kraken and Bitstamp exchanges were set up, followed by two more in 2012. However, Bitcoin prices were low, reaching a value of USD 13 in December 2012. In 2013 Bitcoin prices started to become volatile, with the price fluctuating from USD 13 to USD 1,242. As prices started to rise, more participants entered the Bitcoin blockchain market and 8 new exchanges opened up in 2013. In addition, the market value of the Bitcoin market rose from zero in 2008, to USD 1.5 million in 2010, to around USD 10 billion in 2013 (Coinmarketcap.com, 2020).

Adding to the Bitcoin cryptocurrency, the Litecoin blockchain was launched in 2011 followed by XRP Ripple in 2012. In early 2013 there was some knowledge of cryptocurrency blockchains by a small number of participants and the diffusion stage was still around Stage 1. During 2013 there was a diffusion jump to Stage 2 (Brandvold, Molnar, Vagstad, & Valstad, 2015) and the number of exchanges doubled to 24. From 2013–2016 interest in cryptocurrencies continued to grow steadily but from 2016 Bitcoin prices rose rapidly and more cryptocurrencies appeared, almost daily, and Bitcoins became headline news (Independent, 2020). Bitcoin prices rose strongly in 2017 as shown in Fig. 1 possibly exhibiting signs of a speculative bubble as contagion took hold (Independent, 2020). Diffusion of permissionless blockchains was approaching Stage 3 with many more participants now implementing a cryptocurrency strategy.

The growth and acceptance of permissionless blockchains since 2017 now evidences diffusion reaching the later stages. By the end of 2019, hundreds of exchanges are trading cryptocurrencies such as Bitcoin, Litecoin and Ethereum, with new ones starting all the time. Exchanges continue to open, such as Binance, a major exchange that opened in Malta in 2017, with several others opening in Hong Kong in 2017, and Bitforex opening in June 2018 in Singapore (Ryan, 2018). Increasingly goods and services can be paid for in Bitcoins and other cryptocurrencies (Fosso Wamba, Kala Kamdjoug, Epie Bawack, & Keogh, 2020) making them a currency of exchange.

Further, the popularity of Initial Coin Offerings (ICOs) in 2017 and 2018 evidences wide acceptance of cryptocurrency blockchains, possibly suggesting a speculative bubble (Chohan, 2017; Huang, Meoli, & Vismara., 2019), with tens of billions of dollars raised. However, many of these ICOs were fraudulent (Kaal & Dell'Erba, 2018) such as: Bitconnect; LoopX; the Shenzhen Puyin Blockchain that stole around $60 million; and CryptoKami's fraudulent ICO that cost the public $12 million. Statis Group (2018) reports that 80 % of 2017 ICOs were scams; Carbon Black reports that $1.1 billion worth of digital currency was stolen in the first half of 2018; and Techcrunch (2018) estimates there are 247 "dead" coins and 830 "dead" cryptocurrencies. Indeed, the US SEC has set up a spoof website called Howeycoins (Booz & Hamilton, 2019; Maume & Fromberger, 2019) to protect cryptocurrency participants. The French stock market regulator AMF notes a 14,000 % surge in fraudulent cryptocurrency offerings in 2018 compared to 2016 (Barone & Masciandaro, 2019).

Thus, greed is spurring unethical practices in the permissionless blockchain arena with regulators working on protecting the public in financial markets. Hence, monetary authorities and stock exchanges are developing blockchains; the Cyprus Securities and Exchange Commission (CySEC) is integrating a blockchain into its electronic

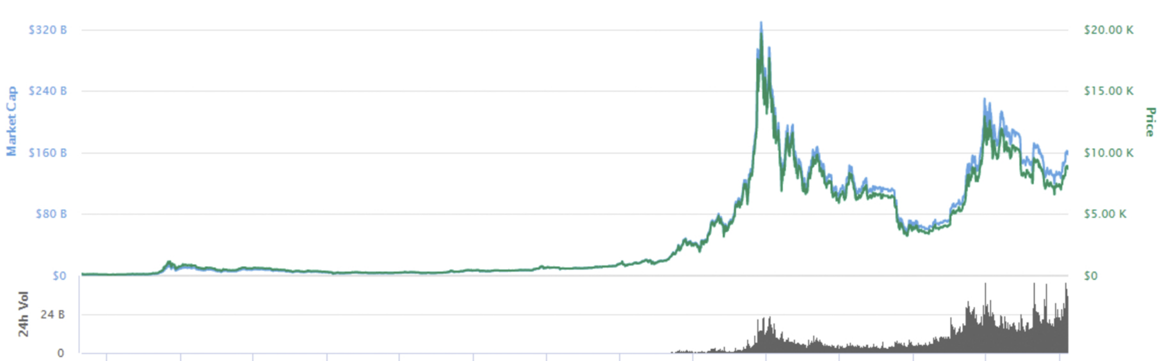

Fig. 1. Bitcoin prices 2013-2020.
Source: Coinmarketcap.com. Accessed January 20, 2020.

payment system, and the Australian Securities Exchange (ASX) is developing a blockchain, called Customer Development Environment (CDE), to replace the previous version CHESS. Bursa Malaysia stock exchange is working on a blockchain-enabled security borrowing and lending proof-of-concept system (Girasa, 2018). In 2019 the central banks of Singapore and Canada successfully used their blockchain networks to send each other digital currency without the use of a third party (Monetary Authority of Singapore, 2019).

Overall, the diffusion of permissionless blockchains has now reached a later stage in the diffusion process and, looking forward, permissionless blockchains in the form of cryptocurrencies are likely to diffuse to a final stage of confirmation. This is in contrast to permissioned blockchains, as explained next.

3.2. Permissioned blockchains and their diffusion trajectory

Permissioned blockchains usually involve a consortium of organizations where transactions are blocked together and verified by authorised gatekeepers instead of anonymous miners. In 2013, Ethereum and Hyperledger were launched and this, in conjunction with the rapid diffusion of Bitcoins (Staples et al., 2017; Tan & Low, 2017), spurred the world's largest banks to establish R3 Corda in 2014: *"to build the future of finance and a new world of commerce"* (Deloitte, 2016; R3, 2020a, 2020b). By 2016 pilot tests of permissioned blockchains were beginning, but there was as yet no implementation (Behnke & Janssen, 2020). Thus, when we undertook our interviews in 2016 permissioned blockchains, unlike permissionless blockchains, were still at an early innovator stage of diffusion.

The finance industry has been, and continues to be, at the forefront of permissioned blockchain developments as noted above. The R3 consortium launched its Voltron Letter of Credit transaction system in 2019 with around 50 institutions across 27 different countries using it. As R3 notes: *"Voltron uses blockchain technology to reduce the time it takes to execute the entire process of paper-based Letter of Credit from 5 to 10 days to under* 24 h. 96 % *of participants in the trial said Voltron will accelerate their Letters of Credit process, improve efficiencies and reduce cost."*

The Italian Banking Association has formed a blockchain consortium of 18 banks called Spunta; JP Morgan is launching a settlement service with over 200 other banks to streamline compliance checks on a permissioned fork of Ethereum. IBM is collaborating with several major international banks to develop the Blockchain World Wire, a cross-border payment system for making faster payments using Stablecoins.

Thus, permissioned blockchain implementation is occurring within the finance sector, as Grover et al. (2019) note. But overall, industry development of blockchains is sporadic and it is unclear how permissioned blockchains will diffuse over the next few years.

3.3. Barriers and drivers of diffusion

The above section shows that the diffusion of permissionless and permissioned blockchains has been very different. As outlined by Mustonen-Ollila and Lyytinen (2003) a number of factors may affect innovation adoption, such as expertise in the technology, compatibility with existing systems and networking and cooperation with others. These can be categorized into barriers and drivers of diffusion. However, extant literature does not differentiate between the two types of blockchain in relation to these factors. In order to evaluate the drivers and barriers to blockchain diffusion we first outline the generic factors in Table 1. We then analyse the two types of blockchain separately in our results. By considering both barriers and drivers we address the concern raised by Frizzo-Barker et al. (2020) who find more papers focus on drivers than barriers. Indeed, as shown in Table 1, they find that technology papers are more likely to outline barriers while organizational studies focus more on the drivers and benefits.

Table 1
Barriers and drivers of innovation and of blockchain diffusion.

Barriers	Drivers	Explanation	References
	Algorithms	Mathematical rules followed in calculations	Powers, 2019; Bruno, 2018; Curran, 2018; Naumoff, 2017; ICAEW, 2016
	Consensus	General agreement	Nakamoto, 2008; ICAEW, 2016; Kamble et al., 2020; Mori, 2016
Miners/ 51 % attack	Miners	Solve the algorithm	Bruno, 2018; Curran, 2018; Naumoff, 2017; Angel & McCabe, 2015; Frizzo-Barker et al., 2020
	Nodes	Computer devices	Kamble et al., 2020
	Cryptographic	Converts text into code	Frizzo-Barker et al., 2020; Kamble et al., 2020; ICAEW, 2016; Mori, 2016
Digital identity/ signatures		Allows access such as through user names and passwords	Frizzo-Barker et al., 2020
	POW	Proof of work: miners get paid working to solve the algorithm	Bruno, 2018; Curran, 2018; Naumoff, 2017
	POA	Proof of Authority: Vetted gatekeepers solve the algorithms	Bruno, 2018; Curran, 2018; Naumoff, 2017
	POS	Proof of Stake: Owners of the blockchain solve the algorithms	Bruno, 2018; Curran, 2018; Naumoff, 2017; Shermin, 2017
Compatibility and inoperability		Exchange data and work with other systems	Dunne et al., 2013; Kamble et al., 2020; Frizzo-Barker et al., 2020; Nam, Leeb, & Leea, 2019
Energy / electricity		Power capacity	Hanson et al., 2017; Kamble et al., 2020
Computing power		Speed and power of the computer device	Hanson et al., 2017; Kamble et al., 2020
Scalability		Able to grow and adapt to demand	VEchain, 2020; Hanson et al., 2017; Frizzo-Barker et al., 2020; Janssen et al., 2020
Criminals, money laundering, fraud/ greed	Bribery and Fraud reduction	Criminal behaviour	Kewell et al., 2017; Piscini et al., 2016; Tuwiner, 2017; Wong, 2017; Kamble et al., 2020
Environment/ wasted resources		Climate change concerns	Frizzo-Barker et al., 2020
Governance		How the blockchain is structured and controlled	Caiazza, 2016; Thakur et al., 2020; Bruno, 2018; Curran, 2018; Naumoff, 2017; Frizzo-Barker et al., 2020

(continued on next page)

Table 1 (*continued*)

Barriers	Drivers	Explanation	References
Legal & regulatory/ lack of common standards		No blockchain standards exist No global set of regulations	Caiazza, 2016; Thakur et al., 2020; Frizzo-Barker et al., 2020; Barone & Masciandaro, 2019; Kamble et al., 2020; Janssen et al., 2020
Security/ Hacking	Prevents hacking	Unauthorised access to a system	Weerakkody et al., 2013; Aste et al., 2017; Kshetri, 2018; Queiroz & Wamba, 2019; Iansiti & Lakhani, 2017; ICAEW, 2016; Kamble et al., 2020; Frizzo-Barker et al., 2020; Grover et al., 2019
Awareness/ lack of participants		Few blockchain participants	Caiazza, 2016; Thakur et al., 2020; Kamble et al., 2020; Frizzo-Barker et al., 2020
Knowledge/ expertise/ resistance		Little understanding of how blockchains work	Caiazza, 2016; Thakur et al., 2020; Kamble et al., 2020; Frizzo-Barker et al., 2020; Janssen et al., 2020
Implementation/ switching costs		Cost of implementing a new system	Kapoor et al., 2014; Frizzo-Barker et al., 2020; Kamble et al., 2020; Janssen et al., 2020
	Anonymity	Identity of person/ organization is hidden	Frizzo-Barker et al., 2020; Kamble et al., 2020; Grover et al., 2019
	Auditability and assurance	Verification of the information	Queiroz & Wamba, 2019; Hanson et al., 2017; Behnke & Janssen, 2020; Tönnissen & Teuteberg, 2020; Kamble et al., 2020
	Authenticity	Genuine	Manski, 2017; Barone & Masciandaro, 2019; Kamble et al., 2020
Collaboration/ cooperation	Collaboration/ cooperation	Working together	Abrahamson & Rosenkopf, 1997; Dunne et al., 2013; Ben_Ari, 2015; Kamble et al., 2020
	Disintermediation/ no intermediaries	Transacting directly with no third parties	Caiazza, 2016; Casey & Vigna, 2018; Ying et al., 2018; Queiroz & Wamba, 2019; Hanson et al., 2017; Hughes et al., 2019; Kamble et al., 2020; Frizzo-Barker et al., 2020; Grover et al., 2019
	Distributed	Spread / scattered around	Nakamoto, 2008; Kamble et al., 2020; Mori, 2016; Grover et al., 2019
	Efficiency /lower transaction costs/ reduced lead times	Improved business processes	Caiazza, 2016; Casey & Vigna, 2018; Queiroz & Wamba, 2019; Hanson et al., 2017; Kamble et al., 2020; Frizzo-Barker et al., 2020; Mori, 2016
	Immutability	Cannot be changed	Frizzo-Barker et al., 2020; ICAEW, 2016; Kamble et al., 2020; Grover et al., 2019
	Integrity/ accuracy	True record	Dwivedi et al., 2013; Frizzo-Barker et al., 2020; Kamble et al., 2020
	Provenance	Origin of something	Queiroz & Wamba, 2019; Hanson et al., 2017; Behnke & Janssen, 2020; Tönnissen & Teuteberg, 2020; Scott et al., 2017; Kamble et al., 2020
	Smart contracts	Contract with the terms written into the code	Hanson et al., 2017; Savelyev, 2016; Kamble et al., 2020; Frizzo-Barker et al., 2020; Mori, 2016
	Transparency /open / visible –	Available for all to see	Broadbent, 2016; Kamble et al., 2020; Frizzo-Barker et al., 2020; Grover et al., 2019
	Traceability	Can be followed through the system	Behnke & Janssen, 2020; Kshetri, 2018; Kamble et al., 2020; Mori, 2016; Grover et al., 2019
	Trustworthy	Can be relied upon	Weerakkody et al., 2013; Broadbent, 2016; Piscini et al., 2016; Queiroz & Wamba, 2019; World Economic Forum, 2016; Kamble et al., 2020; Frizzo-Barker et al., 2020; Grover et al., 2019
	Voting	Choosing	Frizzo-Barker et al., 2020; Grover et al., 2019
	Land registration	Legal land rights	Thakur et al., 2020; Frizzo-Barker et al., 2020
	IOT	Internet of things: controlling electronic items remotely	Kamble et al., 2020
	Industry 4.0/ AI/ machine learning	Using technology in business processes	Kamble et al., 2020; Grover et al., 2019
Barriers and drivers not in the results			
	Hashes	Enables security of the data using mathematical functions	Kamble et al., 2020
	Time stamps/ chronological	Date and time of a transaction	Kamble et al., 2020; Grover et al., 2019
	Tokens	The unit of value or currency of the blockchain	Kamble et al., 2020; Shermin, 2017
Data errors		Errors in the data	Kamble et al., 2020
Privacy	Privacy	Not known by others	Weerakkody et al., 2013; Frizzo-Barker et al., 2020; Kamble et al., 2020; Grover et al., 2019
Volatility		Changes- often unpredictable	Frizzo-Barker et al., 2020
	Decentralised Autonomous Organization DAOs/ sharing	Transparent rules encoded in the blockchain controlled by the organization	Shermin, 2017; Thakur et al., 2020; McConahgy et al., 2017; Abrahamson & Rosenkopf, 1997; Dunne et al., 2013; Frizzo-Barker et al., 2020
	Networks	Interconnected devices / people	Frizzo-Barker et al., 2020; Kamble et al., 2020
	Reliability/ resilience	Trustworth and accurate/ tough	Broadbent, 2016; Dwivedi et al., 2013; Kamble et al., 2020; Frizzo-Barker et al., 2020; Mori, 2016
Technical features not covered in the paper			
Transaction speed		Time taken to perform a transaction	Frizzo-Barker et al., 2020; Janssen et al., 2020
Latency		Time for data to travel	Frizzo-Barker et al., 2020
Throughput		Amount of data transferred within a set time	Frizzo-Barker et al., 2020
Size and bandwidth		Maximum amount of data that can flow	Frizzo-Barker et al., 2020
Usability		Ease of use	Frizzo-Barker et al., 2020
Versioning		Updating the system	Frizzo-Barker et al., 2020
Forks		Diverges into more than one path	Frizzo-Barker et al., 2020
Multiple chains		Many blockchains	Frizzo-Barker et al., 2020

3.4. Barriers of diffusion

One of the most prominent barriers to diffusion is a lack of knowledge and expertise as well as an initial lack of participants. Blockchain ecosystems require many participants and not just technical blockchain experts (Caiazza, 2016; Mustonen-Ollila & Lyytinen, 2003; Thakur et al., 2020). This implies education of participants is needed (Maslova, 2018). There are also network effects where enough participants are needed to allow diffusion to occur (Frizzo-Barker et al., 2020).

Another barrier to blockchains diffusing is scalability (VEchain, 2020; Hanson et al., 2017; Linn & Koo, 2017). Bitcoin processes around 7 transactions per second versus thousands per second on other money processing systems (Frizzo-Barker et al., 2020). Interoperability and compatibility with other systems are also of concern (Dunne et al., 2013) as well as considerations of implementation costs and the switching costs of transitioning from one platform to another (Frizzo-Barker et al., 2020; Kapoor et al., 2014).

Computing power and electricity are important barriers (Hanson et al., 2017; Kamble et al., 2020) with many kilowatt hours needed to solve the mathematical algorithms (Powers, 2019). The environmental implications associated with "wasted" resources required to solve the algorithms are a particular problem for permissionless blockchains (Frizzo-Barker et al., 2020). However, anecdotally side chains, where information is added to a blockchain intermittently rather than as a continuous process (see Mori, 2016) are helping to alleviate this problem.

Changing regulations and a lack of appropriate governance are also usually noted as barriers to diffusion in the literature (Caiazza, 2016; Thakur et al., 2020) with Frizzo-Barker et al. (2020) noting that 34 % of the papers in their systematic review mention appropriate regulation as a challenge. However, many jurisdictions are introducing legal amendments to assist the development of blockchains, such as Thailand's Securities and Exchange Act 2019 enabling blockchain use in trade and security tokenization. In August 2017, the Singapore Monetary Authority introduced its guide to digital token offerings and the Maltese government approved three blockchain and crypto-related Bills in July 2018; the *Digital Innovation Authority Act*, the *Innovative Technological Arrangement and Services Act*, and the *Virtual Financial Asset* (VFA) *Act*. Across Europe the EU *Fifth Anti-Money Laundering (AML) Directive* of July 2018 extended the scope of AML activities to include cryptocurrency platforms and wallet providers, mirrored by Cyprus with regulatory AML and Know Your Customer (KYC) requirements.

Legislators are also introducing laws that recognise digital transactions. For example, the Italian Decreto Semplificazioni 2019 allows computer documents on a blockchain to be legally recognised as well as the electronic time validation stamps that signify the integrity of the data. The US State of Washington also passed a Bill recognizing and protecting the legal status of electronic records on blockchains. Further, the ITIF (2019) noted that "*Policymakers can and should do more to support blockchain innovation and adoption, such as ensuring regulations are targeted and flexible, so as to encourage blockchain experimentation.*" Thus regulation may be either a barrier or a driver depending on the specific situation.

3.5. Drivers of diffusion

The literature identifies a number of drivers for blockchain adoption such as reducing costs through transactional efficiency or disintermediation (Caiazza, 2016; Casey & Vigna, 2018; Queiroz & Wamba, 2019; Ying et al., 2018). The first Bitcoin blockchain allowed buyers and sellers to trade together without the need for an intermediary. Blockchains could become clearinghouses for securities and financial transactions, replacing the multitude of agents involved in traditional intermediation processes. As Broadbent (2016) suggests in a Bank of England speech "*What a distributed ledger would seek to replace, in the case of securities exchange, isn't just a single "third-party centralised clearer", but a complicated system with lots of institutional layers: custodians who look after the securities and perform basic services such as collecting dividends; brokers, through whom trade orders are placed; exchanges and clearing houses where exchange and settlement occur. Each has its own particular function in the process; at each stage, there may be a degree of settlement risk; each is obliged to keep its own record of the same balances and transactions.*"

Further drivers of technological innovation diffusion are immutability and integrity of data (Frizzo-Barker et al., 2020; Kamble et al., 2020) and security against hacking and other cyber threats (Aste et al., 2017; Iansiti & Lakhani, 2017; Kshetri, 2018; Queiroz & Wamba, 2019). The embedded verification, transparency and reliability could replace the need for centralised clearers, saving G7 countries USD 54 billion a year (Broadbent, 2016). Further, cryptography, ring signatures and private keys ensure the privacy of data and anonymity (Frizzo-Barker et al., 2020; Kamble et al., 2020).

Providing assurance over the provenance of goods in the supply chain is another driver (Behnke & Janssen, 2020; Hanson et al., 2017; Queiroz & Wamba, 2019; Tönnissen & Teuteberg, 2020). Global companies such as Carrefour, Nestle, Unilever and Walmart are collaborating on blockchain applications for food traceability and safety. Starbucks is using Microsoft's Azure Blockchain Service to track coffee production; Walmart plans to use the Hyperledger blockchain platform to manage its pork supply chain in China. Ecuador-based Sustainable Shrimp Partnership (SSP) is joining IBM's Food Trust Ecosystem. In Mexico GrainChain is being used by the state of Tamaulipas to expand its grain tracking service. Scott, Loonam & Kumar (2017) note that Provenance has created a global corporate supply-chain ledger using Ethereum, and Manski (2017) suggests that this will authenticate the origin of materials and ingredients in consumer products.

The ability to provide not only provenance but also traceability in supply chains is also a key driver for permissioned blockchains (Behnke & Janssen, 2020; Kshetri, 2018). For example, Gartner (2019) claims that, by 2025, 20 percent of the world's top grocers will be using blockchain technology to provide quality assurance of food products. Skuchain's barcodes and RFID tags digitally enable the transfer of goods across the globe providing transparency across supply chains. Indeed Everledger, one of the first industry blockchains, records diamond transactions and tracks each diamond in a public, secure, and inclusive manner, certifying their ownership history, reducing crime and fraudulent behaviour in the diamond industry (Kewell, Adams, & Parry, 2017). Forty meta data points are used to record the bio-makeup of each diamond - such as the colour, weight, and origin- with well over 1 million diamonds now on the Everledger blockchain. Governments are also experimenting with blockchains with Honduras, Ghana, Georgia and India registering land ownership on blockchains to prevent fraud (see Thakur et al., 2020). Voting processes for government elections are also being developed by national governments (Frizzo-Barker et al., 2020).

The ability to embed smart contracts (see Hanson et al., 2017; Savelyev, 2016) within permissioned blockchains is also driving diffusion. Decentralized Autonomous Organizations (DAOs) are using smart contracts to help govern groups of organizations that share the same interests and goals (Shermin, 2017; Thakur et al., 2020). The Ascribe Terms of Service (ToS) blockchain seeks to simplify the legal processes for both creators and consumers of artistic works (McConahgy, McMullen, Parry, McConaghy, & Holtzman, 2017).

Blockchains also facilitate the Internet of Things (IoT) and Industry 4.0 which require thousands of devices to be connected together to process transactions and industrial processes, improving productivity and efficiency (Kamble et al., 2020).

The technology itself is also providing solutions around governance that are driving its diffusion. Bitcoin was based on Proof of Work (POW), where anonymous miners competed to solve algorithms and were paid for their work in solving these (Bruno, 2018; Curran, 2018; Naumoff, 2017); all cryptocurrencies operate on this basis. However, in 2016 blockchains based on the concept of Proof of Stake (POS) started to appear whereby businesses had ownership stakes in the tokens of the blockchain (Bruno, 2018; Curran, 2018; Naumoff, 2017). As Shermin (2017) notes: "*Blockchains. . create novel opportunities for economic alignment, shared purpose, and coordination between distributed, trustless individuals, at negligible cost … through the shared use of the tokens of a particular blockchain, users have a vested interest in the success of that token. They are economically aligned proportionally to their stake in whichever token they commonly hold. Economic networks, or Web 3.0 consist of networks of people linked by ownership of the same tokens and blockchain[s] can provide an economic transaction layer: a web of humans transacting as economic agents using the blockchains as the interaction mechanism, with their underlying cryptographic tokens.*".

A more recent adaptation in 2017 was Proof of Authority (POA) which brings governance and oversight into the running of blockchains (Bruno, 2018; Curran, 2018; Naumoff, 2017). Our case study of the Italian wine industry discussed later is based on POA. POS and POA also use less electricity than the consensus process adopted by POW-based permissionless blockchains as there is no competition to solve the algorithms which in turn reduces power consumption. Further, POA and POS introduce governance and oversight for entities worried about their reputation and proprietary information.

Overall, there are a number of barriers and drivers of diffusion, but the extant literature does not identify which are pertinent to permissionless blockchains and which to permissioned blockchains or whether they change over time. These features may explain why the two blockchains have diffused so differently. We examine both blockchains in the initial phase of our research but, as permissioned blockchains are much further behind in their stage of diffusion than permissionless ones, we examine the latter in more depth in the second phase of our research, as outlined next.

4. Research method

To explore the barriers and drivers of blockchain diffusion the study is separated into two phases. Phase 1 occurred in 2016 gaining insights from five interviewees in Italy and the UK through semi-structured interviews covering: two Italian blockchain specialists (D1 and D2); two partners from one of the Big4 global professional consultancy firms involved with blockchain organizations (4ITP) and (4UKP), and one Big4 consultancy firm blockchain expert (4UKE). Details of the interviewees are shown in Table 2. The first interviewees were employed by a high-profile company that was a blockchain developer in Italy working on blockchain solutions for businesses with newspaper articles written about it. We interviewed the business specialist and part-owner of the company as well as one of the blockchain developers. We also interviewed the Big4 partner in Italy who was involved with this company. For comparison purposes two interviews were conducted in the UK with Big4 consultancy firm partners who had also been mentioned in the media with connections to blockchain developments to provide a cross-country comparison. At the time we probed more generally about the barriers and drivers of diffusion.

Table 2
Interviewees in 2016.

Interviewee	Organization	Role	Length of interview
D1	Technology	Partner-Blockchain innovator	1.5 h
D2	Technology	Blockchain Developer	2 h
4IT	Big4 firm	Blockchain Partner Italy	30 minutes
4UKE	Big4 firm	Blockchain Expert UK	35 minutes
4UKP	Big4 firm	Blockchain Partner UK	30 minutes

Following Creswell and Plano Clark (2011), Fig. 2 outlines the research process for Phase 1 investigating the barriers and drivers of blockchain diffusion. As we wished to not only probe the stages of diffusion as well as the key barriers and drivers, but to also gain new insights, we adopted a semi-structured interview format to elicit interviewees perceptions on the topic area. We designed a set of questions that covered the main concepts. The questions were general enough to allow interviewees to cover a range of areas, and elaborate on these if they wished, but also ensured that we covered all the key areas. Each interview in Stage 3 lasted between 30 and 120 min and all were recorded and then transcribed in Stage 4 of the process. We used informative categories to analyse the interviews based on archival data deriving themes covering: drivers; barriers; stage of diffusion; permissionless blockchains; and permissioned blockchains in Stages 5 and 6. An independent thematic interpretation was undertaken by three researchers in isolation from the others. These interpretations were compared and discussed in several face-to-face researcher meetings to ensure both inter-coder reliability and the rigour of the analysis. Having identified and agreed on the thematic coding the researchers then reread the transcripts to ensure that nothing had been missed. Several iterations of the thematic analysis were conducted and compared before the ultimate themes were finalised in Stage 7. Finally, the results were written up and pertinent quotes extracted to illuminate the key findings from research analysis in the final stage of the process.

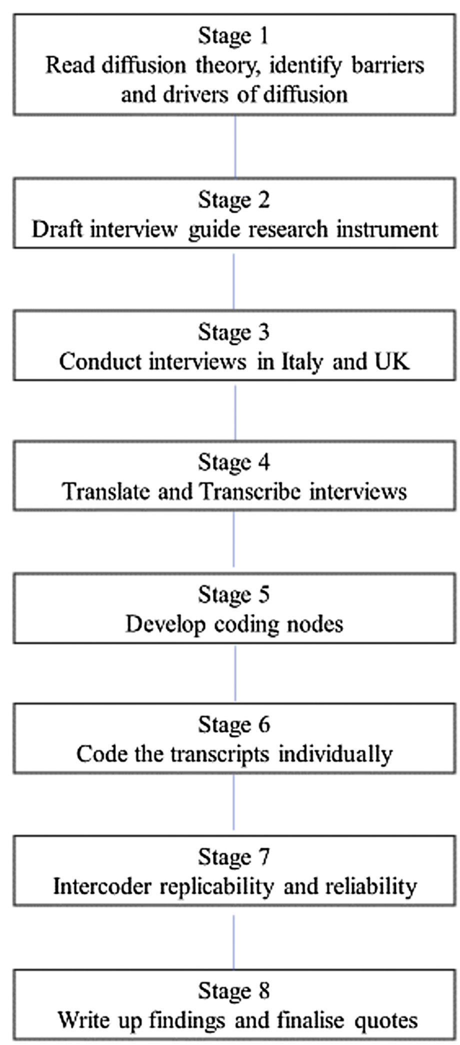

Fig. 2. Stages of the interview process.

By 2019 it appeared that permissionless blockchains were already diffusing, so we decided to explore the barriers and drivers to diffusion of a permissioned blockchain that had already been implemented by a consortium of well-known companies. We were not interested in developers' and consultants' views of blockchains as we had been in 2016, but we were more interested in a real blockchain solution that involved several collaborators around the innovation. We chose the "My Story™" blockchain used by the Italian wine industry as it was already being used by consumers on a global basis. Thus, from a diffusion theory viewpoint, we selected a consortium that could be defined as a fast-follower of the innovation.

The case study (see Yin, 2009) of the Italian wine industry, covers the largest wine producing country in the world (Beverage daily, 2019). The industry began building a blockchain platform in 2019 and later released it to the market. The researchers had contacts and intimate knowledge of the industry (one author is involved with the Italian wine industry). The Italian wine industry blockchain incorporates eight organizations and the case study involved analysing documents and websites as well as conducting six semi-structured interviews with key consortium participants. The diffusion framework of both barriers and drivers was then used to understand the dynamics that affected blockchain diffusion over time. More information on the case study is given in Section 5.3.

5. Results

5.1. Interview evidence: Barriers and drivers of diffusion of permissionless blockchains

A major barrier to permissionless blockchains is the enormous electricity and computing power capacity needed by the miners to solve the algorithms that also limits its scalability. In our interviews the 4UKE interviewee noted that "*quantum computing*" would be needed to surmount current power capacity limitations and elaborated that: *"the problem is you will melt the planet before we can do a permissionless system … we haven't got enough computer power in the world to manage a permissionless system for all of these different scenarios".*

Regulators were beginning to focus on permissionless blockchains due to their rising popularity and worries over the actions of rogue miners colluding to circumvent the consensus process (Angel & McCabe, 2015) which our interviewees acknowledged, noting the perceived lack of traceability and anonymity of the miners, with no governance over their practices. However, countering this, the blockchain developer, interviewee D1, noted that because the miners were "*distributed globally, anonymous, nobody can corrupt them. Nobody knows them, and this software is public"* implying that the miners that added blocks to the chain could not be corrupted with bribes, as happens within centralised organizations and governments, ensuring the integrity of the data.

Scandals had arisen over money laundering and the funding of terrorism using cryptocurrencies (Piscini, Guastella, Rozman, & Nassim, 2016; Tuwiner, 2017; Wong, 2017) but this was not seen as a barrier to diffusion but as an unforeseen outcome that had transpired over the ease of use and associated anonymity. Regarding the reported thefts of Bitcoins, the Big4 blockchain expert, 4UKE, rationalised that it was not the blockchain, but the wallets used to store Bitcoins that had been compromised, and that people should not blame blockchains: *"people were… nicking the wallets, [it was] not the blockchain itself"*. He continued that, during storms in America, *"power was flicking on and off, hackers started to attack"* and people were trying to find power sources *"desperately trying to defend [their] wallets"*.

For permissionless blockchains our interviewee blockchain technologists, D1 and D2, were optimistic that they were diffusing successfully because of the self-interest of miners who profited personally from creating the blocks in the chain. The 4UKP interviewee noted that miners are *"entrepreneurs [and] will be the drivers of public blockchains because they will find ways…entrepreneurial ways of making money through blockchain"*. The 4UKE interviewee agreed: "*The people making most money out of the blockchain are the people who are either mining or people founding some of these networks…"*.

But, despite self-interest motivations, our interviewee D1 explained how blockchains added a whole layer of trust to the internet: *"to trust anyone, you just … have to trust only mathematics… no politics; its mathematics"*. Thus, despite the self-interest of miners or pure market greed, mathematical calculations could not be corrupted, and this engendered trust and had become a driver of permissionless blockchains.

Further, the Big4 blockchain expert interviewee 4UKE noted that the biggest and fastest crowdfunding event ever was now through blockchain effectively displacing intermediaries. Thus, disintermediation was still an important driver of permissionless blockchains, just as Nakamoto (2008) had originally planned.

Importantly, our findings showed that diffusion needs to be categorized further than the current literature suggests. Diffusion of the application of a technology may be restricted, but that does not mean there cannot be widespread diffusion to a critical mass of participants. Our interviewees were of the view that computing power and electricity were the only major barriers to the number of permissionless blockchains diffusing. The drivers and features were evident, but until technological developments could solve this the number of permissionless blockchains would be limited. However, the final stage of mass adoption through the number of participants could be reached despite a limit on the number of permissionless blockchains themselves. The Bitcoin was one blockchain, but it had diffused widely; it is not necessary to have many blockchains to have many participants. Thus, the technology is different from some previous innovations where individual people or businesses had to buy the technology to use it; blockchains exist in the ether for everyone to use.

5.2. Interview evidence: Barriers and drivers of diffusion of permissioned blockchains

Within business, there was little evidence of any diffusion of permissioned blockchains according to the interviewees who noted the lack of participants and lack of knowledge of blockchains and they wished more businesses were aware of the technology. In general, however, the interviewees concentrated on the drivers of blockchain diffusion rather than on the barriers. The Big4 blockchain partner 4 UKP demonstrated his expectation that businesses would adopt blockchains, even though this might be far in the future as comparability and interoperability were still a barrier, but he emphasized that "*instead of having SAP systems, we all have blockchains…and individual companies will have multiple blockchains doing different things."*

Interviewee D1 noted the efficiency of the blockchain as a transaction ecosystem as a driver and blockchain developer D2 focused on the rewards and incentives for business as a driver: "*…You can make, in the future, centralised apps on the model of Airbnb or Uber but at much lower costs. You have to think about all the costs you save by using blockchain technology"*.

Further, the interviewees noted that smart contracts could be an important driver with rules embedded within each transaction, including legal and financial details, in contrast with conventional databases where rules are set for the database or application as opposed to each transaction. Additionally, the terms of the transaction are recorded in computer language instead of a legal language, encompassing agreed contractual arrangements irrespective of jurisdiction or geography. The blockchain developer D2 explained that a "*…smart contract is software and legal… [it's] inside the money. It's not in the system, in the front system or the back system - [it's] inside the money."* Interviewee 4UKE referred to the embedded "codus law" arguing no over-riding authority was needed to define the law: *"the code is the law …the code is the code, and the* *blockchain networks validate that all the transactions are secure."* The need for legal notaries and legal advice would disappear as contracts became digitised in a standardised, understandable way. Interviewee 4UKE noted further that smart contracts would generate new business opportunities. *"…it's all about microgeneration - and blockchain allows you to do it contract-less";* as the contract is embedded in the supply itself it allows small businesses, such as farmers, to sell products without the need for a contractual arrangement for each specific customer.

In addition, permissioned blockchains could change business operations and help efficiency by hosting Internet of Things (IoT) developments, using drones and remote monitoring processes (facilitating Industry 4.0) as Interviewee D1 noted: *"so it's also linking into the whole Internet of Things and remote monitoring - the asset management side of things."*

The interviewees were generally very positive about the benefits associated with the provenance of products and, as the blockchain developer D2 noted: *"[this] could be really a societal benefit in preventing fraud and corruption [through transaction transparency]"*. For instance, large mining companies, diamond traders and governments from developing nations had already began using a blockchain to trace the provenance of diamonds. The Big4 blockchain specialist 4UKE observed "*…the problem in the diamond world is you've got fake certificates-real diamonds, fake diamonds-real certificates, fake, you know, all that kind of stuff. With the blockchain, they've already got a million diamonds in their ledger, and that's now eradicating the [fraud and corruption] problem..".*

He continued that cryptography and digital signatures around the information within a blockchain, that was all linked together, would eradicate the black-market arising from the overproduction of drugs in the pharmaceutical industry and ensure the provenance of the drugs. "*… what's happening with [pharmaceutical companies is] they've come up with a new drug, they put it out for production in Eastern Europe and China and then the factories are producing* 10 % *more than they should be and that's almost impossible for the pharmas to monitor, and then those drugs are ending up on the black-market. So what blockchain would do is secure the amount of drugs that can be provided, certify every single box, that would all go on a blockchain and you would never be able to overproduce.".*

These interview findings suggest that for permissioned blockchains the barriers are lack of awareness and lack of participants. In contrast to permissionless blockchains energy and power constraints were not considered to be barriers. The drivers of permissioned blockchains are provenance and traceability rather than disintermediation as for permissionless blockchains. Thus, the interviews suggest the barriers and drivers of innovation may be different for a technology that can be developed and used in different ways. It is therefore necessary to explore the uses of a technology separately, rather than bundling aspects of a technology together as one innovation. Further, some of the supposed drivers in the literature seemed to have become features of the innovation rather than drivers in themselves. However, underpinning the diffusion of both permissionless and permissioned blockchains was self-interest; profiting from mining or developing blockchains, or reducing costs and inefficiencies.

5.3. Barriers and drivers of the Italian Wine industry permissioned blockchain

In 2019 the Italian wine industry implemented a permissioned blockchain using "MyStory™" that had been developed by one of the consortium participants, Certifier, a global assurance organization. MyStory™ enables consumers of wine to access information about a bottle of wine using a QR code, as described below. Eight organizations are involved in the wine industry blockchain consortium: three well-known wineries as shown in Table 3; four organizations are involved in developing, certifying and verifying the provenance of the wine (Certifier, Valoritalia, Federdoc, and a Big4 specialist); and the eighth organization is the blockchain host, VEchain, 2020. Three wineries are currently on the blockchain, with many more expected to join.

Table 3
The three Blockchain wineries.

	Ricci Curbastro	Ruffino	Torrevento
Date of foundation	1967 (1855)	1877	1948
Location Region (main)	Lombardy	Tuscany	Puglia
Type of wine	Franciacorta	Chianti	Various
No. bottles produced pa	200,000	17,109,074	2,500,000
% Exported	35 %	93 %	75 %
Main export markets	Germany, US, Belgium	USA, Canada	Various

Note: The wineries involved in the Italian blockchain.
Sources: https://www.italianwineshop.it; Mediobanca Research Department; http://www.movimentoturismovino.it; https://www.vinoway.com; http://www.annadimartino.it/puglia-cinque-cantine-cinque-primati; https://www.vinoway.com/recensioni/item/6824-ricci-curbastro-grande-legame-tra-territorio-e-spinta-innovativa.html; http://distribuzionemoderna.info/finanza/ruffino-supera-i-100-milioni-di-fatturato.

Establishing the provenance of their wine is extremely important to these three pioneering, top quality wine producers, countering against any "fakes" purporting to be their wine. As noted in the method section, the case study involved documentary analysis as well as interviews with key personnel at: Certifier, Federdoc and Valoritalia, one of the wineries, and the blockchain specialist at a Big4 consultancy firm involved in developing the blockchain. Interviews were also conducted at two wineries that are not as yet part of the blockchain consortium to discover what was needed to persuade their businesses to become fast followers in adoption.

Certifier is a global quality assurance and risk management company providing certification and verification across a wide range of industries. Certifier created the MyStory™ blockchain to facilitate businesses telling the story of their products to customers and, as part of this process, verifies the accuracy and authenticity of the information, especially off-chain. In our case study off-chain processes cover the production of the wine from the vines, to the grapes, to the wine making processes. According to our case study findings, off-chain verification and certification has become a significant problem for businesses trying to implement global supply chain solutions and this could become a major barrier to wide-scale adoption in the future.

In the wine industry blockchain, each bottle of wine is linked by a QR code that can be scanned by consumers anywhere in the world providing immutable information on the provenance and history of the bottle and the winery. The Big4 blockchain specialist is working with Certifier on the development of this blockchain.

Valoritalia, is authorised by the Italian Ministry of Agriculture, Food, Forestry and Tourism to certify Appellations of Origin, checking every phase of production, from the vine to the bottle, including vine growing, wine-making, bottling and labelling, and providing traceability that guarantees the exact origin of the product for consumers. Wine consortiums, such as Franciacorta and Chianti in our study, are responsible for protecting, supervising and promoting the appellation of their wine but they require certification by Valoritalia that both EU and national laws have been observed.

Confederazione Nazionale dei Consorzi Volontari per la Tutela delle Denominazioni Italiane di Origine (Federdoc) represents 90 wine consortiums, including Franciacorta and Chianti, covering 85 % of total Italian wine production. Federdoc markets the quality of the wines and guarantees compliance with wine production rules and regulations.

VEchain, based in China, hosts the MyStory™ blockchain. VEchain notes on its website that *"*MyStory™ *is an off-the-shelf blockchain based digital assurance solution for the food and beverage industry combining deep industry expertise of prominent industry leaders and Certifier, with independent physical audits, data collection, and verification services."*

It also notes that the Italian wine industry is the first to use MyStory™ in this "disruptive solution" to verify the provenance and traceability of products: "*These industry leaders will feature the* MyStory™

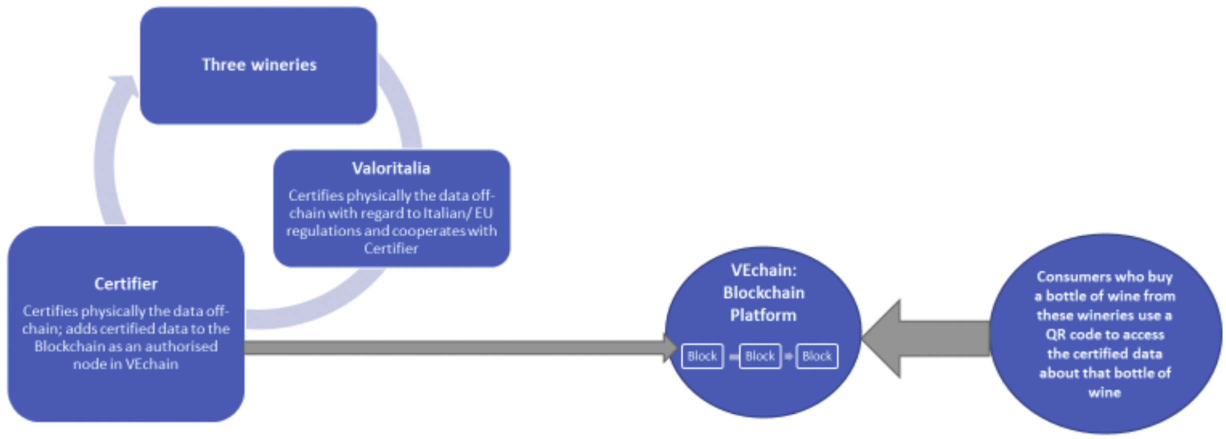

Fig. 3. The MyStory™ blockchain process.

label on their bottles in stores, using the VEchain Thor Blockchain solution and hardware tags".

VEchain is based on Proof of Authority with a detailed governance process validating the authenticity and appropriateness of the gatekeepers on the blockchain. Certifier is one of 101 authorised gatekeepers (nodes) on the VEchain blockchain, and the governance process ensures that only these nodes can add information and blocks to the chain; thus, none of the wineries can add information to the blockchain. Certifier verifies information sent to it by the wineries, such as the number of vines and the condition of the grapes, before it enters the information into the blockchain. As noted above, this off-chain verification process is important, as Certifier states on its website: *"MyStory™ is the first solution based on the latest concept of digital assurance, which goes well beyond monitoring a product from the producer to the consumer. This is only the first step in our objective of coherent and combined use of Blockchain, Internet of Things and Artificial Intelligence to contribute to improving performance, efficiency and transparency of the processes of the firms with whom we work."*

Fig. 3 and 4 summarize the blockchain process as illuminated by the findings of our case study. Fig. 3 shows how the three wineries, Certifier and Valoritalia work together off-chain to create the information for the blockchain. The wineries report information that is checked by Valoritalia and verified by Certifier. Certifier adds this information to the blockchain and consumers around the globe can read the information on each bottle of wine and know that the off-chain processes have also been verified. Fig. 4 shows the information contained within MyStory™ such as the agronomic information and the wine awards that have been won.

The interviewee at one of the two wineries that was not part of the blockchain consortium reasoned that it would be joining once public demand increased. She acknowledged that, as customers started demanding more information about the bottles of wine they were buying, her winery would join the MyStory™ blockchain (r)evolution. Diffusion was, thus, occurring, despite any barriers, as one interviewee noted: "*in my opinion all barriers can be overcome"*. The business incentives were too strong and lack of knowledge of blockchains that had been a barrier had moved on; a focus on technological issues was being replaced by business solutions evidencing an important stage in diffusion, as the Certifier participant noted: "*When, nowadays, I connect to a wi-fi router, I do not pose myself the question as to what kind of technology lies behind it, I connect and that's all. Therefore, the role of blockchain is enabling… it is not merely an enabling technology, but it can support a change in economic paradigms; a change that, in any case, is under way, it is therefore a catalyst of a change that also goes beyond the technology in itself*".

The Big4 participant in the consortium demonstrated the diffusion of blockchain by outlining its growth, and importantly separated growth in blockchains versus growth in participants as clients: "*I'll give you some numbers so you can understand the pace of acceleration [within my Big4]. Two hundred [clients] the first year, one thousand the second year … That's five times as much. And this year it looks like being four thousand, so four times more. So, this is exponential growth, and it's quite visible. If I look at the opportunities … in the first year we [Big4] had two hundred and*

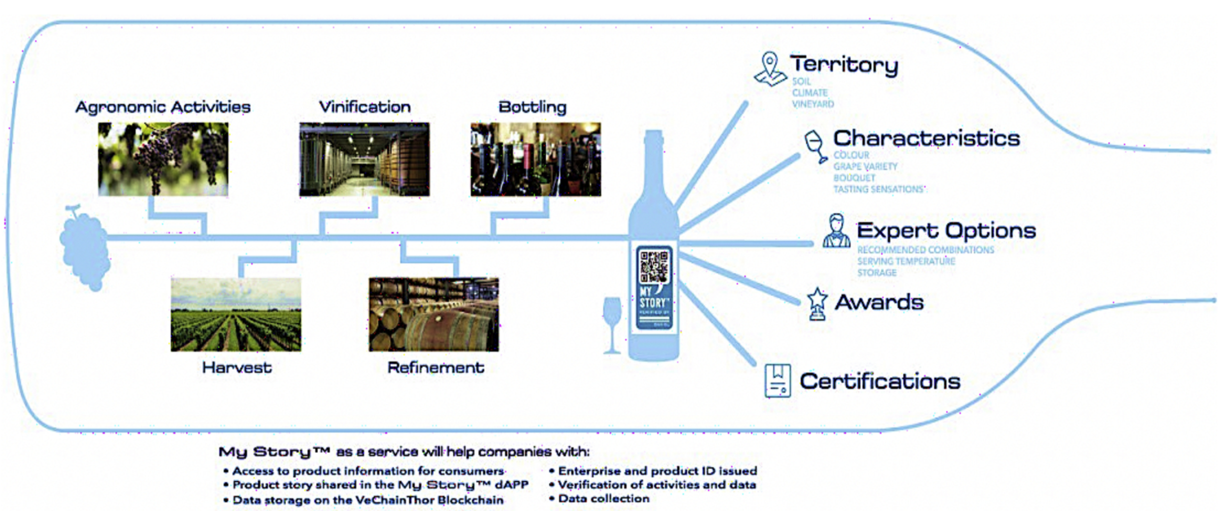

Fig. 4. Information on the MyStory™ blockchain.
Source: Vechain Foundation, https://medium.com/vechain-foundation. Accessed December 16, 2019.

fifty [client developments] opportunities, last year we had fifteen hundred, this year seven thousand; … in terms of opportunity … if you go from two hundred to seven thousand, we're talking of a twenty-five-fold growth [in blockchain developments in my Big4], something of the sort".

Unlike permissionless blockchains where the number that can physically exist is restricted, with permissioned blockchains the number is not restricted; and for both the number of participants can grow exponentially.

Regulation, as noted earlier, was no longer a barrier but was driving business interest in blockchains, as noted by the Certifier: "*The lack of regulation…[is] something that many countries are trying to comply with … [in Italy] the Ministry for Economic Development has set up a committee of thirty experts, with the task to address and define a national strategy for the blockchain; the same in France…Within the frame of Decreto Semplificazioni, an article has been approved, establishing the legal nature of the transactions recorded by DLT technology to which blockchain belongs…The blockchain has no boundaries as a technology … and the nodes can be distributed anywhere. Therefore, I think that, in fact, a higher degree of certitude on a regulation will help quite a lot."*

The case study showed that the barriers had fallen away and the winery blockchain solution centred around transactional efficiency and the provenance of the supply chain. Traditional drivers of blockchain innovations in the literature such as increased security and immutability of data were not mentioned as such and have now become accepted features. Public trust in the provenance of the wines and the assurance that it was, for example, a true Franciacorta or a Ruffino Chianti wine was paramount.

A new driver for business adoption emerged in the case study, that of product differentiation as explained by the Certifier in the MyStory™ blockchain: "*I can have the same wine … bottled in twelve different bottles; but then I produce twelve labels signed by twelve different renowned artists. I can trace each bottle [and] the value of that bottle is not only the wine but also the label - and the combination of these two elements is a different product, so I need multidimensional traceability …because of this diversity."*

Transactional efficiency was important in the case study, not only from an operational perspective but also because blockchains were cheaper to develop than web applications, as the Big4 participant noted: "*It costs more or less the same as developing on the internet, practically, there's no difference, in my opinion… No, I could say more, it is more economical"*.

The Italian wine industry blockchain shows the ease of development; the prototype was developed and tested within just a few months. A private permissioned blockchain was used for testing before hosting it on the public permissioned blockchain for everyone to see. Further, now it has been developed, it can be rolled out to other industries as the Big4 participant explained: "*XXX wants to create a supply chain service, so any type of business, anywhere in the world [can use it]."* He continued that certification was no longer an intermediated function: "*Once Certifier has established this certificate and put it on the blockchain, others can go and check that … a particular wine comes from a particular winery. The request is not sent to Certifier every time, so Certifier stops being an intermediary"*. The result was transparency and cost savings.

Blockchains had much to offer and could help with: "*anti-counterfeiting and so on, to the forms of payment, that other technologies are not potentially capable of managing in an integrated manner, something that blockchain can do, instead"* (Big4 participant). The provenance of products and deterrents against corruption were a powerful motive for the blockchain and an interviewee at a winery that was not part of the blockchain recognised the benefit: "*Certification of this sort is useful in case there are problems of counterfeiting.. in the United States, where these bottles are highly appreciated... How can you certify that …a bottle of Barolo is from a renowned producer? …The blockchain certifies that, let's say, one thousand bottles have entered the United States through the importer, that five hundred were delivered to New York and five hundred to Los Angeles, and of these one hundred are still on the market and the rest have been sold. … there cannot be ten thousand. … The motivation is always the same, to provide end consumers with the certainty that the purchased product is actually the product that they wanted to buy."*

The Certifier also commented on fake products: *"MyStory™ can safeguard, for example, anti-counterfeiting. …acquiring data, or a certain type of data in a digital format, creates a knowledge base … data crossing makes controls more effective; controls nowadays are carried out through inspections but information acquired in a different manner and connected to a different phenomenon can be correlated, using an automatic control logic … MyStory™ … the story, is a different story [each time], to enhance the most important and significant characteristics pertaining to that product... MyStory™ is therefore a story covering some technical aspects, aspects concerning the product, the process and also emotional aspects…"*.

Overall, the wine industry blockchain evidences that businesses are using blockchains to validate the provenance of their goods in a supply chain for customers and the public, offering transparency over their activities, making operations transactionally efficient, and engendering the public's trust in their products.

However, blockchains were not the solution to every business problem, as the Big4 participant cautioned: "*… I'd say we stopped [developing around] ten per cent [of blockchains] after a few weeks…. because we realised that the blockchain wasn't really [a viable solution]"*.

6. Implications of the study

The findings from the interviews and case study of the wine industry have some important implications for business, technologists and academics. The first implication from this research is that a technological innovation may need to be differentiated into its particular types rather than be treated as one development; one type may succeed, and another may be rejected or take much longer to be accepted, as the diffusion of permissionless versus permissioned blockchains in this paper shows. This may be because the barriers and drivers are different, and each can affect the diffusion process.

Second, a successful technological innovation may be measured in two ways: (i) the number of adoptions of the technology; and (ii) the number of participants in the technology. There may be a restricted number of adoptions of the technology because of a major barrier, but that may not necessarily mean it is unsuccessful if many participants and a critical mass of people use the technology, such as the example of permissionless blockchains.

Third, off-chain processes are not discussed enough in the literature. Once a transaction is on the blockchain it is immutable and transparent. But what about processes that occur before being added to a block? This paper shows that off-chain processes such as planting vines, growing grapes and producing wine are all off-chain. Certifier physically checks these processes and verifies them before adding bottles of wine to the MyStory™ blockchain. In the future the lack of verification of off-chain processes may become a barrier to the wide-scale adoption by business of supply chain blockchains.

Fourth, the study shows that some barriers and drivers disappear and become accepted features of an innovation, such as cryptography and security in this paper. The use of algorithms, cryptography and the consensus process, security against hacking and the immutability of data are now features of blockchains (ICAEW, 2016). These are no longer necessarily drivers in themselves. Trust in business may also result from permissioned blockchain adoption (Piscini et al., 2016) but as an outcome not a driver (Queiroz & Wamba, 2019). This reflects the views at the World Economic Forum (2016) where open-data transparency was argued to engender trust between organizations and their stakeholders. As Queiroz and Wamba (2019) posit, trust and transparency are not a predictor of blockchain intention to adopt the technology, rather they are features of it arguably for both permissionless and permissioned blockchains.

Fifth, previous barriers can turn into drivers of diffusion, such as regulation in this paper. Regulation is a driver of blockchain diffusion especially as anti-bribery laws, anti-money laundering rules as well as modern slavery laws are persuading businesses to investigate blockchains to authenticate their supply chains and provide traceability of transactions to ensure that laws are not inadvertently breached (Barone & Masciandaro, 2019).

Sixth, drivers of one type of technology may become drivers for another, such as that of disintermediation. Innovations can be adapted for other situations, such as from permissionless blockchains to permissioned blockchains and a driver of one type of innovation can turn into a driver for another type. For example, the initial launch of the Bitcoin permissionless blockchain was to disintermediate markets, but this was coopted by the financial sector to develop permissioned blockchains for transactional efficiency and cost savings bringing about disintermediation (Hughes et al., 2019), albeit still in the financial sector.

Seventh, we find that once an innovation has diffused drivers are no longer necessary to keep the momentum going. After implementation, continuous improvements are undertaken (see Hughes et al., 2019) and become accepted practice, such as new cryptocurrencies, and proof of stake and proof of authority.

Finally, an important implication is that self-interest is the ultimate driving force behind technological innovation across industries and financial markets, whether it is to increase profits or cut costs (business) or make money (miners).

7. Conclusions, limitations and future research

As a contribution to the literature, and in answer to our first research question, we found that the barriers and drivers of diffusion of permissionless and permissioned blockchains are not the same - and they affect diffusion in different ways. As shown in Fig. 5, the trajectory of permissionless and permissioned blockchain diffusion from 2007 before the Nakamoto (2008) White Paper to 2019 are very different. Permissionless blockchains have reached a much later stage of diffusion with implementation on a wide scale; many cryptocurrencies are traded on a daily basis and many exchanges exist where cryptocurrencies can be exchanged for other cryptocurrencies or for fiat currencies such as US Dollars and Euros. By the end of 2019, permissionless blockchains have become widely accepted by society with knowledge of Bitcoins, and cryptocurrencies being used to pay for goods and services. Diffusion of permissioned blockchains has not been as widespread and varies from the fast followers of our case study, to mainstream businesses that are assessing the success of the fast followers, to others who are aware of blockchains but are not yet persuaded to follow suit.

Our second contribution is to demonstrate how a new technology can be adapted for very different scenarios depending upon the mix and importance of the barriers and drivers. Permissionless blockchains have become a market-driven solution to trading currencies. Permissioned blockchains are becoming an institutional-driven solution to the conduct of business with transactional efficiency, cost-cutting and the management of the provenance and traceability of goods in global supply chains such as the wine industry, important considerations.

In answer to our second research question, and as our third contribution, we find that the barriers and drivers of diffusion change over time as the stages of diffusion change; barriers and drivers are not static but are dynamic and new drivers may emerge, and barriers may fall away. Thus, examining innovation at a static point in time may not be useful when innovation is a dynamic fast-moving process. Table 4 summarizes the barriers, drivers and features of blockchains as evidenced from our findings. Some barriers for permissionless blockchains still exist such as power consumption (but anecdotally the development of side chains is reducing these power requirements and scalability problems) but the waste of resources has now become a new barrier and concern. Regulators are still a barrier, enacting laws and worrying how to regulate permissionless blockchains, but for permissioned blockchains regulations have changed from a barrier to a driver, such as anti-slavery, anti-money laundering and anti-bribery laws increasingly requiring the traceability of money and of products across supply chains. Some drivers have become more important, such as collaboration within industries as the R3 Corda project and our Italian wine industry demonstrate. Governance as an initial barrier has disappeared as new features, such as proof of stake and proof of authority, enable businesses in industry-wide blockchains to implement governance structures. New drivers are also appearing, such as product differentiation and the focus is shifting from technical aspects to practical business uses, such as off-the-shelf blockchain solutions MyStory™ and dedicated blockchain hosts such as VEchain.

Prior research asks for more case studies (Behnke & Janssen, 2020) and an in-depth analysis of blockchain adoption (Hughes et al., 2019; Janssen et al., 2020; Queiroz & Wamba, 2019), which this paper addresses and, although this reports just one case study and a limited number of interviews, it adds to the burgeoning literature. Our interviewees and case study participants were involved in blockchains and hence, although not generalizable, they reflect the views of those with in-depth blockchain knowledge.

Future research could provide more case studies of blockchains especially in the same industry across countries or blockchains in different industries in the same country. In addition, research is needed into the certification of off-chain practices of businesses to ensure that provenance, not just traceability, is assured for customers and consumers. Future research could also consider barriers and drivers of permissionless versus permissioned blockchains separately as we do in this study and, to address the findings of Frizzo-Barker et al. (2020), more studies could concentrate on the non-technical barriers of diffusion. More generally, studies are needed to examine the diffusion process over time to see whether the barriers and drivers change as different stages of the diffusion process are reached and analyse the spillover effect from one innovation to another, as the diffusion process is not typically clear or linear.

Overall, the outlook for blockchain diffusion is bright. Financial

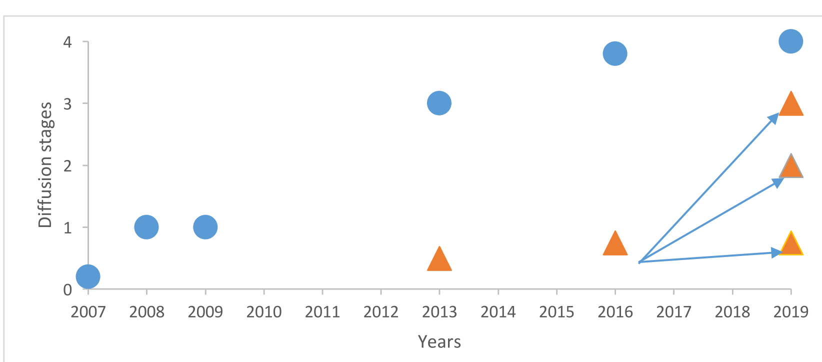

Fig. 5. Blockchain diffusion 2007-2019.
Note: The circles represent permissionless blockchain diffusion and the triangles represent permissioned blockchain diffusion that represents the fast-followers (top triangle), those assessing the success of the fast-followers (middle triangle), and those to be persuaded (bottom triangle).

Table 4
Barriers, drivers and features of permissionless versus permissioned blockchains.

Literature on blockchains		Explanation	Permissionless			Permissioned		
Barrier	Driver		Barrier	Driver	Feature	Barrier	Driver	Feature
	Algorithms	Mathematical rules followed in calculations			x			
	Consensus	General agreement			x			
Miners	Miners	Solve the algorithm			x			
	Nodes	Computer devices						x
	Cryptographic	Converts text into code						x
Digital identity/ signatures		Allows access such as through user names and passwords						x
	POW	Proof of work: miners get paid working to solve the algorithm			x			
	POA/ POS	Gatekeepers/ owners solve the algorithms					x	
Compatibility and inoperability		Exchange data and work with other systems				x		
Energy /electricity		Power capacity	x					
Computing power		Speed and power of the computer device	x					
Scalability		Able to grow and adapt to demand	x					
Criminals, money laundering, fraud/ greed		Criminal behaviour		x	x		x	
Environment/ wasted resources		Climate change concerns	x					
Governance		How the blockchain is structured and controlled	x				x	
Legal & regulatory		No blockchain standards exist No global set of regulations	x				x	
Security/ Hacking	Prevents hacking	Unauthorised access to a system					x	
Awareness/ lack participants		Few blockchain participants				x		
Knowledge/ expertise/ resistance		Little understanding of how blockchains work				x		
Implementation/ switching costs		Cost of implementing a new system					x	
	Anonymity	Identity of person/ organization is hidden	x	x	x			
	Auditability and assurance	Verification of the information					x	
	Authenticity	Genuine					x	
Collaboration/ cooperation	Collaboration/ cooperation	Working together					x	
	Disintermediation/ no intermediaries	Transacting directly with no third parties		x			x	
	Distributed	Spread / scattered around			x			x
	Efficiency / lower transaction costs/ reduced lead times	Improved business processes					x	
	Immutability	Cannot be changed						x
	Integrity/ accuracy	True record			x			x
	Provenance	Origin of something					x	
	Smart contracts	Contract with the terms written into the code					x	
	Transparency /open / visible –	Available for all to see			x		x	
	Traceability	Can be followed through the system					x	
	Trustworthy	Can be relied upon		x			x	
	Voting	Choosing					x	
	Land registration	Legal land rights					x	
	IOT	Internet of things: controlling electronic items remotely					x	
	Industry 4.0/ AI/ machine learning	Using technology in business processes					x	
New barriers/ drivers/ features								
	Wallets	Digital place to store digital money			x			
	Self-interest	Put one's own interest first		x			x	
	Product differentiation	Distinguishing it from others					x	
Off-chain		Outside the blockchain				x		
Proprietary information		Only known by an organization				x		

markets will become more efficient, businesses will benefit from transactional efficiency, reduced costs and, ultimately, greater profits. For society there may also be a reduction in fraud and corruption, as transactions become verified and encrypted in the blockchain's immutable distributed ledger across the blockchain community.

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Credit author statement

All the researchers have worked on this paper over the last 4 years at different times and in different ways. As the paper has evolved dynamically over time it is hard to now go back and specify what each author contributed to the study and the paper. The authors have worked together for 15 years on a number of funded projects and papers and attributing one particular paper to each member of the research group is quite difficult. We are happy that overall each author has contributed to the study.

Compliance with ethical standards

There were no humans or animals involved in this research and the authors have complied with ethical standards of research.

Conflict of interests

The authors declare that there are no conflicts of interest with respect to the research, data, authorship or publication of this article.

References

Abrahamson, E., & Rosenkopf, L. (1997). Social network effects on the extent of innovation diffusion: A computer simulation. *Organization Science, 8*(3), 289–309.

Angel, J. J., & McCabe, D. (2015). The Ethics of Payments: Paper, Plastic, or Bitcoin? *Journal of Business Ethics, 132*, 603–611.

Aste, T., Tasca, P., & Di Matteo, T. (2017). *Blockchain technologies: The foreseeable impact on society and industry. Computer, September*.

Barone, R., & Masciandaro, D. (2019). Cryptocurrency or usury? Crime and alternative money laundering techniques. *European Journal of Law and Economics, 47*, 233–254.

Behnke, K., & Janssen, M. F. W. H. A. (2020). Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management, 52*, 101969.

Ben_Ari, A. (2015). *Blockchain predictions for 2016, Blockchain News.* Accessed August 2016 http://www.the-Blockchain.com/2015/12/14/adi-ben-ari-Blockchain-predictions-for-2016/.

Beverage daily, (2019). https://www.beveragedaily.com/Article/2019/04/15/Global-wine-production-reaches-record-level. Accessed January 2020.

Bjornenak, T. (1997). Diffusion and accounting: The case of ABC in Norway. *Management Accounting Research, 8*, 3–17.

Booz, H., & Hamilton, D. F. (2019). *Bringing blockchain into government: A path forward for creating effective federal blockchain initiatives*Report available at: https://www.data-foundation.org/bringing-blockchain-into-government. Accessed June 2019.

Brancheau, J. C., & Wetherbe, J. C. (1990). The adoption of spreadsheet software: Testing innovation diffusion theory in the context of end-user computing. *Information Systems Research, 1*(2), 115–143.

Brandvold, M., Molnar, P., Vagstad, K., & Valstad, O. C. A. (2015). Price discovery on bitcoin exchanges. *Journal of International Financial Markets Institutions and Money, 36*, 18–35.

Broadbent, B. (2016). *Central banks and digital currencies, Bank of England speech.* Accessed August 2016 http://www.bankofengland.co.uk/publications/Pages/speeches/2016/886.aspxBhttp://www.bankofengland.co.uk/publications/Pages/speeches/2016/886.aspx/.

Bruno (2018). https://bitfalls.com/2018/04/24/whats-the-difference-between-proof-of-work-pow-proof-of-stake-pos-and-delegated-pos/.

Bumblauskas, D., Mann, A., Dugan, B., & Rittmer, J. (2020). A blockchain use case in food distribution: do you know where your food has been? *International Journal of Information Management, 52*, 102008.

Caiazza, R. (2016). A cross-national analysis of policies affecting innovation diffusion. *The Journal of Technology Transfer, 41*, 1406–1419.

Carson, B., Romanelli, G., Walsh, P., & Zhumaev, A. (2018). *Blockchain beyond the hype: What is the strategic business value? McKinsey and Company.* https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/blockchain-beyond-the-hype-what-is-the-strategic-business-value.

Casey, M. J., & Vigna, P. (2018). *In blockchain we trust. MIT technology review*https://www.technologyreview.com/s/610781/in-blockchain-we-trust/.

Chohan, U. W. (2017). *Initial coin offerings (ICOs): Risks, Regulation, and accountability. Discussion paper series: Notes on the 21st century.* Available at SSRN: https://ssrn.com/abstract=3080098.

Cohen, B. (2017). The rise of alternative currencies in post-capitalism. *Journal of Management Studies, 54*(5), 739–746.

Coinmarketcap.com (2020). *www.coinmarketcap.com.* Accessed January 20, 2020.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). California: Sage Publications.

Curran, B. (2018). *What is proof of authority consensus? Staking your identity on the blockchain, blockonomi.* https://blockonomi.com/proof-of-authority/.

Deloitte (2016). *Bitcoin, Blockchain & distributed ledgers: Caught between promise and reality, Deloitte. Centre for the Edge, Australia*.

Di Vaio, A., & Varriale, L. (2020). Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry. *International Journal of Information Management, 52* 102014.

Dierksmeier, C., & Seele, P. (2018). Cryptocurrencies and business ethics. *Journal of Business Ethics, 152*, 1–14.

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review, 48*, 147–160.

Dunne, T., Helliar, C. V., Lymer, A., & Mousa, R. (2013). Stakeholder engagement in internet financial reporting: The diffusion of XBRL in the UK. *The British Accounting Review, 45*, 167–182.

Dwivedi, Y. K., Kapoor, K. K., Williams, M. D., & Williams, J. (2013). RFID systems in Libraries: An empirical examination of factors affecting system use and user satisfaction. *International Journal of Information Management, 33*, 367–377.

Fosso Wamba, S., Kala Kamdjoug, J. R., Epie Bawack, R., & Keogh, J. G. (2020). Bitcoin, Blockchain, and FinTech: A systematic review and case studies in the supply chain. *Production Planning and Control, 31* 2-3, 115-142.

Frizzo-Barker, J., Chow-White, P. A., Adams, P. R., Mentanko, J., & Ha, D. (2020). Blockchain as a disruptive technology for business: A systematic review. *International Journal of Information Management, 51*, 102029.

Gartner (2019). https://www.gartner.com/en/newsroom/press-releases/2019-04-30-gartner-predicts-20-percent-of-top-global-grocers-wil, accessed May 2019.

Girasa, R. (2018). *International regulation. Regulation of cryptocurrencies and blockchain technologies. Palgrave studies in financial services technology. Palgrave macmillan*.

Grover, P., Kar, A. K., & Janssen, M. (2019). Diffusion of blockchain technology. *Journal of Enterprise Information Management, 32*(5), 735–757.

Hanson, R. T., Reeson, A., & Staples, M. (2017). *Distributed ledgers, scenarios for the Australian economy over the coming decades, Data 61, CSIRO, Canberra*.

Huang, W., Meoli, M., & Vismara, S. (2019). The geography of initial coin offerings. *Small Business Economics*, 1–26.

Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V., & Akella, V. (2019). Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *International Journal of Information Management, 49*, 114–129.

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. *Harvard Business Review, 95*(1), 118–127.

ICAEW (2016). *Chain reaction, economia.* Accessed July 2017 http://economia.icaew.com/features/july-2016/how-blockchain-will-impact-accountants-and-auditors/.

Independent (2020). https://www.independent.co.uk/life-style/gadgets-and-tech/features/bitcoin-2020-cryptocurrency-prediction-decade-blockchain-revolution-a9225581.html. Accessed January 20, 2020.

ITIF, I. I. F. (2019). *A policymaker's guide to blockchain.* https://itif.org/publications/2019/04/30/policymakers-guide-blockchain.

Janssen, M., Weerakkody, V., Ismagilova, E., Sivarajah, U., & Irani, U. (2020). A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors. *International Journal of Information Management, 50*, 302–309.

Kaal, W. A., & Dell'Erba, M. (2018). Initial coin offerings: Emerging practices, risk factors, and Red flags. In F. Möslein, & S. Omlor (Eds.). *Fintech handbook*. Verlag C.H. Beck, University of St. Thomas (Minnesota) Legal Studies Research Paper No. 17-18.

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modelling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management, 52*, 101967.

Kapoor, K. K., Dwivedi, Y. K., & Williams, M. D. (2014). Innovation adoption attributes: A review and synthesis of research findings. *European Journal of Innovation Management, 17*(3), 327–348.

Kemp, L. (2015). *London Blockchain conference. Blockchain for the diamond industry.* Accessed June 2017 www.youtube.com/watch?v=8tc8m1LMWTg/.

Kewell, B., Adams, R., & Parry, G. (2017). Blockchain for good? *Strategic Change, 26*(5), 429–437.

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management, 39*, 80–89.

Lanzanis, R. (2015). *Technology behind Bitcoin could transform accounting as we know it. Tech Vibes.* Accessed October 2016 https://techvibes.com/2015/01/22/how-technology-behind-bitcoin-could-transform-accounting-as-we-know-it-2015-01-22/.

Linn, L. A., & Koo, M. B. (2017). *Blockchain for health data and its potential use in health IT and health care related research.* www.Healthit.gov.

Manski, S. (2017). Building the blockchain world: Technological commonwealth or just more of the same? *Strategic Change, 26*(5), 511–522.

Maslova, N. (2018). *Blockchain: Disruption and opportunity, Strategic Finance magazine.* July 2018, https://sfmagazine.com/post-entry/july-2018-blockchain-disruption-and-opportunity/.

Maume, P., & Fromberger, M. (2019). Regulations of initial coin offerings: Reconciling U.S. And E.U. Securities laws. *Chicago Journal of International Law, 19*, 548–585.

McConahgy, M., McMullen, G., Parry, G., McConaghy, T., & Holtzman, D. (2017). Visibility and Digital Art: Blockchain as an ownership layer on the internet. *Strategic Change, 26*(5), 461–470.

Monetary Authority of Singapore, M. A. S. (2019). *Central Banks of Canada and Singapore conduct successful experiment for cross-border payments using distributed Ledger Technology.* Accessed June 2019 http://www.mas.gov.sg/News-and-Publications/Media-Releases/2019/Central-Banks-of-Canada-and-Singapore-conduct-successful-experiment-for-cross-borderpayments.aspx.

Mori, T. (2016). Financial Technology: Blockchain and securities settlement. *Journal of Securities Operations & Custody, 8*(3), 208–217.

Mustonen-Ollila, E., & Lyytinen, K. (2003). Wy organizations adopt information system process innovations: A longitudinal case study using diffusion of innovation theory. *Information Systems Journal, 13*, 275–297.

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system.* available at: https://bitcoin.org/bitcoin.pdf.

Nam, D., Leeb, J., & Leea, H. (2019). Business analytics adoption process: An innovation diffusion perspective. *International Journal of Information Management, 49*, 411–423.

Naumoff, A. (2017). *Why blockchain needs 'Proof of authority' instead of 'Proof of stake' cointelegraph.* https://cointelegraph.com/news/why-blockchain-needs-proof-of-authority-instead-of-proof-of-stake accessed Feb 2019.

Orr, G. (2003). *A review of Diffusion of Innovations by Everett Rogers (1995).* Retrieved from Stanford University https://web.stanford.edu/class/symbsys205/Diffusion%20of%20Innovations. Accessed June 2017.

Piscini, E., Guastella, J., Rozman, A., & Nassim, T. (2016). *Blockchain: Democratized trust, Tech Trends 2016, innovating in the digital era, Deloitte.* https://www2.deloitte.com/content/dam/Deloitte/de/Documents/technology/ER_3039_TT6_Blockchain_DE.pdf/ Accessed July 2017..

Powers, B. (2019). https://breakermag.com/new-report-says-renewable-energy-will-not-solve-bitcoins-sustainability-problem/; accessed 4/10/19.

Queiroz, M. M., & Wamba, S. F. (2019). Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *International Journal of Information Management, 46*, 70–82.

R3 (2020a). Available at: https://www.corda.net/ Accessed January 2020.

R3 (2020b). https://www.corda.net/blog/a-timeline-of-corda-adoption-ongoing/ accessed January 2020.

Ram, A., Maroun, W., & Garnett, R. (2016). Accounting for the Bitcoin: Accountability, neoliberalism and a correspondence analysis. *Meditari Accountancy Research, 24*(2), -35.

Rogers, E. M. (2003). *Diffusion of innovations* (fifth edition)). New York: The Free Press.

Ryan, C. (2018). Assessing the evolution of cryptocurrency: Demand factors, latent value, and regulatory developments. *Michigan Business & Entrepreneurial Law Review, 1*, 73.

Sahlin, K., & Wedlin, L. (2008). Circulating ideas: Imitation, translation and editing. In R. Greenwood, C. Oliver, K. Sahlin, & R. Suddaby (Eds.). *The sage handbook of organizational institutionalism*. London: Sage.

Savelyev, A. (2016). *Contract law 2.0: 'Smart' contracts as the beginning of the end of classic contract law. Working paper series, National Research University Higher School of Economics, Russia*.

Scott, B., Loonam, J., & Kumar, V. (2017). Exploring the rise of blockchain technology: Towards distributed collaborative organizations. *Strategic Change, 26*(5), 423–428.

Shermin, V. (2017). Disrupting governance with blockchains and smart contracts. *Strategic Change, 26*(5), 499–509.

Smith, E. (2017). *Who should be smart about smart contracts? Financial director* March 2017.

Staples, M., Chen, S., Falamaki, S., Ponomarev, A., Rimba, P., Tran, A. B., et al. (2017). *Risk and Opportunities for systems using blockchain and smart contracts.* Sydney: Data 61, CSIRO.

Statis Group (2018). *Cryptoasset market coverage initiation: Network creation*Report available at: https://research.bloomberg.com/pub/res/d28giW28tf6G7T_Wr77aU0gDgFQ. Accessed February 2019..

Swan, M. (2015). *Blockchain: Blueprint for a new economy.* Sebastopol, CA.

Tan, B. S., & Low, K. Y. (2017). Bitcoin_its economics for financial reporting. *Australian Accounting Review, 27*, 220–226.

Techcrunch (2018). *Thousands of cryptocurrency projects are already dead.* available at : https://techcrunch.com/2018/06/29/thousands-of-cryptocurrency-projects-are-already-dead/. Accessed: February 2019.

Thakur, V., Doja, M. N., Dwivedi, Y. K., Ahmad, T., & Khadanga, G. (2020). Land records on blockchain for implementation of Land Titling in India. *International Journal of Information Management, 52*, 101940.

Tönnissen, S., & Teuteberg, F. (2020). Analysing the impact of blockchain-technology for operations and supply chain management: An explanatory model drawn from multiple case studies. *International Journal of Information Management, 52*, 101953.

Tuwiner, J. (2017). *Bitcoin mining pools, BuyBitcoinWorldwide.* https://www.buybitcoinworldwide.com/mining/pools/ 13/07/2017/ Accessed 25/10/17.

VEchain https://cdn.vechain.com/vechainthor_development_plan_and_whitepaper_en_v1.0.pdf, accessed February 2019.

Weerakkody, V., El-Haddadeh, R., Al-Sobhi, F., Shareef, M. A., & Dwivedi, Y. K. (2013). Examining the influence of intermediaries in facilitating e-government adoption: An empirical investigation. *International Journal of Information Management, 33*, 716–725.

Wong, J. (2017). *China's Bitmain dominates bitcoin mining. Now it wants to cash in on artificial intelligence.* https://qz.com/1053799/chinas-bitmain-dominates-bitcoin-mining-now-it-wants-to-cash-in-on-artificial-intelligence/ 20/08/2017/ Accessed 25/10/17.

Woodside, J. M., Augustine Jnr, F. K., & Giberson, W. (2017). Blockchain technology adoption status and strategies. *Journal of International Technology and Information Management, 26*(2), 65–93.

World Economic Forum (2016). *The future of financial infrastructure: An ambitious look at how blockchain can reshape financial services, World Economic Forum, August, p.130.* http://www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf/ Accessed September 2017.

Yin, R. K. (2009). *Cases study research: Design and methods* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Ying, W., Jia, S., & Du, W. (2018). Digital enablement of blockchain: Evidence from HNA group. *International Journal of Information Management, 39*, 1–4.