Jose Gustavo Prieto Munoz*

'Crypto-investment' in International Economic Law: A First Sketch

https://doi.org/10.1515/gj-2020-0031
Published online July 14, 2020

Abstract: In January 2009, Bitcoin was launched as the first 'cryptocurrency', a term used to refer to a 'digital representation of value' operating with Distributed Ledger Technology (DLT). Commonly known as 'Blockchain', DLT has been an object of study in different legal disciplines, which seek to understand its financial and legal impacts. However, international law literature is still silent regarding the impacts that DLT technology could have on the different legal regimes. This article contextualizes DLT as digital governance 'infrastructure' that could affect the way that public authority is exercised; in this sense, cryptocurrencies are the product of such infrastructure. Taking this notion into account, it is further argued here that the concept of 'crypto-investment' could be useful in international investment law when certain conditions come into play.

Keywords: legitimacy, infrastructure, global governance, blockchain, crypto assets, international law

1 Introduction

In January 2009, Bitcoin was launched as the first Virtual Currency (VC) or 'cryptocurrency'. I use the term here to refer to a 'digital representation of value' operating with Distributed Ledger Technology (DLT), commonly referred to as 'Blockchain'. This technology can be framed by the concept of 'decentralized computing' (Van Valkenburg 2018), in which computer applications can run simultaneously on many computers, rather than running on only one central server. This further implies that the computer application runs across different national jurisdictions, facilitated by 'consensus mechanisms' that is, a process that

This text was drafted during a Fellowship at the Law Department of the University of Turin (Project Dipartimento di Eccellenza MIUR 2018–2022).

***Corresponding author: Jose Gustavo Prieto Munoz**, UNITO Department of Law, University of Turin, Turin, Italy, E-mail: jgprietomunoz@gmail.com

employs 'cryptographic algorithms' such that a number of computers (usually referred to as blocks or ledgers) come to *"agree on some shared set of data and continually record valid changes to that data"* (Van Valkenburg 2018).

Cryptocurrencies are the most common use of DLT technology and have at least three intended financial functions: (i) as a means of payment; (ii) as a store of value (crypto assets); and (iii) as "loyalty schemes" (vouchers) to access goods or services at a future date (Lastra and Allen n.d., 9). In this vein, cryptocurrencies and DLT have become increasingly important in the digital economy, operating across national jurisdictions in a way that could transform the current international regulatory framework as well as the way in which authority is exercised outside the state. For this reason, the relation between DLT and law has been an object of study for financial experts, lawyers, and regulators, who all seek to understand its financial and legal impacts. This also includes exploring whether cryptocurrencies should be considered 'money' and used as legal tender in the future.

The international law literature has remained silent regarding the impact that DLT technology could have on the different legal regimes that operate beyond state borders. Still, several cases and developments demand a closer look from this discipline. For instance, questions have been raised regarding the categorization of cryptocurrencies as protected 'investments' in international investment law that challenge current categories within the various self-contained regimes of international economic law.

Given this background, an inquiry into the potential impact of DLT on international law is highly relevant. The topic can be approached in two ways. The first is to inquire what DLT technology can do for international law. For instance, how using this technology might improve the adjudication of international disputes by courts and arbitral tribunals. The second approach would focus on understanding the concepts that this technology offers and how they could be categorized within the scope of international law scholarship. The former is the concern of this article.

In concrete, I aim to explore the following questions: What impact would the 'decentralization' of authority inherent to DLT have on international investment law? Could the products of DLT be contextualized within the concept of "investment" by international investment law? Alternatively, is it necessary to consider adopting a new concept in international investment law?

I offer some answers to these questions first by contextualizing DLT as digital governance infrastructure that entails that blockchain is not only a "thing" but brings with it a set of "relations, processes and imaginations" (Kingsbury 2019, 179). In this sense, cryptocurrencies are the product of such infrastructure. Taking this notion into account, I sketch some ideas that could be useful for developing a concept of 'crypto-investment' for future international economic law.

The roadmap of this preliminary inquiry into the impact of DLT goes as follows: Section 2 explores the ideas behind the development of DLT, especially the notion of this technology as a political concept of governance. Section 3 analyzes how these political ideas relate to some of the fundamentals of international law, specifically the notion of state-based public authority. In Section 4, I sketch some ideas about the need to further elaborate the category of 'crypto-investments' within international economic law.

2 The Idea of Governance Behind the Development of DLT

Section 2 provides an account of the ideas behind the development of DLT. First, I point out that the notion of electronic cash and 'blockchains' of information has already been a topic of discussion in the computer science literature for several decades. Then, I explain that the innovative character of DLT lies in its potential use as a digital infrastructure for governance, extending its usefulness beyond the production of cryptocurrencies.

DLT is a technology that can be defined as '*shared decentralized digital ledgers that use cryptographic algorithms to verify the creation and transfer of digitally represented assets over a peer-to-peer network*' (Maupin 2017b). In sum, this technology allows informatic applications to operate simultaneously on many computers across different jurisdictions using pre-agreed conditions for the system. These pre-agreed conditions are usually referred to as 'consensus' or 'general agreement'[1] on how to validate, update, and reconcile data across all the computers in the DLT system. Given these characteristics, any application that is running using DLT is supposed to be immune to any kind of external attack or hacking since the computers [blocks] of the systems are spread around the world and do not depend on a central authority to function.

Nonetheless, like any technological development, DLT is not created in a conceptual vacuum; it is based on ideas that challenge the current concepts of state-based public authority. Thus, the main inherent claim for Bitcoin was the need for governance in the financial system without centralized power being vested in public bodies such as states, or private bodies such as financial institutions. In this vein, the Bitcoin manifesto of 2009 expressly justifies the need to provide an electronic payment system that allows parties to transact 'directly' with

1 See the discussion about Consensus in (Werbach 2018, 136).

each other without the need for a 'trusted third party' (Nakamoto 2009, 1)[2]. However, the launch of Bitcoin in 2009 was just the latest steep in a notion of decentralization of authority that had hovered over the development of the Internet for a long time.

In 1983, David Chaum's *'Blind signatures for untraceable payments'* already underlined the tension between the right to privacy and the control of illegal activities in the growth of electronic banking services as means of payment. At that time, privacy was understood as *'preventing the unauthorized extraction of information from communications over an insecure channel.'* (Diffie and Hellman 1976, 644). Privacy was also the best known 'cryptographic problem' (Diffie and Hellman 1976), but Chaum's concern was to offer a solution while at the same time providing some accountability for payments.

In this tension, Chaum on the one hand, saw that a 'third party' could access data related to an *'individual's whereabouts, associations and lifestyle'* (Chaum 1983, 199–203), and on the other hand, recognized the danger that a completely anonymous payment could suffer from *'lack of controls and security'* (Chaum 1983). It followed that blind signature, a 'new Cryptography,' could provide a technical solution to balancing the power of the 'third party' and the need for security.

With the expansion and commercial use of the Internet, referred to as the 'modern Internet' (see: De Filippi and Wright 2018, 15–25) during the 1990s, more concrete ideas on how to best implement Chaum's ideas were developed by the same epistemic community in computer science. Some voices advocated for the prevalence of the right to privacy as a fundamental element in a free society. For instance, in his 'Cypherpunk manifesto' (1993), Eric Hugues defined privacy as *'the power to selectively reveal oneself to the world'* (Hughes 1993), and he made a call to defend this power of individuals from governments, corporations, and 'faceless organizations' through the use of cryptography.

In this same vein, and during the same decade, several attempts (Wang, Zhang and Cao 2004, 247) were made to create an electronic cash system. In the 1990s, Chaum launched 'digicash,' (see also De Filippi and Wright 2018), a transnational economic enterprise based in California and Amsterdam, that aimed to materialize his early ideas for having an electronic money system that balanced privacy and control.

However, 'digicash' and other similar efforts failed for different reasons, all related, in one way or another, to an important characteristic of the system: its centralization. All of these efforts still required a central entity that could exercise the necessary authority needed to address certain problems, including how to store the information related to countless transactions that operators of such a

2 There is still some controversy of who is Satoshi Nakamoto.

system would demand. In other words, these different attempts at establishing a system of electronic money still needed a 'third' party, such as a bank or a network of banks, to prevent misuse such as 'double spending'—duplicating and repeatedly spending electronic currency (Wang, Zhang and Cao 2004).

Thus, one system created to avoid a fiat currency and a government, central, or private bank they had the authority to run it, in itself required a central authority to validate the information regarding its transactions. If its creators were worried about how the 'third' party might abuse its power to affect the privacy—freedom—of individuals, it should also be concerned that another type of authority would act similarly if left in charge of validating transactions and storing information about those transactions.

Over the next years, one problem that needed to be solved, which was the object of attention from the computer science epistemic community that developed the first version of electronic cash, was precisely this issue of centralization as the only solution to double-spending. It is in this context that, after several earlier projects, Bitcoin appeared in the 21st century as a response to the 'global financial crisis'.

Thus, the innovative element in Bitcoin is its capacity for decentralization. In this sense, the notion of creating private electronic money was not new. In fact, as described above, it was an idea that had been discussed in the literature for several decades. The notion of 'blockchain', a process for storing information, was also not new; similar ideas such as 'digital time-stamping' (Haber and Stornetta 1991) had been considered decades earlier in the 1990s. DLT, however, introduced the notions of a decentralized digital infrastructure, with its own political ideals[3], and brought all of those previous ideas together.

DLT is not only a technology that produces an electronic or virtual currency, but also aims to provide digital infrastructure for decentralized governance. In this sense, the core concept in DLT is its capacity for 'decentralization'. Nevertheless, this concept has different meanings for the various actors and stakeholders involved with DLT. In her study of the idea of 'decentralization' in DLT, Angela Walch identifies two uses of the word: a technical description, and a political concept (Walch 2019, 1–36), even though, as she notes, both uses may deviate from reality (Walch 2019).

First, as a technical description, DLT is a 'network of computers' that operates through 'peer-to-peer' connections between computers, rather than on a central server. See in more detail in (Walch 2019). This technical use is similar to Valkenburg's idea of a 'decentralized computing revolution' where a computer application can be run simultaneously on many computers around the world,

3 For a critical assessment of those political imaginations, see (Golumbia 2016).

"in a way that avoids trusting the honesty or integrity of any one computer or its administrators" (Van Valkenburg 2018, 6).

This technical feature means that if one computer ('block' or 'node') of the network is attacked or compromised, as can happen in illegal hacking operations aimed at conventional bank institutions, the system as a whole should not be affected. That is the trust element referred to in the notion of 'decentralized computing'.

Second, there is the use of the word 'decentralization' as a political concept of 'diffusion of power' (Walch 2019). Since a DLT system lacks a central computer that can keep control over records of the transactions that are performed, is also doesn't allow a single actor to influence the whole system (Walch 2019). This political concept of decentralization is the conceptual basis for launching Bitcoin as a response to the power accumulated by a few institutions deemed 'too big to fail' (IMF 2011, 2)[4].

3 The Idea of Decentralization in DLT and International Law

If power is the capacity 'of forcing others to a certain behavior' (Kelsen 1967), then the 'decentralizing' capacities of DLT technology mean that no one, including the state itself, should have the capacity to dominate others. However, in this context, 'decentralization' could also pose questions about the notion of 'sovereignty' that is the basis for international law and statehood. Section 3 briefly comments on how the political concept of 'decentralization' relates to the fundamental ideas of international law, especially the idea of state-based public authority and sovereignty. First, I briefly describe how the notion of sovereignty in international law was sketched in the 16th century. Then I describe how DLT as a 'decentralized' political idea could change the way that this old concept is conceived, pointing to the need for evolution in international law.

The modern notion of sovereignty comes from the 16th century, especially influenced Jean Bodin in *'Les Six Livres de la République'* (1576), who used the term to describe the sum of two powers: the monopoly of legitimate force and the power to impose a law on society without being bound by a higher law[5]. This understanding of sovereignty influenced the political thinkers, including Thomas

4 International Monetary Fund IMF. 2011. "Switzerland: 2011 Article IV Consultation—Statement by the Executive Director for the Switzerland". IMF Country Report No. 11/115 (May 2011).

5 For a complete reconstruction of the concept of 'sovereignty' from the times of Jean Bodin see the comprehensive study of Grimm (2015, 17–30); see also Grimm (2016, 42).

Hobbes who, in his book Leviathan, understood this concept of sovereignty to mean that restoring domestic peace required an omnipotent and irresistible authority (Grimm 2015).

This body of work by Bodin and especially Hobbes influenced the political ideas of international legal scholars who were curious about the legal status of the agreements between states. A glance at the famous treaty *'law of nations'* (1758) by Emer de Vattel, who relied heavily on Hobbes work, illustrates Hobbes influence on the work of international legal scholars (Vattel [1758]1811). Vattel used this same concept of sovereignty and authority to elaborate his theory of international law. For Vattel, nations and states were synonymous in defining societies of men who united together to promote their mutual safety and advantage, but with the necessity of establishing a public authority invested in a sovereign leader: *"the law of the nations is the law of the sovereigns."* (Vattel [1758]1811). Even though international law has come a long way since Vattel's book was published, this notion of sovereignty and authority is still present in the logic of many current developments in the field.

Coming back to the current century, 'Satoshi Nakamoto' was probably not thinking about Bodin, Hobbes, or Vattel when launching Bitcoin in the 21st century. Nonetheless, the notion of 'decentralization' as a political concept manifested in the very creation of DLT. At first glance, it seems to undermine the main principle of sovereignty and public authority by aiming to create a system that goes, at least in theory, beyond the jurisdictional power of states. This vision can be seen in the current literature on DLT. For instance, De Filippi and Wright describe the impact of DLT in the law in the following way:

> With blockchains, people can construct their own system of rules or smart contracts, enforced by the underlying protocol of a blockchain-based network. These systems create order without law and implement what can be thought of as private regulatory frameworks […] They endow software developers with the power to create tools and services that avoid jurisdictional rules and operate transnationally to coordinate a range of economic and social activities (De Filippi and Wright 2018).

However, the first years of the development of DLT technology allow us to make at least two observations regarding the concept of 'decentralization' in international law. The first is that, at least for the foreseeable future, DLT will not replace the authority of states. It has become clear that despite their 'decentralized' potential, these 'private regulatory frameworks', as they were called by De Filippi and

Wright, are not completely outside jurisdictional control. In fact, this has resulted in DLT-related enterprises being ordered to stop in numerous cases[6].

In the same vein, the notion of 'order without law' does not mean that law will disappear. On the contrary, in recent years there has been interest on the part of several states and international organizations to promote and attract developers of DLT technology to create enterprises under their jurisdictions. This same concept of 'decentralization' has been tempered by the emergence of different types of DLT systems, from the original types which did not require public permission to closed DLT systems based on private permission, with several variants in between.

The second observation on the operation of DLT reveals that these capacities for 'decentralization' do not eliminate authority, but rather transform it into new forms. For instance, recent studies have shown that the people (usually referred to as the 'miners') behind each 'ledger' or block of a DLT system are concentrated in a few countries. In addition, while there are thousands of private cryptocurrencies negotiated in the market, there are only a few fiat-crypto exchanges that control the majority of these transactions. Finally, the highly technical nature of these economic transactions means that a new epistemic community composed of programmers and fintech entrepreneurs is being empowered to set the vocabulary and conceptual categories that are going to determine how this system will be regulated at the national, international, and transnational levels.

As a consequence, emerging DLT structures do not threaten the existence of international law, but they do challenge current categories used in the different international legal regimes by posing the dilemma of how consolidated legal regimes should internalize this new technology. It is important to note that most of the current international economic regimes, such as the World Trade Organization (WTO) and thousands of International Investment Agreements (IIAs), were negotiated in the 90s.

From the foregoing it can be seen that the use of DLT technology and its impact on the digital economy implies the emergence of a public/private transnational and cross-sectoral global governance system (see Maupin 2017a), that could (should) affect not only the way that economic transactions are performed but also how international legal scholars think about those transactions.

---

6 For instance, the intervention by Japan's Financial Services Agency in the cryptocurrency exchanges BItstation and FSHO in 2018, see https://www.ft.com/content/24f818e8-2276-11e8-9a70-08f715791301, last accessed 27 May 2020.

4 Concluding Remarks: Crypto-investment and International Economic Law

Sections 2 and 3 explained how DLT's political concept of decentralization has affected the conceptual basis of international law, not by undermining it, but rather by demanding that the discipline evolve. In the future, international economic law needs to explore new concepts that address the changes introduced by new technologies such as DLT. One of these concepts could be to include the notion of 'crypto-investments' as a category in international economic law.

Introducing any new term is always a difficult task, especially in a discipline like international law that is less adaptable and resilient for a number of reasons—such as the time it takes to draft, negotiate, and ratify new treaties with different states. However, the use of DLT and the growth of the digital economy demands that we revise the current categories used in international economic treaties. There are reasons for the introduction of the term 'crypto-investment' in IIAs and investment related treaties. First, the current categories, i.e. Foreign Direct Investment (FDI) and Portfolio Investment, do not seem to cover the complexity of DLT infrastructures. In this regard, ICSID Article 25 (1) states that "*The jurisdiction of the Centre shall extend to any legal dispute arising directly out of an investment*" leaving some space for the parties to a treaty to define what constitutes an 'investment'. A different definition of the term 'investment' can be found across the network of IIAs.

However, despite allowing some space for the definition of 'investment', there are also some objective criteria to use as references. There is usually a conceptual distinction made between FDI and Portfolio Investment, where the control over the assets is an important criterion. There is no uniform definition for FDI but arbitration tribunals usually point to some common elements that constitute investment: contribution of assets, risk, control, duration and, in a more contested way, a contribution to the host State's economy[7].

The use of DLT represents the digitalization of an asset in a 'decentralized' infrastructure of governance, which means that it is not introduced into a specific territory, like a physical asset. Thus, it may not be clear if an investment or participation in a DLT structure could be categorized as FDI unless it represents the operation of services physically linked to its development, such as 'mining'—adding information to a DLT system with the expectation of reward from the same system—on a large scale. For example, a foreigner could install assets in the

7 Salini Costruttori S.p.A. and Italstrade S.p.A. v. Kingdom of Morocco, ICSID Case No. ARB/00/4. Decision on Jurisdiction (16 July 2001): para 57.

territory of another state that has an incentive for 'mining' activities, such as cheap electricity. In this example, the operation implies the foreigner is established within the territory of another state as with any other economic activity.

The other category, 'portfolio', is used to refer to an investment where there is no direct management over an asset; it does not seem to include the concept of 'decentralization' inherent to DLT. Unlike traditional portfolio investments, many DLT structures lack centralized decision-making authority. For instance, if a person decides to purchase stocks in a company, it is understood that such a company will operate under a centralized management structure that includes a CEO or a board of directors. By contrast, the structure of a DLT could lack specific economic directors.

Thus, if the product of DLT does not acquire the category of 'money' or 'legal tender' inside a jurisdiction, it is worth exploring the contours of the third category of investment, 'crypto-investment' as a new term that can used in international law, independent from the current concept of 'portfolio' and FDI. In this line, a recent report prepared under the auspices of the European Central Bank defines 'crypto-assets' in the following way:

> [an] asset recorded in digital form that is not and does not represent either a financial claim on, or a financial liability of, any natural or legal person, and which does not embody a proprietary right against an entity. Yet, a crypto-asset is considered valuable by its users (an asset) as an investment and/or means of exchange, whereby controls to supply and the agreement over validity of transfers in crypto-assets are not enforced by an accountable party but are induced by the use of cryptographic tools (ECB 2019).

This economic definition constitutes a starting point and contains three elements that could be used to delineate a legal term in the context of IIAs or related international treaties: (i) the digitalization of an asset; (ii) connection to a DLT governance infrastructure; and (iii) a strong link to the economy of a state.

From those elements, the first (digitalization of assets) and second (connection to DLT infrastructure) could be inferred from the evolution of DLT expressed in the previous two sections. However, the third element implies that the asset does not have to be territorially linked with a third state as does FDI. Alternatively, the DLT needs to have a strong link to the economy of the state; therefore, the third state could use its power to affect the digital infrastructure, thereby creating a need for protection in international law.

An inquiry into this concept does not imply a blind endorsement of all types of DLT technology and uses. On the contrary, it could provide an appropriate conceptual-legal tool for states that want to engage with international regulation and the promotion of economic transactions in the global digital economy. Thus, the same motivations that impel the state to grant traditional forms of investment

protection in the form of IIAs could also play a role in expanding this protection to DLT infrastructures.

There is a long way to go in the construction, development, and acceptance of a concept of crypto-investment in international economic law. Nonetheless, the history of international law shows us that concepts and ideas have evolved in different directions. One of these is the concept of 'investment'. During the first years of international law as a discipline—taking the publication of Vattel's (1758) 'Law of Nations' as a reference point—the majority of economic struggles between privates and states were described as conflicts relating to the 'property' of foreigners or aliens.

In the second part of the 20th century, after the expropriations during the October and Mexican revolutions (Leiter 2017), the concept of 'investment' began to be included in the vocabulary of international law, especially with the first Bilateral Investment Treaty in 1959. Recent technological innovations, including the creation of DLT structures together with the growth of the global digital economy, invite a rethink of the conceptual categories taken for granted in international law. In this context, a further step could be the inclusion of some notion of 'crypto-investment' in international law.

References

Chaum, D. 1983. "Blind Signatures for Untraceable Payments." In *Advances in Cryptology: Proceedings of Crypto 82*, edited by R. L. Rivest, D. Chaum, and A. T. Sherman, 199–203. New York: Springer Science+Business Media.

De Filippi, P., and A. Wright. 2018. *Blockchain and the Law: The Rule of Code*. London: Harvard University Press.

Diffie, W., and M. E. Hellman. 1976. "New Directions in Cryptography." *IEEE Transactions on Information Theory* 22: 644–52.

ECB (European Central Bank). 2019. "Crypto-Assets: Implications for Financial Stability, Monetary Policy, and Payments and Market Infrastructures". In: *Occasional Paper Series*. No 223 (May 2019). Frankfurt am Main, Germany: European Central Bank.

Golumbia, D. 2016. *The Politics of Bitcoin Software as Right-Wing Extremism*. Minneapolis: University of Minnesota Press.

Grimm, D. 2015. *Sovereignty: The Origin and Future of a Political and Legal Concept*. New York: Columbia University Press.

Grimm, D. 2016. *Constitutionalism: Past, Present, and Future. Serie Oxford Constitutional Theory*. Croydon: Oxford University Press.

Haber, S., and W. S. Stornetta. 1991. "How to Time-Stamp a Digital Document." *Journal of Cryptology* 3: 99–111.

Hughes, Eric 1993. *A Cypherpunk's Manifesto*. Also available at: https://www.activism.net/cypherpunk/manifesto.html.

Kelsen, H. 1967. *Principles of International Law*. New York: Holt Rinehart & Winston.
Kingsbury, B. 2019. "Infrastructure and Infrareg: On Rousing the International Law 'Wizards of Is'." *Cambridge International Law Journal* 8 (2): 175–86. 179.
Lastra, R. M., and J. G.Allen. July 2018. "Virtual Currencies in the Eurosystem: Challenges Ahead." *Monetary Dialogue* 1–57. https://doi.org/10.2861/460747.
Leiter, A. 2017. "The Silent Impact of the 1917 Revolutions on International Investment Law And What It Tells Us about Reforming the System." *European Society of International Law - ESIL Reflections 6* (10). Also available at SSRN: https://ssrn.com/abstract=3177888.
Maupin, J. 2017a. "Blockchains and G20: Building an Inclusive, Transparent and Accountable Digital Economy." Policy Brief Serie 101, Editorial. Waterloo, ON, CA: Centre for International Governance Innovation.
Maupin, J. 2017b. "Mapping the Global Legal Landscape of Blockchain and Other Distributed Ledger Technologies". *CIGI Papers*.
Nakamoto, S. 2009. *Bitcoin: A Peer-to-Peer Electronic Cash System*. Also available at: https://bitcoin.org/bitcoin.pdf.
Van Valkenburgh, P. 2018. "Exploring the Cryptocurrency and Blockchain Ecosystem". In *Testimony Before the United States Senate, Committee on Banking, Housing, and Urban Affairs. One Hundred Fifteenth Congress. Second Session. (October 11 2018)*: 1–67. 6. Also available at: https://www.govinfo.gov/.
Vattel, E. D. (1758) 1811. *The Law of Nations or Principles of the Law of Nature Applied to the Conduct and Affairs of Nations and Sovereigns. Le droit des gens ou principes de la loi naturelle*. London: W. Clark and Sons.
Walch, A. 2019. "Deconstructing "Decentralization": Exploring the Core Claim of Crypto Systems". In *Cryptoassets: Legal, Regulatory, and Monetary Perspectives*. Oxford University Press. Retrieved 29 Jun. 2020, from https://www.oxfordscholarship.com/view/10.1093/oso/9780190077310.001.0001/oso-9780190077310-chapter-3.
Wang, H., Y. Zhang, and J. Cao. September 2004. "An Electronic Cash Scheme and its Management". *Concurrent Engineering: Research and Applications* 12 (3): 247–57.
Werbach, K. 2018. *The Blockchain and the New Architecture of Trust*. The MIT Press.