Blockchain Technology and the Financial Market: An Empirical Analysis

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Abstract

This study investigates the relationship between blockchain technology and the financial market. The US and China are used as case studies for the 2008–2016 period using fully modified least square and Toda-Yamamoto causality technique. The estimates show that blockchain technology has positive and significant relationship with the financial market in the US and China. In other words, the higher the levels of blockchain innovation in these countries, the more developed the financial markets. This suggests that the presence of blockchain innovation in financial markets spurs financial development. Blockchain innovation is therefore a positive significant factor for well-developed financial markets. The findings also indicate that macroeconomic factors such as lagged financial development, GDP per capita, the growth rate of GDP, FDI and trade openness have significant and positive relationship with financial development in the two countries. Among the institutional variables, government effectiveness has significant and positive effects only in the US.

Keywords: Blockchain technology; bitcoin; smart contracts; financial markets

JEL: D47, O16, O31, O34

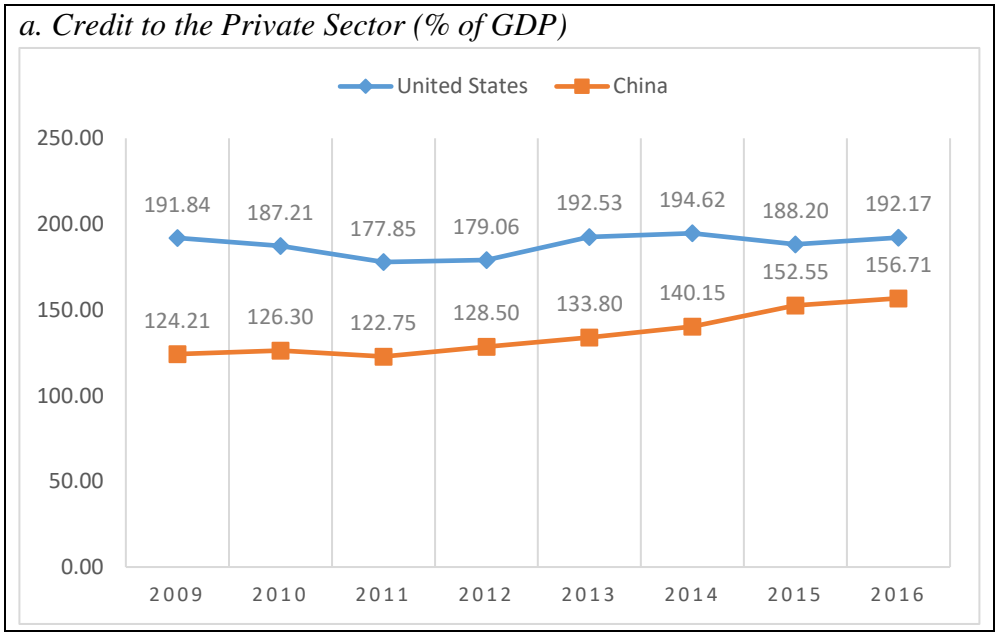
1. Introduction

Blockchain, also known as distributed ledger technology, has made significant inroads into financial markets since it surfaced in 2009, particularly as the underlying technology that powers the cryptocurrency Bitcoin. Because of the significance of blockchain technology, it has attracted huge attention and triggered multiple projects in different industries. For example, financial markets are the primary users of blockchain, due to its well-known application to the crypto-currency Bitcoin (Nakamoto, 2008). However, blockchain has gone beyond Bitcoin. With respect to cryptocurrencies, there are networks and mediums of exchange using cryptography to secure transactions such as Litecoin, Ripple and Monero (Buterin, 2013, 2014). Regarding securities issuance, trading and settlement, there are companies going public and issuing shares directly,

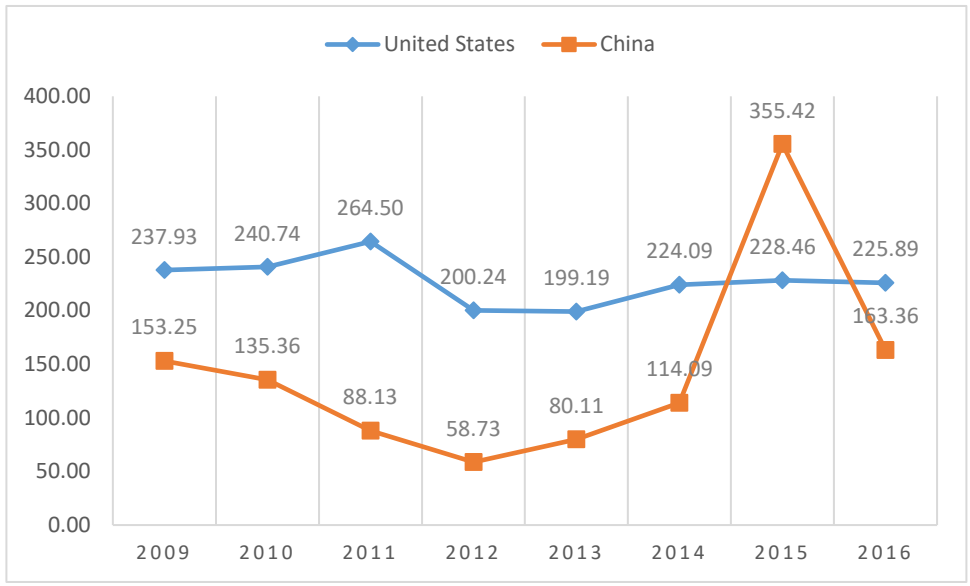
without a bank syndicate (e.g., NASDAQ private equity, Medici, Blockstream, Coinsetter). Private, less liquid shares are traded in a blockchain-based secondary market. In insurance, properties (e.g., real estate, automobiles, etc.) are registered and insurers can check the transaction history both using blockchain (e.g., Everledger). In addition, major banks and financial institutions (e.g., Goldman Sachs and Morgan Stanley) are exploring the potentials of blockchain technology in different areas of their businesses, including payments, stock trading, and other transaction-based processes (Beck et al, 2016). The expected gains are increased speed, security, transparency and reduced transaction costs among others (Beck and Müller-Bloch, 2017).

Considering the potentials of blockchain for the financial market, the financial markets in the US and China are embracing blockchain earnestly and developing capabilities in that area. The United States and China are a particularly interesting combination to study in the light of the extent of differences in the depth of the financial markets in the two countries and, perhaps more interestingly, across various measures. As shown in Figure 1, while private credit is relatively scarcer in emerging markets such as China, in developed markets such as the United States, there are more abundant sources of funding. For example, credit to the private sector (% of GDP) of United States has always exceeded that of China. A similar picture also emerges from the stock markets. While the market size is ample in the United States, it is relatively smaller in China. In particular, the stocks traded (% of GDP) of United States is worth 225.9% of GDP in 2016, which is far higher compared to 163.4% in China in the same year.

Figure 1. Differences in Financial Depth in United States and China



b. Stocks traded (% of GDP)



Data Source: World Bank (2017)

It has been argued in the literature that blockchain technology can boost the prospects of financial markets in many countries, especially in emerging markets such as China where financial markets are relatively smaller (Walch, 2015; Guo and Liang, 2016; Underwood, 2016; Zhu and Zhou, 2016; Nofer, Gomber, Hinz and Schiereck, 2017; Peter and Moser, 2017; Ellis and Hubbard, 2018). For example, the banking industry in China is confronted with the effects of interest rate liberalization and profit decline triggered by narrowing interest-rate spread (Guo and Liang, 2016). Blockchain technology could be used to transform the payment clearing and credit information systems in the banks, and thus enhance the efficiency of the industry. However, some studies in the literature have argued that while blockchain offers new possibilities for financial markets, it also challenges the existing traditional financial markets: the long-established incumbents, banks and credit card companies (Lindman, Tuunainen and Rossi, 2017). Blockchain technology challenges their dominance over payment services.

To better understand this puzzle, research on the role of blockchain technology in financial markets is clearly called for. So far, the studies on blockchain technology have mainly focused on technology issues (e.g., Yli-Huumo et al, 2016; Belle, 2017; Sikorski, Haughton and Kraft, 2017; Zheng et al, 2017; Meunier, 2018). Another main research has been the legal frameworks and their applicability (Novoselova and Grin, 2018; Scriber, 2018; Zhang et al, 2018). Now as the number of applications to the financial market is increasing, further research is called for. According to Seebacher and Schüritz (2017), while blockchain technology is expected to revolutionize the way financial transactions are performed, the real world impacts and benefits are still not clear. The question therefore is: "What is the relationship between blockchain and the financial market?"

This study therefore contributes to the literature on the relationship between blockchain and the financial market. The insights from the outcome of the study would be useful for policymakers, so

that they could pay more attention to blockchain technology to ensure that the potential gains are fully maximized. It could also provide insights on re-assessment of the relationship between blockchain and the financial market. Indeed, the present paper is the first paper to empirically determine the relationship between blockchain and financial markets, especially in the US and China.

The structure of the paper is as follows: Section 2 presents the theory and the review of literature. Section 3 provides the framework while section 4 presents data and methods. Subsequently, section 5 provides an empirical analysis and section 6 presents the discussion. Section 7 presents the implications while Section 8 closes with a conclusion.

2. Theory and the Review of Literature

The Unified Theory of Acceptance and Use of Technology (UTAUT) was proposed by Venkatesh, Morris, Davis and Davis (2003). The theory was grounded on eight famous models in the field of information technology, combining components across the eight models which include the Theory of Reasoned Action (Fishbein and Ajzen, 1975), the Social Cognitive Theory (Bandura, 1986), the Technology Acceptance Model (Davis, 1989), the Theory of Planned Behavior (Ajzen, 1991), the Model of PC Utilization (Thompson, Higgins and Howell, 1991), the Motivational Model (Davis, Bagozzi and Warshaw, 1992), the Combined Technology Acceptance Model and Theory of Planned Behavior (Taylor and Todd, 1995), and the Innovation Diffusion Theory (Moore and Benbasat, 1991; Rogers, 1995). The UTAUT explains user intentions to use an information system and consequent usage behavior. Some of the key constructs are effort expectancy and performance expectancy as predictors of behavioral intentions to use information technology while facilitating conditions directly impact usage behavior (Evans, 2018a; Adeola and Evans, 2019). Venkatesh et al. (2003) found that the UTAUT account for a notable 70% of the variance in behavioural intention to use and about 50% in actual use. More recent studies have also found strong support for the theory (e.g., Williams, Rana and Dwivedi, 2015; Celik, 2016; El-Masri and Tarhini, 2017; Howard, Restrepo and Chang, 2017; Maruping, Bala, Venkatesh and Brown, 2017).

In relation to the UTAUT, blockchain technology has effort expectancy, performance expectancy, and facilitating conditions in the financial market. Blockchain technology allows direct secure trading and transactions, without a record keeper or middle-man. Blockchain simplifies the financial processes by automation and decentralization. It provides faster exchanges, security, trust, risk reduction, and transparency. Thus, all facets of financial markets can benefit from the trust-free and fast transaction system of blockchain (Beck and Müller-Bloch, 2017). Since blockchain technology supports the proper functioning of the financial market, the technology is therefore expected to have huge impacts on financial markets across the globe.

The positive effects of well-developed financial markets on economic growth and development have spurred various studies on the determinants of a well-developed financial market (e.g., Beck and Maimbo, 2012; Huang, 2011; Takyi and Obeng, 2013; Evans, 2015; Evans and Adeoye, 2016; Adeola and Evans, 2017). Based on the theoretical and empirical literature, factors such as political economy, institutions and other related factors have been identified as significant factors for the financial system (Voghouei, Azali and Jamali, 2011). Among the determinants of well-developed financial system, the institutional conditions are perhaps one of the most studied factors. Many studies have shown that financial systems are stronger when institutions protecting and matching the needs of investors are present (Demirgüç-Kunt and Levine, 2008; Evans, 2018b). The empirical evidence has shown that enforcing the contracts and the rights of creditors tend to deepen financial markets (Law and Azman-Saini, 2008). Studies such as Law and Habibullah (2009) have shown that institutional quality is a significant determinant of capital market and banking sector development. Ayadi, Arbak, Naceur and De Groen (2015) showed that strong legal institutions have significant positive effects on financial development.

With regard to macroeconomic factors, the literature has shown that an environment of economic stability is necessary for a well-functioning financial system. For example, higher inflation undermines real returns, increases likely borrowers and reduces likely lenders. Some studies in the literature have shown that inflation leads to banking crises (Demirgüç-Kunt and Detragiache, 2005). In fact, countries with high inflation has been shown to experience low levels of banking and stock market development (Boyd et al., 2001). Takyi and Obeng (2013) showed that inflation exerts a negative and statistically significant effects on financial development both in the short and long run. Ayadi et al (2015) also found that inflation undermines banking development. In fact, McKinnon (1991) argues that price stability is important for financial intermediation and that high inflation harms long-term contracts, exacerbates information asymmetry and moral hazard, and that inflation hampers financial development.

A country's openness to financial flows also determines the level of development of the financial market. FDI and remittances are perhaps some of the important flows. Billmeier and Massa (2009) found that remittances is important for stock market development. Similarly, Aggarwal et al. (2011) provided evidence that remittances expand bank deposits and credit to the private sector. Law and Habibullah (2009) has shown that trade openness is significant in promoting capital market development. Baltagi, Demetriades and Law (2007) showed that trade openness determines financial development differences across countries. Their results showed that countries that are not open can benefit greatly in terms of financial development if they open their trade and capital accounts. Takyi and Obeng (2013) showed that trade openness is a significant determinant of the development of the financial market. Seetanah, Padachi, Hosany and Seetanah (2010) and Huang and Temple (2005) also found statistically positive effects of trade openness on financial development. Other determinants of financial development are per capita income and growth rate of GDP. Law and Habibullah (2009) showed that real per capita income are significant determinants of capital market and banking sector development. Takyi and Obeng (2013) also

showed that per capita income is a significant determinant of the development of the financial market.

Blockchain technology was first introduced in Nakamoto's (2008) whitepaper as the underlying technology of Bitcoin. Since then, many studies on blockchain have sprung up ranging from analysis of consensus algorithms (e.g., Eyal and Sirer 2014) to issues of privacy of smart contracts (e.g., Kosba et al. 2016). In information systems, studies on blockchain have mainly focused on cryptocurrencies. The studies have highlighted weaknesses of Bitcoin, such as theft, scalability issues, and structural problems (e.g., Barber et al., 2012; Croman et al., 2016); privacy implications of Bitcoin (e.g., Miers et al. 2013; Bonneau et al. 2014); and inclusive blockchain protocols (e.g., Lewenberg et al. 2015).

A stream of the literature has also focused on the importance of blockchain technology for financial markets (e.g., Buitenhek, 2016; Guo and Liang, 2016; Xu, 2016; Broby and Paul, 2017; Cuccuru, 2017; Romano and Schmid, 2017). For example, Buitenhek (2016) explored the characteristics of blockchain and explained it can have profound impacts on the financial industry in areas ranging from payments and identity services, settlements, as well as new product creation based on 'smart contracts'. Broby and Paul (2017) showed that blockchain can potentially expedite cheaper, more efficient and secure operations. The authors suggested that blockchain and distributed ledgers can facilitate financial settlements and transactions. Hofmann, Strewe and Bosia (2018) showed that blockchain enables faster and cheaper payment systems. Also, Till et al (2017) showed that blockchain technology could re-create global health financing.

Further, Beck, Czepluch, Lollike and Malone (2016), using a design science approach, showed that secure and trust-free blockchain-based transactions have the potential to transform many existing trust-based transaction systems. Lee (2015) showed that a crypto-securities market would not entail the replacement of the traditional stock market. Rather, it would be an alternative market for users who are dissatisfied with the current regime. Catalini and Gans (2016) showed that blockchain technology allow market participants to perform costless verification, lowers the costs of auditing transaction information, and allows new marketplaces to emerge. They showed that when a distributed ledger is combined with a native cryptographic token (such as Bitcoin), "marketplaces can be bootstrapped without the need of traditional trusted intermediaries, lowering the cost of networking" (p. 2). Beck and Müller-Bloch (2017) showed how an incumbent bank deals with blockchain innovation. They showed how banks can employ blockchain in a timely and sustainably, as well as build the necessary competences.

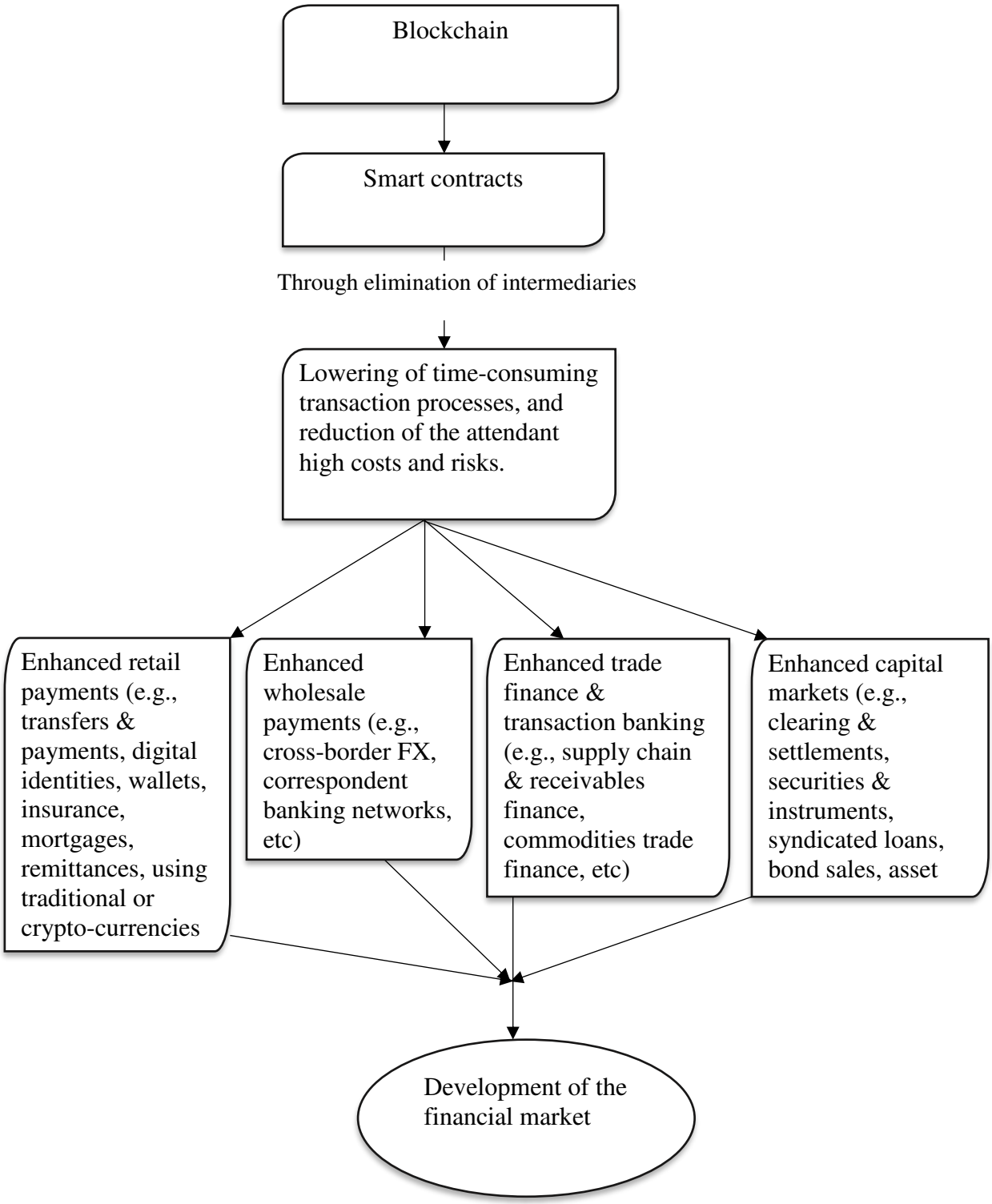
Overall, the existing literature is mostly limited to explaining technical details and exploring theoretical use cases. The empirical determination of the potential effects of blockchain technology for financial markets is a neglected issue. Studies such as Seebacher and Schüritz (2017) have shown that blockchain technology, as a service system, supports the proper functioning of a service system, by facilitating co-creation of value, offering mechanisms of coordination and ensuring availability of information. Therefore, the technology is expected to have huge impacts on the financial market. However, existing studies in the literature have explored various determinants

of well-developed financial markets, to the disregard of the importance of blockchain technology. This study fills that gap in the literature. Hence, this study attempts to show that blockchain technology can have substantial effects on financial markets.

3. Framework of blockchain and the financial market

One of the main contributions of this study is in terms of the role of blockchain technology in the financial market. As depicted in Figure 1, blockchain is important for the financial market as it eliminates intermediates and thereby leads to the development of the market. Blockchain provides a distributed database/ledger shared among a peer-to-peer network with a linked sequence of blocks, holding time-stamped transactions which are secure by public-key cryptography and verifiable by the network community (Vukolić, 2015; Iansiti and Lakhani, 2017; Kuo, Kim and Ohno-Machado,2017; Ølnes, Ubacht and Janssen, 2017; Dai, Zhang, Wang and Jin, 2018). A distributed ledger is a consensus of replicated and synchronized digital data shared across multiple sites, countries, or institutions, and there is no central/regulatory authority (Maull et al, 2017; et al; Ølnes et al, 2017). Blockchain therefore enables a system of creating a distributed ledger where every online transaction involving digital assets can be verified at any time, without compromising the privacy of the digital assets or the parties involved (Crosby, Pattanayak, Verma and Kalyanaraman, 2016).

Figure 1. Framework for Blockchain and the Financial Market



Source: Author's own

An emerging use of blockchain is smart contracts (also referred to as blockchain contracts, digital contracts, self-executing contracts or smart property). A smart contract is a computer protocol that automatically executes the terms of a contract. In other words, a smart contract digitally facilitates and enforces a transaction. For example, contracts such as transferring money or receiving products could be converted to computer code, stored and replicated on the system, and supervised by the network of computers. A smart contract therefore serves to enable two anonymous parties to engage in transactions with each other, without the need for an intermediary (Fairfield, 2014; Christidis and Devetsikiotis, 2016). Blockchain technology therefore allows direct secure trading and transactions, without a record keeper or middle-man (Underwood, 2016; Hsiao, 2017; Klaus, 2017).

By eliminating intermediaries (middlemen) in the financial market, blockchain reduces transaction costs, saves time and removes conflict (Underwood, 2016; Freund, 2017). Through blockchain, smart contracts, for example, can replace lawyers and banks involved in contracts for asset deals. The workings of financial markets, especially capital markets, involve time-consuming processes, complicated procedures, high costs, and risks which could be lowered by the application of blockchain technology. For example, stock market participants such as brokers, traders and regulators have to navigate complex processes which can take days to complete transactions, due to intermediaries. Blockchain simplifies the processes by automation and decentralization (Zyskind and Nathan, 2015; Peters and Panayi, 2016; Freund, 2017). Digital assets such as contracts, shares, and stock options can be traded as smart contracts. Blockchain reduces the high costs while facilitating transactions. Blockchain therefore has huge potentials for financial markets, because it provides faster exchanges, security, trust, risk reduction, and transparency (Beck and Müller-Bloch, 2017).

4. Data and Methods

4.1. Data

This study employs quarterly data for the period 2009-2016 for the US and China. The data are extracted from the World Bank (2017) database, except the institutional variables which are from the Economist Intelligence Unit (2016) and the number of Bitcoin users which is extracted from quandl.com. The United States and China are a particularly interesting combination to study in the light of the extent of differences in financial development. Financial markets in US and China are embracing blockchain earnestly and developing capabilities in that area. China is an emerging market while the United States is a developed market. The outcomes of the study will be applicable across both emerging and developed market contexts.

4.2. The Model

The econometric model closely follows Chinn and Ito (2006), Hauner (2009) and Ayadi et al (2015). The model includes our variable of interest, blockchain technology and is specified as follows:

$$Fd_t = \theta_1 + \theta_2 Blockchain_t + \varepsilon_t \quad (1)$$

Where *Fd* is financial development; *Blockchain* is blockchain technology; and t is the year. Identification and proxies of the variables are based on the existing literature. Credit to private sector (% of GDP) and stocks traded (% of GDP) are combined to form a composite index of the development of the financial market (*Fd*) through principal component analysis (see Dogan and Turkekul, 2016; Adeola and Evans, 2017; Shahbaz, Bhattacharya and Mahalik, 2018). Similarly, number of Bitcoin users is used as the proxy for blockchain. The number of Bitcoin users are defined as persons who accessed Bitcoins in the last 24 hours. It is used as a measure of blockchain in the same manner that number of internet users is used to measure internet usage in the literature (see Vu, 2011; Evans and Adeoye, 2016; Evans, 2018c). Bitcoin is a decentralized peer-to-peer digital currency and is the most popular example using blockchain technology (Crosby et al, 2016). The literature has shown that macroeconomic variables such as GDP per capita, GDP growth, inflation, FDI, remittances and trade openness are important for financial development. Model (1) is augmented with the macroeconomic variables:

$$Fd_t = \theta_1 + \theta_2 Blockchain_t + \theta_3 Gdpc + \theta_4 Gdpgrowthd_{t-1} + \theta_5 Inflation_t + \theta_6 Fdi_t + \theta_7 Remit_t + \theta_8 Trade_{t+} \varepsilon_t \quad (2)$$

Where *Gdpc* is GDP per capita, *Gdpgrowth* is the growth rate of GDP; *Inflation* is the rate of inflation; *Fdi* is FDI; *Remit* is Remittances (% of GDP); and *Trade* is trade openness.

Further, the literature has shown that institutional variables such as government effectiveness and the rule of law are important factors for the development of financial systems. Model (2) is therefore augmented with the institutional variables:

$$Fd_t = \theta_1 + \theta_2 Blockchain_t + \theta_3 X_t + \theta_3 Gdpc + \theta_4 Gdpgrowthd_{t-1} + \theta_5 Inflation_t + \theta_6 Fdi_t + \theta_7 Remit_t + \theta_8 Trade_t + \theta_9 Goveff_t + \theta_{10} Rulelaw_t + \varepsilon_t \quad (3)$$

Where *Goveff* is government effectiveness; and *Rulelaw* is rule of law.

Identification and proxies of the variables are based on the existing literature on the determinants of financial development (Chinn and Ito, 2006; Hauner, 2009; Ayadi et al, 2015). GDP per capita controls for wealth effects. Inflation is a factor for banking development and stock market activity (Boyd et al., 2001; Evans, 2019a). FDI, remittances and trade openness are also important for financial development in the literature (Billmeier and Massa, 2009; Law and Habibullah, 2009; Seetanah et al, 2010; Aggarwal et al, 2011; Takyi and Obeng, 2013; Evans, 2019b). Institutions are also important factors for the development of financial systems (Demirgüç-Kunt and Levine, 2008) as financial managers and investors cannot operate in a vacuum, but make decisions within large and complex financial environments.

4.3. Method of Data Analysis

The method of data analysis employed is the fully modified ordinary least square (FM-OLS). The FM-OLS is a semi-parametric technique and an optimal estimator of cointegrating regressions (Breitung and Pesaran, 2008; Adeola and Evans, 2017; Evans, 2019c; Evans and Kelikume, 2019). The approach is robust to serial correlation and endogeneity. The estimates are thus robust and consistent. Further, FM-OLS can be applied to the variables irrespective of the order of integration, i.e., whether they are purely I(0), purely I(1) or mixed (Phillip and Hansen, 1990). Additional intricacies of the FM-OLS approach are detailed in Phillips and Hansen (1990) and Pedroni (1995; 2000).

The Toda-Yamamoto approach to causality technique is used to estimate the causality between blockchain and financial development. The Toda-Yamamoto causality technique is more advanced than other causality techniques such as the conventional Granger causality test (Granger, 1969). The advantage of this causality technique is that (1) it makes use of vector autoregression (VAR) rather than the conventional Granger causality test; (2) the variables do not necessarily have to be stationary; (3) the order of integration of each variable does not have to be the same, and (4) the variables do not have to be cointegrated (Toda and Yamamoto, 1995).

5. Empirical Analysis

There is considerable evidence in the literature that time series data are often non-stationary. Non-stationarity, if ignored in estimation, can lead to spurious regression. For more details on non-stationarity, see Nelson and Plosser (1982), and Chatfield (2016). To test for stationarity therefore, this study uses the Elliot, Rothenberg and Stock Point Optimal unit root test (ERS) which is more computationally robust than the traditional unit root tests such as Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests (Evans and Kelikume, 2018; Evans, 2019d). As shown in Table 1, the ERS test shows that some variables are stationary at I(0) and some at I(1), implying that the variables are a mix of *I*(0) and *I*(1) and suitable for the FM-OLS approach.

Table 1. Elliott-Rothenberg-Stock Unit Root Test

	I(0)	I(1)
Fd	3.45***	2.26**
Blockchain	6.49	1.55*
Gdpc	31.01	2.59**
Gdpgrowth	80.41	2.21**
Inflation	8.98	0.79*
Fdi	7.34	0.40*

Remit	10.71	1.42*
Trade	7.10	1.67*
Goveff	3.02***	2.04**
Rulelaw	3.37***	1.41*
	1% level	1.87
Test critical values:	5% level	2.97
	10% level	3.91

*Note: *, ** and *** significant at 1%, 5% and 10%. Lag length is selected using Spectral OLS AR based on SIC, maxlag=9.*

To use the FM-OLS approach for estimation, a cointegrating relation must first be established among the variables (Adeola and Evans, 2017; Evans, 2019e). Therefore, the Hansen Parameter Instability co-integration test is employed to test for cointegrating relationships. As shown in Table 2, the cointegrating test rejects the null hypothesis of no co-integration for the three models. This suggest that there are long-run relationships among the variables in the three models.

Table 2. Cointegration test: Hansen Parameter Instability

		Cointegrating equation deterministics: C	
		Lc statistic	Prob.[a]
Model 1	*Fd, Blockchain*	0.43**	< 0.03
Model 2	*Fd, Blockchain, Gdpc, Gdpgrowth, Inflation, Fdi, Remit, Trade*	0.88**	< 0.02
Model 3	*Fd, Blockchain, Gdpc, Gdpgrowth, Inflation, Fdi, Remit, Trade, Goveff, Rulelaw*	1.59**	< 0.01

*Note: ** significant at 5%. [a]Hansen (1992b) Lc(m2=4, k=0) p-values, where m2=m-p2 is the number of stochastic trends in the asymptotic distribution.*

Having established the presence of long-run relationships among the variables, the estimation of the models using FM-OLS is implemented as shown in Table 3 and 4. Most importantly, blockchain technology has significant and positive relationship with financial development in the two countries, meaning that the higher the levels of blockchain innovation in these countries, the more developed the financial markets. Further, GDP per capita (*Gdpc*) has significant and positive relationship with financial development. This finding confirms the results of Law and Habibullah (2009), and Takyi and Obeng (2013) who showed that real per capita income is a significant determinant of capital market and banking sector development. Also, the growth rate of GDP has significant and positive relationship with financial development. In line with Boyd et al (2001), and Demirgüç-Kunt and Detragiache (2005), inflation has negative but insignificant effects on

financial development. FDI has significant and positive effects. Consistent with Law and Habibullah (2009), and Takyi and Obeng (2013), trade openness has significant and positive effects. However, remittances have insignificant and positive effects in the US but significant and positive effects in China. Among the institutional variables, only government effectiveness has significant and positive relationship with financial development in the US while the rule of law is insignificant but positive. Both government effectiveness and rule of law has insignificant but positive relationship with financial development in China.

Table 3. Relationship between blockchain technology and financial development in the US

Dependent Variable: *Fd*

	I		II		III	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Blockchain	0.78*	0.17	0.82**	0.37	0.17**	0.08
Gdpc			1.21*	0.37	1.72***	0.86
Gdpgrowth			0.02**	0.01	0.05*	0.01
Inflation			-0.04	0.08	-0.03	0.28
Fdi			0.13*	0.03	0.12***	0.05
Remit			0.07	0.06	0.79	0.46
Trade			0.38**	0.15	0.06**	0.02
Goveff					0.23*	0.05
Rulelaw					0.42	0.17
R^2	0.74		0.97		0.97	
Adjusted R^2	0.73		0.96		0.96	

*Notes: Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth). Note: * and ** indicate 1% and 5% levels of significance.*

Table 4. Relationship between blockchain technology and financial development in China

Dependent Variable: *Fd*

	I		II		III	
	Coeff.	Std. Error	Coeff.	Coeff.	Std. Error	Coeff.
Blockchain	0.37**	0.13	0.23**	0.09	0.03	0.01
Gdpc			1.27**	0.59	0.23**	0.09
Gdpgrowth			0.16*	0.04	0.11**	0.05
Inflation			-0.13	0.17	-0.53	0.44
Fdi			0.19***	0.09	0.15**	0.06
Remit			0.46*	0.03	0.33***	0.16
Trade			0.18**	0.06	0.02***	0.01

Goveff			0.51	1.92
Rulelaw			0.53	1.33
R^2	0.67	0.82	0.87	
Adjusted R^2	0.64	0.81	0.79	

*Notes: Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth). Note: * and ** indicate 1% and 5% levels of significance.*

Cointegration among the variables, as shown above (see Table 2), suggests the existence of causality. The results of the Toda-Yamamoto tests are summarized in Table 5. The empirical results show that there is uni-directional causality between blockchain technology and financial development in the two countries. This means that while blockchain technology causes financial development, it is not caused by financial development. This shows that blockchain technology spurs financial development in the two countries.

Table 5. Toda-Yamamoto Causality Tests

Direction of Causality	The US	China
Blockchain technology ⟶ Financial development	9.71**	6.99***
Financial development ⟶ Blockchain technology	2.09	0.67

*Note: ** and *** indicate 5% and 10% levels of significance.*

6. Discussion of Results

The purpose of this study is to investigate the role of blockchain technology in financial markets, using the cases of the US and China. Although the determinants of well-developed financial markets have been studied in the past, growing blockchain technology may have inspired a new set of effects. The study is therefore different in determining the role of blockchain technology in financial markets.

The empirical evidence has shown that there is significant and positive relationship between blockchain technology and financial markets, meaning the higher the levels of blockchain innovation in these countries, the more developed the financial markets. The empirical results have also shown that there is uni-directional causality between blockchain technology and financial development, meaning that blockchain technology causes financial development in the two countries. In line with studies such as Beck et al (2016), Broby and Paul (2017), and Hofmann et al (2018), the current study has shown that the presence of blockchain innovation in financial markets can spur financial development. Blockchain innovation is therefore a positive significant factor for the proper functioning of financial markets. This finding is consistent with Buitenhek

(2016) who showed that blockchain can have profound impacts on the financial industry in terms of payments and identity services, settlements, and smart contracts. Broby and Paul (2017) also showed that blockchain can potentially expedite cheaper, more efficient and secure operations. Hofmann et al (2018) showed that blockchain enables faster and cheaper payment systems. Catalini and Gans (2016) showed that blockchain enables costless verification, lowers the costs of auditing transaction information, and allows new marketplaces to emerge.

In addition, the study has shown that macroeconomic factors are important for the development of the financial market. For example, GDP per capita has positive and significant relationship with financial development, meaning that higher levels of GDP per capita is consistent with well-developed financial markets. Similarly, the growth rate of GDP, FDI and trade openness has significant and positive relationship with the financial market. Interestingly, remittances have insignificant and positive effects in the US but significant and positive effects in China. These findings are consistent with studies in the literature (e.g., Beck and Maimbo, 2012; Huang, 2011; Voghouei et al, 2011; Takyi and Obeng, 2013) which identify factors such as political economy, and other related factors as significant factors for the financial system.

The empirical evidence has also provided some surprise findings concerning the importance of institutions in the development of the financial market. Among the institutional factors, government effectiveness has significant and positive effects on the development of the financial market in one of the countries: the US. This finding is comparable with the literature which showed that financial systems are stronger when institutions protecting and matching the needs of investors are present (Demirgüç-Kunt and Levine, 2008) and that institutional quality is a significant determinant of capital market and banking sector development (Habibullah (2009; Ayadi et al, 2015).

7. Theoretical and Managerial Implications

7.1. Theoretical Implications

While the literature has suggested positive effects of blockchain technology on the financial market (Buitenhek, 2016; Broby and Paul, 2017; Hofmann et al, 2018), this study has gone a step further and expanded the literature by empirically determining the effects of blockchain technology on the financial market in the US and China. Not only that, the study also provided new insights into the relationship between blockchain technology and the financial market by looking at the interaction effects of macroeconomic and institutional variables on the relationship between blockchain technology and the financial market. In other words, the study went beyond the inquiry of the effects of blockchain technology and the financial market and revealed the significance of macroeconomic and institutional environment in the relationship.

7.2. The Banking Industry

The study has shown that blockchain technology has positive and significant effects on the financial market. For example, by eliminating intermediaries in the banking industry, blockchain reduces transaction costs, saves time and removes conflict. It is therefore crucial for stakeholders in the banking industry to replace large chunks of current business in the industry with blockchain. Blockchain can be used to transform a number of complex intermediary functions in the industry such as identity and reputation, payments and remittances, savings, lending and borrowing, trading, insurance, risk management, audit and tax functions. It may be worthwhile for global giants such as JPMorgan Chase and Citigroup, currently investing in the technology, to embrace blockchain in order to streamline their businesses, reduce risk and transaction costs.

The case of Bitcoin illustrates the principle that blockchain can change the practice of money transactions. Using cryptography, different kinds of assets can be transferred all over the world peer-to-peer over the internet. The absence of intermediaries also upholds data security; the current practice where third parties collect personal data can imply risk of security breaches. In such cases, blockchain can be used to render third parties obsolete, thus increasing user's security. By establishing contracts using cryptography and replacing third parties, blockchain can be used to disrupt the entire transaction processes in the banking industry as well as to automatically execute contracts in a secure, transparent and cost-effective manner. In other words, blockchain can be used to decentralize most of existing forms of intermediary services. For example, interbank payments rely on complicated intermediary processes including bookkeeping, payment initiation, balance reconciliation, transaction reconciliation, etc. As well, cross-border payments require complicated clearing procedures for every country. A remittance may require nearly 3 days to arrive. These processes are lengthy and costly, demonstrating low efficiency. Blockchain technology can be used to eliminate intermediary financial institutions, which will promote service efficiency and reduce transaction costs.

7.3. Capital Markets

The workings of capital markets involve time-consuming processes, complicated procedures, high costs, and risks which could be lowered by the application of blockchain. Through blockchain, smart contracts, for example, can replace lawyers and banks involved in contracts for asset deals. Smart contracts can also be used to control the ownership of shares. Blockchain can be used to raise funds in a peer-to-peer way, through distributed share offerings. For example, in 2016, blockchain companies raised $400 million from investors and $200 million through initial coin offerings (ICO). These ICOs, rather than IPOs, are content and digital rights management platforms which make investing in ICOs and managing digital assets easy (e.g., SingularDTV, the DAO, ICONOMI, Cosmos). According to Tapscott and Tapscott (2017, p. 5): "Done right, ICOs can not only improve the efficiency of raising money, lowering the cost of capital for entrepreneurs and investors, but also democratize participation in global capital markets."

7.4. Emerging markets

If emerging markets such as China strives to develop their financial markets, it is advisable to take the lead and use blockchain to fundamentally transform the existing models of finance. For example, the banking industry in China is currently facing multiple pressures and changes, including declined profits and increased risks. Some of the pressures result from the sudden Internet finance boom which has affected traditional banking business. At this point, it will be necessary for the banking industry to tap into blockchain to accelerate service innovations, thereby adapting to changing customer demands and the competitive environments. Since blockchain is capable of transfer and asset digitization, it can be used to reconstruct the whole banking industry to increase the efficiency of clearing and settlement of financial assets transactions, while also reducing costs.

7.5. The Future of Intermediation

In financial markets in the US and China, intermediation is still the dominating solution for verifying ownership of assets and transaction processing. Intermediaries/middlemen provide information services or product brokerage. In most cases, a chain of intermediaries performs the careful checking of each involved party in a transaction. There are various intermediaries in the market, such as exchange operators, investment bankers, lawyers, auditors and crowd-funding platforms (such as Indiegogo). With the adoption of blockchain in financial markets, the role of intermediaries is at stake. Changing times have traditionally closed old doors and opened new windows, as the adage goes. In many cases, demand for intermediary services will decline. However, if it's assumed that blockchain will result in some form of decline in intermediary services, many of the intermediary services that will ultimately be displaced will be services that "no one really wants," or at the very least, services that consumers have difficulty using. For many of the current intermediaries, blockchain innovations are likely to move them to a different spot that creates more value to businesses and consumers.

8. Concluding Remarks

This study has examined the effects of blockchain technology on financial markets in the US and China for the 1977–2016 period using FM-OLS. The empirical results have shown that blockchain technology has positive and significant relationship with the financial market in the US and China. Similarly, lagged financial development, blockchain, GDP per capita, the growth rate of GDP, FDI and trade openness have significant and positive effects while inflation has insignificant and negative effects in the two countries. Remittances have insignificant and positive effects in the US but significant and positive effects in China. Among the institutional variables, only government effectiveness has significant and positive effects in the US while the rule of law is insignificant but positive. Both government effectiveness and rule of law has insignificant but positive effects in China.

Policy implications are important. The study has shown that blockchain technology has positive and significant relationship with the financial market. The implication is that, as countries strive for well-developed financial market, blockchain technology should be seen as an open door for laying the foundations of a well-developed financial market. This is particularly important for emerging markets who strive for well-developed financial markets. In view of this, policymakers and stakeholders in the financial market need to pay more attention to blockchain technology to ensure that the potential gains are fully maximized. All stakeholders have the responsibility to collaborate and develop policies and applications that can take full advantage of the benefits of blockchain to every facet of the financial market.

Blockchain technology is still new and gaining increasing prominence in financial markets. It is however apparent in this study that there are potentially empowering benefits of the technology in financial markets. Since the technology is still at an early stage, it thus requires a deeper understanding of how the potentials can be realized in financial markets. Further studies are therefore needed to consider how blockchain technology could be channeled to the real struggles people face in finance, especially within different political and cultural contexts. One blockchain may not fit all. A powerful starting point would be to build further research into the extent to which financial markets in developing countries are adopting blockchain. In this context, potentials of blockchain's usage in fostering financial inclusion may be important.

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