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Internet architecture and the layers principle: a conceptual framework for regulating Bitcoin

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Abstract: Bitcoin is the first decentralised, peer-to-peer network that allows for the proof and transfer of ownership of virtual currencies without the need for a trusted third party. It has created a platform for tremendous financial innovation, but at the same time the role of traditional regulatable financial intermediaries is bypassed. The purpose of this article is to address the important policy question of how we can capture Bitcoin's potential benefits for the economy while addressing new regulatory challenges. To do so, we first conceptualise the Bitcoin ecosystem through the layered model of internet architecture. Second, we apply the layers principle of internet governance to identify control points and guidelines for regulation that respect the integrity of the layers. Third, we conclude with the need for governments to adopt an adaptive and novel regulatory approach to ensure that society can benefit from Bitcoin's revolutionary potential. This work forms a baseline for further understanding of the governance of Bitcoin and the various actors within the ecosystem based on the layers principle of internet architecture.

Keywords: Bitcoin, Cryptocurrency, Finance, Internet architecture, Internet governance

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INTRODUCTION

The information intensity of the financial services industry has long marked it out for transformation by information technology. As early as 1984, then CEO of Citibank Walter Wriston famously said, "information about money has become almost as important as money itself" (Bass, 1996). Until very recently, however, finance was domesticated by traditional banks and payment processors. We now see cyberspace starting to shape the domain of high finance. The watershed moment occurred in 2009, when Bitcoin was invented. Bitcoin takes everything we know about the internet and cryptography, and creates a platform for financial innovation, much as the internet is a foundation for digital services.

Bitcoin is the first decentralised, peer-to-peer network that allows for the proof and transfer of ownership of virtual currencies without the need for a trusted third party, bypassing the role of traditional financial institutions. On the one hand, it provides the foundation for tremendous financial innovation. On the other hand, governments fear the coming of a world without regulable financial intermediaries.

This research article addresses the policy dilemma of how we can capture Bitcoin's potential benefits for the economy while addressing the challenges to law enforcement. As the internet and finance starts to shape each other, we have few conceptual anchors to model the collision of law and policy in the cyber arena with the modes of interactions in the Bitcoin ecosystem. Inspired by the alignment strategy developed by Choucri and Clark (2012) for cyberspace and international politics, this article seeks to develop an alignment strategy to explicate the Bitcoin ecosystem through well-established principles of internet architecture, drawing important insights on a regulatory approach for Bitcoin.

This article is organised as follows. We first establish Bitcoin as a logical layer for finance on which innovation can happen. We then extend this analysis to include the entire Bitcoin ecosystem of actors by applying the layered model of the internet. Next, we identify the appropriate layer of regulation using the layers principle of internet governance. We conclude with policy prescriptions for governments to create adaptive organizations that match Bitcoin's revolutionary potential.

BITCOIN AS THE LOGICAL LAYER FOR FINANCE

In 2008, Bitcoin was first described in a white paper (Nakamoto, 2008) published under the pseudonym Satoshi Nakamoto, its elusive creator. On 6 March 2014, Newsweek reported (Goodman, 2014) that it had tracked down Nakamoto, which doesn't appear to be true. While curiosity in Nakamoto's identity is understandable, more importantly, it offers us a useful opportunity to examine the nature of Bitcoin. Intentionally decentralised and open source, Bitcoin has no leader by design. In fact, Nakamoto handed over control of the Bitcoin software to an open source community around mid-2010. The Bitcoin protocol has generative quality which allows third parties to write new software to run on top of it. As Zittrain (2006, pp. 295-296) explains, such kind of code "is first nurtured by its author and then set free to find its life in a larger community". It is therefore not important to know who Nakamoto is. As Bitcoin developer Garzik (2014) blogs following the Newsweek report, "much like other spoken languages around the world, the Bitcoin protocol grows and changes as its users change,

ultimately controlled by no one".

Bitcoin shares the same qualities of the internet which make the latter the most important platform for innovation and creativity in modern times. To appreciate the significance of Bitcoin, it helps to understand the layers architecture of the internet as proposed by Solum and Chung (2004). The internet is a neutral platform. Anyone can develop network applications with or on top of TCP/IP, the protocol that makes the internet possible as a network of networks. It is the logical layer on top of which sit internet applications such as the World Wide Web, email and peer-to-peer softwares. The abstraction of an upper 'application layer' is important because no permission is necessary for anyone to develop applications, and innovation is decentralised and placed in the hands of individual innovators. In short, the 'stupid network' can be completely oblivious to the specific 'smart applications' that are in use. This application of the broad version of the end-to-end arguments leads to a network that is non-discriminatory (van Schewick, 2010). This guarantees what one of the fathers of the internet, Vint Cerf, called permissionless innovation: maximising the internet's overall value to society.

Therefore, the real value of Bitcoin lies not so much in its potential to become a substitute for money, but rather in its ability to act as the internet of money ("Bitcoin's future: Hidden flipside", 2014). Bitcoin is much more than a substitute - it is like a logical layer for finance (Dourado, 2014) that will support a revolution in the way people own and pay for things. As every Bitcoin transaction is defined by code, money can be programmed to come with conditions. For instance, money will be released only if a third person agrees, or people will fund a project only when a threshold is passed. The technology behind Bitcoin also allows continuous micropayments that are impossible with traditional payment systems due to the prohibitive transaction costs. This makes fine-grained usage-based pricing possible for the first time. Bitcoin can even represent ownership of physical assets. For instance, a car can only be turned on with the Bitcoin token. It is impossible to predict what kind of applications will emerge, but one thing we can be certain about is that waves of financial innovation will happen on the Bitcoin platform.

Much like the transformations brought by the internet, policymakers are intrigued by Bitcoin. Bitcoin is a disruptive technology, which raises both hopes and fears in the minds of politicians and bureaucrats. Hopes, because the innovation potential appears limitless; fears, because the peer-to-peer nature of Bitcoin means that it almost certainly cannot be regulated. The challenges of getting policy right are big and complex. These two key themes were reflected in hearings conducted by the US Senate in November 2013 (US Senate Committee on Homeland Security & Governmental Affairs, 2013; US Senate Committee on Banking, Housing & Urban Affairs, 2013). On the one hand, it is recognised that there is an incredible amount of innovation and development happening. Then Federal Reserve chairman Ben Bernanke said virtual currencies "may hold long-term promise". On the other hand, there is a perceived need to guard against illicit uses of Bitcoin. Tom Carper, the Homeland Security Committee's chairman, summarised this nuanced sentiment well: "rather than play 'whack-a-mole' with the latest website, currency, or other method criminals are using… we need to develop thoughtful, nimble and sensible federal policies that protect the public without stifling innovation and economic growth" (Strauss and Foley, 2013).

A LAYERED MODEL OF THE BITCOIN ECOSYSTEM

What policy prescriptions should we follow so that we can confront the risks while reaping Bitcoin's beneficial potential? Before we answer this question, let's take stock of the structure of the Bitcoin ecosystem using the layered model of the internet. While well understood, there is a plurality of views on the layered nature of internet architecture. In Solum and Chung (2004), cyberspace is thought of as a modularised, interconnected layered system consisting of six layers: the physical, link, internet protocol (IP), transport, application, and content layers. Choucri and Clark (2012) introduce a simplified "four-layered model that captures the essential features of interest": the physical layer forms the internet's physical foundations; the link, IP and transport layers encapsulate the logical functions of an application; information is stored and transmitted through programmes in the application layer; users make decisions and carry out actions with information in the content layer.

Regardless of the model used, they essentially describe the internet's vertical hierarchy bottom up from the physical infrastructure handling the flow of data, the protocols and software that make use of the physical foundations, the encoded content that is stored and transmitted in the cyberspace, up to the end users and organisations who shape the cyber-experience. The upper layers depend on the functions of the lower layers, but not the other way round. These models allow us to locate Bitcoin actors and activities, and explicate the dynamics among them in terms of relative power and influence. For simplicity, we will employ the four-layered model in this article. Over the past two years, a vibrant ecosystem has developed around Bitcoin, situated across the upper three layers of the internet architecture:

- The logical layer - The Bitcoin protocol was launched in 2009 by a programmer with the pseudonym Satoshi Nakamoto. It is rooted in the Cypherpunk culture which is driven by a group of cryptographers with an outsize influence in the digital world (Grinberg, 2012). Early pioneers called miners use software programmes that follow a mathematical formula to produce bitcoins. These technophiles, intrigued by the potential of cryptographic payments, laid the foundation for innovation where anyone can build on top of the Bitcoin protocol. Notably, the Bitcoin protocol contains the block chain, a transaction database shared by all nodes in the system. Based on the block chain, applications can be built on top and information flows can be reconstructed, as explained in the next section of the article.

- The information layer - Bitcoin will not attract mainstream attention were it not for actors in this layer. They serve as adapters which interface between the technical community and the real economy, two otherwise incompatible networks (Böhme, 2013). They are the intermediaries which make Bitcoin accessible to the general public through user-friendly applications. For example, exchanges offer their services to non-miners to exchange between bitcoins and conventional currencies. Wallet and escrow services allow individuals to store bitcoins securely and conveniently. Payment processors which provide integration services make it easy for merchants to accept bitcoins from consumers. In the future, traditional financial institutions and incumbent payment systems may also adopt the Bitcoin technology to increase efficiency and remain competitive.

- The user layer - Bitcoin has attracted a wide range of users, from traders and speculators taking advantage of Bitcoin's price volatility, individuals sending remittances, to consumers making real payments. An increasing number of merchants, retailers and businesses are accepting bitcoins. On the other hand, criminals are attracted by Bitcoin's pseudonymity to engage in illegal activities such as money laundering, terrorism financing, drug dealing and online gambling.

IDENTIFYING THE APPROPRIATE LAYER FOR REGULATION

Based on the foregoing, we put forth initial observations about the Bitcoin ecosystem. The logical and user layers are populated by private actors from the Bitcoin community and real economy respectively. These actors are small and can easily escape from regulation and enforcement. At the information layer, intermediaries of various kinds have emerged to bridge the two networks. Their position in the internet architecture enables them to capture information flows and identify wrongdoers. In addition, they are larger and more established actors, making them more amenable to state regulation. Accordingly, intermediaries in the information layer are appropriate targets of regulation.

The rise of peer-to-peer technologies such as Bitcoin eliminates a layer of intermediation from the networks they create; in the case of Bitcoin, people can technically send money from one wallet to another without going through middlemen. Law enforcement has long relied on financial intermediaries to help them prevent, detect, and investigate illegal transactions. Zittrain (2006) fears that the loss of these natural points of control will cause those with challenged interests, namely the regulators, to foreground a new and less palatable set of intermediaries: software authors.

In reality, most people will rely on intermediaries in the information layer when they use Bitcoin. Following Zittrain's logic, the presence of gatekeepers in the Bitcoin ecosystem allows for the possibility to regulate lightly while still curtailing the worst online harms. It will be unrealistic to treat Bitcoin as an ungovernable space. In the balance, this approach provides checks on unambiguously damaging activities while avoiding interventions on innovation. It is often postulated that Bitcoin transactions are anonymous, which may drive policymakers into over-regulation, which means banning the Bitcoin protocol at the logical layer. Bitcoin, however, is based on a shared global ledger of all transactions called the block chain. While pseudonymous, all transactions are publicly available. Using data mining approaches, value flows through the system can be reconstructed and thus regulative policies enforced. For example, Ron and Shamir (2013) have used data from the block chain to trace how the operator of Silk Road, a marketplace in which illegal substances and services were traded, hid his bitcoin holdings from the authorities. More broadly, Ron and Shamir (2012) have analysed the full Bitcoin transaction history until May 2012 and identified many statistical properties of the system. Arguably, these research are illustrations of how data flows in the logical layer can be assembled and analysed to become recognisable information in the information layer, just as how programmes in the information layer of the internet interpret data flows from the lower layers as content.

Focusing regulatory efforts on the information layer conforms with the layers principle of internet governance. As Solum and Chung (2004) note, a problem that arises in one layer is most effectively dealt with at the same layer. Layer-crossing regulations - regulations targeted at a lower layer to discriminate against problems in the upper layer - are inherently overinclusive and underinclusive. This is because, by design, the lower layer is not supposed to know about the content of the payload data received from the upper layers. Consequently, the lower layer must necessarily have substantial innocent uses, and at the same time, lack the complete information required to perform effective discriminatory functions. Taking action at a lower layer with the goal of influencing an upper layer often creates a 'blunt instrument' with

consequences broader than the original intention. The most common examples are various internet filter programmes at the logical and application layers targeted as content problems at the user layer, which often lead to over-blockage.

The illicit use of Bitcoin is a problem that arises at the information and user layers. Drug dealers, terrorists and other criminals leverage Bitcoin technologies and various intermediaries to move money while making it difficult for law enforcement to track those movements. But to prohibit Bitcoin at the logical layer for this reason is to forego the legitimate uses and tremendous potential of the technology. Instead, the problem can be dealt with at the information layer. Criminals need to go through intermediaries in this layer to exchange between the Bitcoin and real economies. As a result, these exchange mediums collect and retain significant amounts of information, which can be utilised by law enforcement to detect money laundering and the underlying criminal activity.

That being said, a constructive regulatory context is critical. The transactional efficiency brought by Bitcoin is tremendous. According to research by Goldman Sachs (2014), the annual net savings for merchants and consumers could potentially add up to over $150 billion in retail point of sale and $12 billion in e-commerce fees. However, the actual savings will be less due to the likely rising regulatory and operating costs. Traditional financial institutions are subject to well-established anti-money laundering regimes with stringent requirements on customer due diligence, record keeping, and reporting of suspicious activities. These laws and regulations of general applicability can in theory be applied to the emerging non-financial, information-based companies in the Bitcoin economy. But a balance needs to be struck between eliminating instances of gatekeeper-aided wrongdoings and avoiding excessive burdens on gatekeepers. It is important to allow new Bitcoin services to develop by ensuring that entrepreneurial innovators can easily comply with existing or new regulations (Brito, 2013b).

AN ADAPTIVE APPROACH TO REGULATION

Drawing from lessons of advanced digital economies that have reaped the internet's benefits for economy and society, governments need to follow an adaptive style when considering regulations for Bitcoin intermediaries, relying on experimentation and adjustment (Boston Consulting Group, 2012). Whitt (2009) explicates the importance of 'adaptive policy-making' by governments to grapple with dynamic technological changes and maximise innovation. Like many other technologies, Bitcoin disrupts the status quo, and governments feel pressure to respond. Every time they overreact, however, they risk chilling innovation. There will be new challenges, but the opportunities are abundant. To put this in perspective: Silk Road, the now-defunct Bitcoin marketplace for illegal drugs, had a monthly transaction of only $1.2 million, compared with a Bitcoin economy that amassed $770 million in transactions during June 2013 (Brito, 2013a). Illicit activities are only a small part of the Bitcoin economy, but they attract disproportionate media attention. More critical is how businesses and regulators work together to create a new finance ecosystem that serves the real economy more effectively.

Traditional financial regulators are relatively ill prepared to understand internet architecture in a subtle, fine-grained way. They are further constrained by organisational culture and practices. At worst, they are inward looking and resistant to change. This is complicated by the fact that Bitcoin does not exactly fit existing regulatory definitions of currency, commodity, or payment network. Moreover, the financial ecosystem will be characterised by new, internet-based entrants operating alongside incumbent banks looking to implement digital currency strategies

in response to competitive pressures. In this context, it is important for them to stay abreast of technology trends and emerging business models around the world (Cainey, 2014). Amidst the blurred boundaries, different regulatory authorities will need to work together in new ways, and collaborative mechanisms should be established not only within but also across the various industries (Villasenor, Monk and Bronk, 2011).

Most importantly, regulators should not saddle new intermediaries with the legacy regulatory burden intended for traditional financial institutions, which often have decades-long institutional heritage of developing and deploying systems to identify illicit financial transactions (Brito, 2013b). They need to modulate and fine-tune existing practices. For example, Christopher (2013) notes that law enforcement efforts to combat money laundering have traditionally focused on prosecuting financial institutions' regulatory violations to prevent crime. Applied in the cyberspace, such heavy-handed approach will create a whack-a-mole situation whereby Bitcoin intermediaries will be driven into anonymity and reemerge in another part of the ecosystem. Instead, by treating them as partners, law enforcement can develop a better understanding of the landscape and make informed decisions about which entities to target for the underlying crimes. This novel approach will allow for learning for future policymaking without dampening innovation.

To conclude, the layered model of internet architecture helps us to explore critical features of the Bitcoin ecosystem. It is important for policymakers to recognise that Bitcoin, like the internet, is a promising platform upon which financial innovation can happen. The layers principle distills the complexities of the ecosystem into control points and guidelines for regulation that respect the integrity of the layers. It is concluded that Bitcoin intermediaries in the information layer are appropriate targets of regulation. This approach provides policymakers a way to curtail online harms and avoid interference on online architectures and innovation. In establishing a regulatory regime, policymakers need to adopt an adaptive and novel approach to ensure that illicit activities can be deterred while ensuring that society can fully benefit from the innovation and creativity on the Bitcoin network.

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