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RESEARCH ARTICLE

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Distributed ledger technology: Applications and implications*

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Abstract

Distributed ledger technologies (DLTs) are rewriting conventional notions of business transacting, creating fresh opportunities for value creation and capture. Using qualitative interview data as a primary resource, the proposed five-point model synthesizes these possibilities, demonstrating how they may lead to "disruptive innovation." A further conceptual model is subsequently provided with a view to assisting future problem solving in the area.

1 | INTRODUCTION

The relationship between technological development and business model innovation has been a matter of academic debate for many years (Schumpeter, 1939). Distributed ledger technology (DLT) is one of the latest in a long list of digital technologies that appear to be heralding a new industrial revolution (Perez, 2009). This was emphasized in a recent report by the UK government's Chief Scientific Officer (Walport, 2016), in which it is stated that "in distributed ledger technology we may be witnessing one of those explosions of creative potential that catalyse exceptional levels of innovation" that could have "the capacity to deliver a new kind of trust to a wide range of services" (p. 4). This article presents empirical evidence of how these developments might occur and their implications for business model innovation. We conducted a workshop of senior industrialists, taped and transcribed their comments, and identified a conceptual model that has five elements: DLTs as a new and unique technology; leading to transparency and trust; leading to new ways of thinking, which combine with different solutions to produce a disrupted future (business and economic models). Our second contribution arises from an extensive series of interviews over a 6-month period which has produced a conceptual model of the limitations of DLTs, that is to say, where they cannot be used and what types are appropriate for what conditions. In combination, they provide a link between the technology of distributed ledgers and the business and economic models that are developing alongside the technology.

* JEL classification codes: D20, O38, O39.

2 | TECHNOLOGICAL REVOLUTIONS

Perez (2009) argues that technological revolutions can be seen stretching back to the original Industrial Revolution, followed by the railway revolution, the oil revolution, and now the information and telecommunications revolution. She identifies three drivers common to all the revolutions: a significantly lower cost input, a new method of communication, and altered logistics and infrastructures. These lower costs of inputs create tensions in existing markets, leading to financial bubbles and crashes, and ultimately changed institutions. In short, as Jacobides, Knudsen, and Augier (2006a) observe, technological revolutions lead to changes in the economic model of who does what, who gets what.

Two major enablers of the digital revolution are the blurring of boundaries between physical and digital worlds and the development of open standards. The blurring of physical and digital is occurring across many industries. For example, Yoo, Boland, Lyytinen, and Majchrzak (2012) describe how the convergence of GPS, mobile digital technology, in-car navigation and entertainment systems, and onboard microprocessors not only enables novel features for the car but also has had an impact on related industries such as insurance, safety, and car maintenance. This ability to separate the information from the physical world requires a special infrastructure, often based on sensors or devices collecting data on individuals. Once this infrastructure is in place, then information is free to flow, after being dematerialized. An immediate effect of dematerialization is *liquefication* (Normann, 2001), or the movement of information across the digital infrastructure and its combination with other liquified assets to create potential new insights. Digital technology makes it possible for almost any asset

to be dematerialized and, since this information is quickly liquified, this produces new markets for the information.

The second enabler is the development of open standards, which are "a set of specifications to which all elements of products, processes, formats, or procedures under its jurisdiction must conform" (Tassey, 2000, p. 588) or, more broadly, a technology that "is accepted for current use through authority, custom or general consent" (Hemenway, 1975; Tassey, 2000, p. 417). Standards encourage interoperability, which can lead to disruptive effects in proprietorial systems and associated rent, but can equally be used to enable trade restrictions, for example, in relation to accounting standards and qualified auditors. They also frequently incur development and compliance costs, and can prevent activity ranging from discriminatory pricing through to illegality. One important aspect of standards development is their position on a spectrum of openness—from closed and proprietary through competing ecosystems to full open standards. Open standards are characterized by being generally available, without restrictions on use or change, and developed by a mutual community consensual process. In the digital economy, open standards can be seen as being accompanied by open formats and open-source software.

3 | BUSINESS MODELS

For many public and private organizations, this digital revolution is leading to a comprehensive reassessment of their business practices, as innovation in technology frequently requires innovation in an organization's business model to reconsider its value and guide its ongoing operation (Baden-Fuller & Haefliger, 2013).

There has been considerable debate about the precise nature of the relationship between technology innovation and business model innovation. Academics, commentators, and practitioners have considered whether business model innovation can be separated from technology innovation, based on the degree of influence each has on the other, where and how innovation in either of these elements impacts a firm's success, and how contextual aspects such as size and maturity of both the firm and its market domain influence the rate of innovation (Al-Debei & Avison, 2010; Baden-Fuller & Haefliger, 2013; Doganova & Eyquem-Renault, 2009; Markides et al., 2013). However, fundamentally, commentators agree that technological change requires a simultaneous adjustment of the business model to be effective.

Many authors (Ali, Barrdear, Clews, & Southgate, 2014; Amit & Zott, 2001; European Central Bank, 2012; Walport, 2016) agree broadly that a business model describes the way in which a firm or organization creates value, based on a tripartite framework describing the ways in which value is proposed to the customer, and to which markets products and services are going to be offered (Baden-Fuller & Haefliger, 2013); the way in which the organization is configured around a management structure and operating systems to deliver value; and the way in which pricing and revenue streams are managed to capture value (Markides, 2015).

Recent syntheses of the business model literature demonstrate that the field is moving toward a shared understanding of what a business model describes, following a period of exploratory research in the area (Chesbrough, 2010; Zott, Amit, & Massa, 2011). This assessment began by identifying where the notion of a business model is positioned within the strategic terrain, as a construct that is said to co-align or "bridge" the domains of activity and decision-making, leading to debate over the kinds of primary coordination tasks around which business models are expected to cohere (Casadesus-Masanell & Heilbron, 2015; Casadesus-Masanell & Ricart, 2010; Chesbrough, 2010; Markides, 2015; Teece, 2010; Zott & Amit, 2010; Zott et al., 2011). Elucidation of the concept suggests that the role of the business model is part operational and part representational, serving a similar function to the "working architectural blueprint" or engineer's drawings (Casadesus-Masanell & Heilbron, 2015; Chesbrough, 2010; Markides, 2015; Teece, 2010; Zott et al., 2011, p. 1022).

Consideration is also being given to the effects and implications of business model constructs, as devices that are mostly employed to bring about organizational change and introduce novel forms of value creation (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Morgan, 2010; Chesbrough, 2010; Teece, 2010; Zott et al., 2011). Business models are viewed as the primary catalyst through which the "logic" of established firms (Casadesus-Masanell & Ricart, 2010, p. 43), markets, and institutions can be deliberately interrupted, to make way for the introduction of a new technology, value creation method, or financial instrument (Chesbrough, 2010; Jacobides et al. 2006a,b; Teece, 2010; Zott et al., 2011, p. 1024). In the main, subsequent discussion has sought to capture empirical data on this "disruptive effect," as exemplified by Zott and Amit (2007) and Rumble and Mangematin (2015)'s recent study of 77 firms operating multi-dimensional business models.

This has necessitated consideration of the assertion that de novo enterprises possess an aptitude and agility for business model innovation that is unrivalled in established firms, creating the potential for competing prototype business models to emerge within the same space (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Morgan, 2010; Casadesus-Masanell & Heilbron, 2015; Casadesus-Masanell & Ricart, 2010; Chesbrough, 2010; Markides, 2015; Markides & Oyon (2010); Teece, 2010; Zott et al., 2011). There is less agreement on the application of the business model construct, particularly with respect to the advantages it provides compared with normative theories of the firm, strategy, and supply chain (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Morgan, 2010; Casadesus-Masanell & Heilbron, 2015; Casadesus-Masanell & Ricart, 2010; Chesbrough, 2010; Markides, 2015; Teece, 2010; Zott et al., 2011) and whether, inter alia, the unit of analysis should be single firms representing autonomous (self-contained) business models or if, as is frequently suggested, the locus of value creation is in fact distributed among collaborating partners in the supply network and the embedded economic niche (Markides, 2015).

Doubts remain as to the use of the business model as an analytical tool, and their use may be strongly contextual (Baden-Fuller & Haefliger, 2013; Baden-Fuller & Morgan, 2010; Teece, 2010), leading some commentators to argue in favor of using cognitive approaches to explain variations in the depiction and interpretation of business models amongst firms, managers, and stakeholders (Mikhalkina & Cabantous, 2015, p. 4). Complementary topics include business models as

authority structures—in which they are foremostly considered to be ascriptions of power, and a means of controlling the firm using cognitive models, analogical thinking, rules, heuristic levers, and practical constructs (Casadesus-Masanell & Heilbron, 2015; Demil & Lecocq, 2015; Mikhalkina & Cabantous, 2015).

Expressions of concern regarding the efficacy, applicability, and contextual significance of business models are echoed in and by a related discussion within the literature about authorship, that is to say, who designed and/or has acquired proprietary rights to a value creation concept; whether a model genuinely delivers value-added; whether these gains can be replicated; whether the model has impact; how this impact and diffusion can be measured; and whether this should include measures other than the bottom line (Baden-Fuller & Haefliger, 2013; Casadesus-Masanell & Heilbron, 2015; Demil & Lecocq, 2015; Mikhalkina & Cabantous, 2015).

Baden-Fuller's work offers perhaps the most succinct summary of the current situation with regard to business model alignment, evolution in the context of digital transformation. Baden-Fuller and Haefliger (2013) emphasize that the choice of business model influences how technology is monetized and the profitability of a firm using that technology. The business model thinking of managers, entrepreneurs, and developers strongly influences the technology choices they make. There is a two-way, complex relationship between business model development and technology innovation that is still widely misunderstood, and under-researched.

The objective of this research is to explore the relationship between technology and business model alignment by, considering the *potential* applications of DLTs. We do this in two ways: firstly by empirically exploring the wider themes of DLTs and the business and economic model issues arising from their application; secondly, through a consideration of the fundamental features of DLTs, we will develop a conceptual model that identifies the limitation of the technology.

4 | RESEARCH APPROACH

In order to investigate the claims surrounding the impact of DLT, we convened a workshop for 19 delegates from a wide range of industry partners including Merrill Lynch, Accenture, British Standards Institute, EY, Tata Consulting, and a range of small companies developing blockchain solutions. The workshop lasted for two hours and was facilitated by the authors with a short set of research questions, including: What are the dimensions of this new landscape? What and where are the boundaries? Who are the main players? Are people trying to make money or a new society? What sort of governance is emerging/will emerge? What are the key parts in this system? What are the likely relationships? What could be the emergent outcomes? What are the potential systemic effects? The discussion was taped, transcribed, coded, and analyzed. The results are reported below.

A key fundamental issue was a definition of terms. For example, when talking about cryptocurrencies, there is a need to distinguish between these as currencies or investment vehicles (assets). At the platform level, there are multiple ways of thinking about the blockchain: as an ecosystem of algorithmic trust not mediated by centralized third parties, as a community-maintained infrastructure, as a register of assets, as a facilitator of the collaborative commons, as a disruptive innovation (Zuberi & Levin, 2016) by, for example, linking smart contracts and the Internet of Things (Zhang & Wen, 2016), as an ecosystem of players in a DLT relationship with different roles and value expectations, as a technological upgrade with social and organizational implications, and as a class of objects of which there are many different types with different purposes and implications:

> *I don't think it's blockchain. I think it's distributed ledgers, of which blockchain[s] are one particular form. Bitcoin, cryptocurrency, blockchain and distributed ledger are used by most people to mean the same thing, and actually they're very discrete different things.*
>
> *… a permissioned shared ledger that's only available to a group of private actors is a database. So let's just take that out of the discussion and focus on use-cases where anyone can have access. It's not a shared ledger unless anyone can have access to it.*

The definition used in this research is that:

> Distributed ledgers are a type of database that is spread across multiple sites, countries or institutions, and is typically public. Records are stored one after the other in a continuous ledger, rather than sorted into blocks, but they can only be added when the participants reach a quorum. (Walport, 2016, pp. 17–18)

In addition to the considerable challenges around definitional issues and the further work required, we identified five main theses. These are discussed below and summarized in Figure 1 at the end of this section.

4.1 | A new unique technology

The first application of DLT, and one with which the technology has misleadingly become synonymous, was the cryptocurrency *Bitcoin*. However, it is the specific characteristics of the underpinning DLT where uniqueness and disruptive potential lie. This renders the distributed ledger the important unit of analysis:

> *The reason that this is getting a lot of industry focus right now is because what they currently have is not good enough. So we're coming from on the one hand it's very much cryptocurrency driven, it's very much an interesting technology, and we're saying forget Bitcoin, [think] distributed ledger. If you read what the securities services industry are starting to look at, it's because they can't cope with what they have today in the way that new technology is changing the game. So that's a really old-fashioned way of looking at this new technology.*

In its purest form DLT (such as the Bitcoin blockchain) represents a unique technology in two ways. Firstly, it is distributed in nature: agreement about the state of the ledger is achieved by (remunerated) consensus by the network of users rather than having to rely on trust in a third-party intermediary. Secondly, users can "deposit" on the

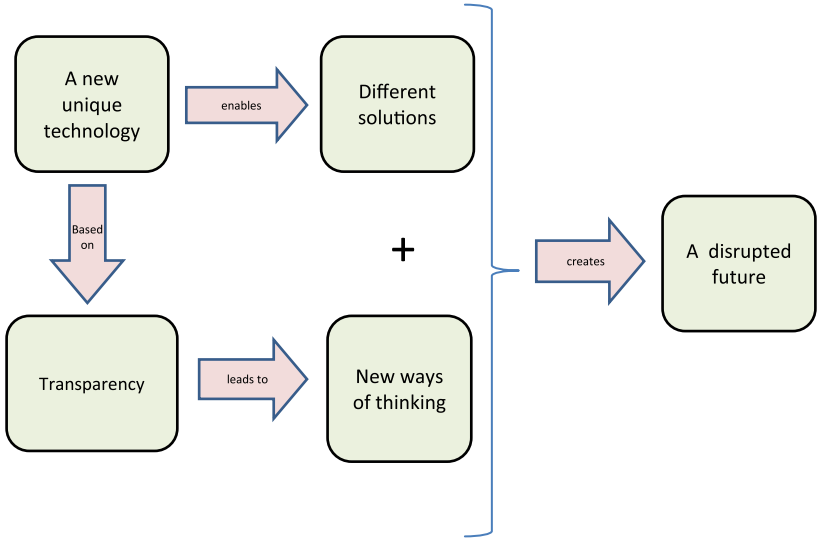

FIGURE 1 The combination of distributed ledger themes [Color figure can be viewed at wileyonlinelibrary.com]

ledger (blockchain) digital assets (e.g. records, acts, and states), the record of which is rendered immutable, transparent, and auditable yet resistant to censorship and manipulation due to the technology's cryptographic and distributed foundations. Further, whilst all transactions are immutably recorded, the system can enable high levels of anonymity or pseudonymity for transacting parties: that is, transactional activity records are visible at a meta-level and remain tamper-resistant but identifying individual parties may be rendered difficult or impossible. These qualities, assuming sufficient and maintained encryption and technical architecture, render the blockchain highly resilient:

> *The systemic contagion is cropping up time and time again in financial services, in industry, in the National Grid, and block chain distributed ledgers provide a level of national security, of security of supply*.

It is clear from the configurational possibilities of these characteristics that different streams of use-case types may emerge. In terms of cryptocurrencies, for example, Bitcoin is concurrently "anonymous" untraceable digital cash and a means of instant transaction and settlement. In terms of DLT more widely, ledgers may be closed, accessible to a defined category of user (permissioned ledger), or open, accessible by everyone (unpermissioned ledger), which implies different ledger architectures for different purposes and classes of digital asset. If all of society is able to utilize valuable data on an unpermissioned ledger, this becomes a "non-trivial" matter, taking "information asymmetries out of the market," allowing for "disintermediation to occur" and "transformations across industry sectors."

4.2 | Trust and transparency

A key issue that arose was the topic of trust, especially in regard to comparing and contrasting the role, meaning, acquisition, and maintenance of today's system and a more DLT-oriented world. As individuals become more aware of the inherent value of personal data, of its exploitation and occasional mismanagement by organizations, and consequent intrusions into privacy, the notion of trusted third parties intermediating personal data is under threat:

> *We're talking about trust between two parties and knowledge that one party holds and another doesn't hold, and makes a return on that knowledge in that relationship, and whether or not that becomes public, and what that means when it becomes public.*
>
> *The reason why we all have shared copies of the ledger is because there are members of the network who are disreputable, untrustworthy…*

DTLs provide an antidote to this by removing asymmetries, and may force some organizations fundamentally to rethink their relations with users and approaches to privacy. For example, to what unit of analysis is the notion of trust a critical consideration, to the individual, to a record, to something else? And to whom is it a critical consideration as the needs and desires of individuals, corporates, and governments may not always coincide?

This concern is also relevant to public services, as evidenced by this common access example of books in a public library:

> *There's a bunch of feral people who come and take public assets, and I want them to return them at a particular date in the future. And so you've got to have a lack of trust, and they need to keep records. So it could be between government and business about accountancy tax or it could be any form where an asset or a liability is created and transferred and needs to be reconciled or you wish to make a declaration that you may wish to rely upon in the future, and you want that to be a matter of public record.*

On a more general issue, a shared consensual ledger replaces the need for trusted third-party intermediaries with a consensus of rightness, to use in place of processes where there is no need for trust, which is a new model of thinking:

> *If it's a trusted network where everybody is secure and trusted, you wouldn't bother doing this. Shared ledger is where some members of the network are potentially untrustworthy, and that's why we need a consensus protocol or block chain, in order to manage it*.

And privacy issues extend to corporate and organizational concerns:

> *So if you're thinking of financial services, transactions between trusted parties, you don't really want people knowing that you're acquiring a company or you're investing huge amount of money in not a great asset, let's say. But you know it's good and you want to do it. You're going to go ahead but your shareholders wouldn't approve. You don't want that in the public domain. So that's a great application for the private networks. But then the information you need to share with the regulator, so you put in your annual report. All of that sort of stuff can go in the public domain. So to a certain extent it's going to come down to businesses choosing what they want in, what they want out*.

In effect, DLTs remove the need for trusted third-party (socially constructed and sometimes flawed) intermediaries and replace it with "trust in the algorithm," sometimes inappropriately referred to as a "trustless system." But what is the impact of this alternative trust mechanism, one in which truth is agreed and maintained by consensus rather than by an authority or a trusted intermediary? This could lead to a change in the way that monetary-based relationships are thought of and considered:

> *Asymmetry … is pretty much the basis of most economics. So we're fundamentally talking about a fundamental restructuring of economic relationships*.

4.3 | Different solutions

As has already been noted, there was a general consensus that the DLT is the important phenomenon, but questions remain about its impact: what will it change and by how much? In other words, what are the characteristics of problems that lend themselves to a DLT-type solution? It was suggested that its greatest impact may be felt in industries where having an audit trail/immutable log is crucial (e.g. aerospace) or where there are many (paper) layers or multiple players between buyers and sellers (e.g. securities trading).

As a new technology, DLT disrupts the hub-and-spoke model of databases and promises a reframing of, or alternative solution to, existing problems, practices, and processes, with potentially wide-ranging impacts:

> *It's that the whole architecture, the flexibility, the fluidity, the ability to – the pain barrier has just dropped across multiple domains*.

For example, DLT, potentially, fundamentally changes the nature of record keeping in two ways. First, as a consequence of its distributed nature (a single ledger exists as a true record but is held in multiple synchronous copies by users), records are transparent and accessible by all. Second, again because it is distributed, there is no proprietary ownership of the ledger, which means that business models previously based on information asymmetries may be undermined. A further consequence of this is that DLT could impact and remove technological and mental silos within and across organizations, both commercial and public:

> *… it brings together database, network, access, workflow, you're seeing discrete silos of technology which can be addressed in an integrated way for the first time… So where the intranet opened up innovation within an organization this is going to do the same for business process*.

Which would enable more value to be extracted from the data and potentially lead to cost reductions:

> *When you are able to get the meta-information about a transaction, you can start to then price it and use it… that's huge*.

4.4 | New ways of thinking

DLT has the potential not only to disrupt business, but also to challenge accepted practices and in effect our mental models of how the world works. Three major sub-themes were identified:

Shared data. In the current "centralized" paradigm, personal bank account balances are housed across multiple repositories in which data are duplicated and necessarily continuously updated and reconciled. This results in extra frictional costs in reconciling balances and transferring information between institutions. A shared, distributed ledger would render this system redundant.

New economic models. For example, digital supply chains are fundamentally different from manufacturing supply chains. Any supply chain based on DLT and smart contracts, in which payments or value transfers are made with the transaction, could significantly affect the need to carry working capital. Already, the music industry is experimenting with such a system to manage the distribution of royalty payments, so that when a piece of music is bought online its associated smart contract could take the money from your bank account and instantly pay the artist:

> *I think there is one new economic model… where we don't need working capital any more. I can have some grass, I can lend that to the cow, the cow can eat the grass, I keep a record of the grass, it produces milk, I keep a record of the milk, eventually it gets to the supermarket, the supermarket sells it to the consumer. And everyone who has contributed to that pint of milk get their money at that point of sale. And so the promise, the obligation, is wrapped up on the block chain, and it is resolved at the point of sale, and all the parties have their obligation fulfilled. And that transforms supply chain enormously*.

Identity management. In a world of identity theft and online fraud, there is a huge need for more secure ways for individuals to manage their identity. At the moment, identity is expensive or

ecosystem-specific, frequently requiring individuals to prove who they are (often according to different criteria of proof)—from applying for passports to buying a ticket for a football match. The process is time-consuming and vulnerable to fraud. Identity management, in which identity is secure and portable, is emerging as a significant technical possibility through DLT. For example, a diverse range of agencies, including governments, banks, NGOs, supermarkets, and sports clubs, hold identity records of varying currency, content, and completeness, with different rules for maintenance and access. Putting everything into one ledger would remove many of these inefficiencies:

> *I have a private key and I enable people to access my information on a permission basis but it is stored in the shared ledger in the cloud, so I want to apply for a new bank account. My identity is stored in the shared ledger. I give my private key to the institution who wants to open my bank account and if there is a central entity and it's done a KYC profile for me that is an industry standard, I can have a bank account same day.*

4.5 | Disrupted future

The openness of DLT unlocks the potential for new economic models based on more complete information and the potential for aggregating an individual's life and disaggregating markets. Specifically, it has the potential to contribute to the idea of a "sharing economy" as an alternative to the "exchange economy." These sort of collaborative commons have been enabled at a local level by Internet technology, but DLT offers the opportunity for global scale.

Because DLTs have the potential to embed "smart contracts" and algorithms within the mechanism, activity and payment can be synchronized. This releases the potential for "open innovation," where alternative algorithms may be applied—for example to analyze power consumption and cost management on a real-time basis.

A social benefit may arise from a different understanding of trust. Duplication exists in part because each party cannot trust the other to always accurately record and report events. It changes the dynamics of information asymmetry, which challenges the current economic paradigm.

The simple sharing of information could be of significant social benefit. DLT protocols remove the need to maintain duplicated separated records, and associated expense, by having multiple copies of a trustless system always in agreement. Uber might provide an example of this and a potential jumping off point as well. If all vehicles were "hashed" so their locations were continuously visible, other services could be built on that location and availability information, as evidenced by apps leveraging existing new information flows, such as bus tracker apps.

Whilst such use-cases provide an interesting and alternative context to financial services in which the wider applications of DLTs can be explored, the challenge for social use applications is their dependence on cryptocurrencies and, more specifically, mining operations to maintain the blockchain on which they free-ride (Ali et al., 2014; Baek & Elbeck, 2015; Brennan & Lunn 2016; McWaters et al., 2016; Walport, 2016; Welch, 2015). Blockchains exist because "miners" invest effort in return for reward in order to validate digital currency transactions (Ali et al., 2014; Back & Elbeck, 2015; Welch, 2015). Without the currency, the blockchain would not exist.

The four earlier themes combine to form a path in which a disrupted future can be created. This is set out in **Figure 1**.

4.6 | Limitations of DLT

To address our second objective, we identified a number of implementation challenges emerging from the start-up community and linked that to four outcomes: DLTs are currently not an appropriate solution, permissionless/public DLTs as in the Nakomoto blockchain (Lemieux, 2013), permissioned public (e.g. Ripple), and permissionless private (e.g. R3CEV). These key challenges were synthesized from the team's research visits over a 6-month period and then distributed to a panel of experts for comments and refinement. This expert group included blockchain developers, users from across industries, and entrepreneurs developing blockchain solutions. We have devised the flowchart shown in **Figure 2** to identify when and which type of DLT will be useful in different scenarios. It has been developed from interviews with members of the core developer teams of Bitcoin and Ethereum, supplemented by a review of the existing technical literature and a comprehensive review of 20 proof-of-concept (PoC) projects conducted over a period of 3 years.

Figure 2 proposes a series of steps to be considered as part of the DLT acquisition process. The first of these steps is assessment-focused, requiring potential adopters to consider whether the solution necessitates transactions processed on a millisecond basis.[†] A "yes" answer, which is indicative of high-performance requirements of this kind, would mitigate toward a non-DLT solution.

If this is not a requirement ("no"), then: Does the solution require the management of contractual relationships or value exchange? This is a key aspect of DLT—the exchange of value (transaction) rather than merely the exchange of information (transmission). No: do not use DLT; yes: use DLT. Do you want/need to use a trusted third party? The role of third parties within a DLT solution is an important aspect to assess. If the solution requires a third party to act as a point of trust, then a DLT will only be of use in a certain small subset of cases.

The next issue is whether shared write access is required. This means whether multiple partners need to be able to write to the same ledger for the solution in question and be able to read them.

If the writers are known and trusted and they have unified interests, then the role of a DLT is questionable. With unified interests between known and trusted parties, it is possible to use a relatively simple database. If the writer's interests are not unified, a DLT can help manage these differences.

The next stage relates to the control of functionality. If solution owners do NOT need to be able to control functionality (e.g. be able to

[†] A preliminary field guide for Bitcoin transaction patterns.

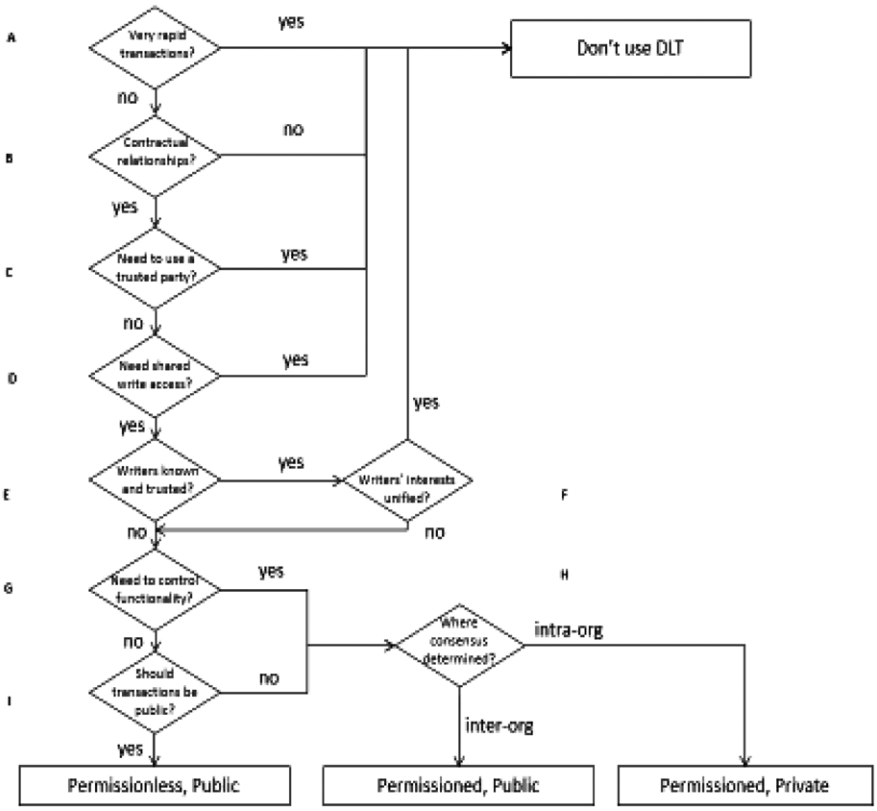

FIGURE 2 Flowchart of application of DLTs

add extra applications on top of the DLT solution), then the next step is G. If control over functionality is required, then a decision about the locus of consensus needs to be determined (H).

If the transactions are able to be stored publicly, then a permissionless public DLT can be used; if private transactions are required, then a decision about the locus of consensus needs to be determined (H).

Consensus can be determined in two ways—internal to a company's boundaries (inter-organizational) or across company boundaries (intra-organizational). For those that are inter-organizational, a permissioned, public ledger DLT can be used. For intra-organizational, a permissioned, private DLT can be used.

5 | CONCLUSION

This article has provided an overview of the fundamental features of DLTs, identifying the main challenge as to the interaction between blockchain technological developments and business model. The objective of the research was, therefore, to explore the relationship between technology and business model by considering the *potential* applications of DLTs. We achieved this in two ways. Firstly, we ran a workshop with industry groups to identify the main themes. A model (Figure 1) was presented, which summarizes the findings. Secondly, we interviewed members of the core developer teams of Bitcoin and Ethereum, reviewed the existing technical literature, and were involved in the review of 20 PoC projects developed. This resulted in a flowchart (Figure 2) of the limitations and types of DLTs.

There are a number of major questions left for research in DLTs, some of which have implications across the developing digital technologies. These include such fundamentals as: How many DLTs will there be? What will be the number of permissioned and unpermissioned ledgers? How will the miners be remunerated and what are the emerging governance structures? How will DLT influence transparency supply-chain development? How does "who does what, who gets what" change and how will existing economic structures be affected? For cryptocurrencies there are specific issues such as the impact of a diminution in governmental control over the money supply; the relevance of a created value which is non-monetary in nature (e.g. energy coin; Wörner & Von Bomhard, 2014). Finally, looking ahead, what are the early indicators of a disrupted future and when will the tipping point be reached on a platform?

DLTs offer the potential for the first truly dual *digital economy* technology; that is, through such features as smart contracts, a digital technology that can enable the economy to work in totally new ways. It has the potential to redefine how we organize our economic system, which may even redefine the notion of a firm itself. These research questions are fundamental not just to the development of DLTs, but to the future of the whole economic system.

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