Financial Innovations and Blockchain Applications: New Digital Paradigms in Global Cybersociety

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Abstract Cryptocurrencies—digital assets—are discussed from the viewpoint of the medium of exchange and the store of value with a focus on Bitcoin. The issue of trust towards the unit of accounts is viewed in the perspective of historical events including fiat currency reforms in the past all over the world. It is argued that a major test of the present global financial system and its emerging new technology alternatives has not occurred yet. The notion of intrinsic value of currency is strongly attached to the stability of the social and economic system, which landscape will be probably drastically altered in the next few decades due to the rise of artificial intelligence. The chapters in this book which are focusing on the current aspects of financial innovations also point out the possible directions and dilemmas the future may bring us.

Keywords Money · Cryptoasset · Cryptocurrency · Blockchain · Currency reform · Financial crisis · Time series prediction · Machine learning

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1 Introduction

The origins of numeracy, the ability to count and work with numbers, are historically documented by archeological findings of tally sticks (Ifrah 2000). Scientific progress has always transformed the society—in the example of the tally, where the number of objects is represented by the (count of) notches on the tally stick—not only the tally served as a number representation object, it often had the transaction function of being convertible in the counted object. This has been especially the case when the tally was endorsed by a high-ranking member of the society. The material form of money, as is well known, is therefore tightly related to the current level of science and technology and goes hand in hand with trust. In our example of the tally stick money precursor, it is the trust that at a later point of time the tally can be converted to the underlying object (store of value) or would be accepted as a means of payment instead of the physical delivery of the represented goods. One feature of money the individual tally stick does not necessarily have is however the *general unit* of accounts property—the universal application of the same counting unit, i.e. the emergence of money in the modern sense of the word as a mediator of all economic transactions (see, e.g. Weatherford 1998).

The requirement for mediating all economic transactions can be met by using a highly marketable asset, which first naturally appeared in the form of grain or livestock, before it was substituted with precious metals. The latter step would not be possible without social hierarchy in which the objects of desire were set by the upper class that controlled the community and the use of its technology. About three thousand years ago in China, bronze models replicating cowrie shells appeared as money (Kerr 2013). In the Iron Age, coins minted from precious metals that represented the notion of economic value appeared in the ancient Mediterranean area (Pavlek et al. 2019), where system of a commodity-based legal tender has prevailed through the medieval times. Our discussion this far was based on the history of numeracy and its relation to money; however, numeracy goes hand in hand with literacy. Promissory notes to deliver money, based on trust and the legal system framework, have first been documented in China during the Han dynasty (von Klaproth 1823), and first precursors of paper money appeared as early as in the seventh century during the Tang dynasty (Pickering 1844). This abstraction of financial value from the underlying value of coin metal asset decoupled the trust in the economic system from the asset value of the legal tender—money went even more abstract and modern currencies were born. Still, the promissory note feature of paper money by the obligation to convert banknotes to gold on demand persisted in the world for quite a long time—convertibility of US dollar to gold was officially terminated by the US President Richard Nixon as late as in 1971 (cf. Zoeller and Bandelj 2019). Instead, the national motto "In God We Trust" on the US dollar banknotes illustrates the truth of the incomplete human control framework and the uncertain future that has been a part of money notion since its inception.

Whom is it therefore that we trust considering the store of value function of fiat currencies? A mainstream answer would perhaps emphasize the role of the government and the role of the central bank in each country; in today's interconnected world, a true cyberworld of computerized financial system, perhaps also a rising global financial order. In the gold standard world, it was the Bretton Woods system at global scale; at present, various institutions influence the dynamics of the intertwined competing world financial system, such as the International Monetary Fund, the World Bank, but also European Central Bank, Asian Infrastructure Investment Bank, and others, based on the region and viewpoint.

What does money mean today? Here is the quotation of Petr Sýkora, co-founder of the charitable foundation Good Angel in the Czech Republic (Petka 2013):

> Money today is just stored as the ones and zeros in a computer system. It does not have to be there tomorrow…

Let us take Czechoslovakia as a historical example how a sudden currency reform can ruin personal savings—there is an infamous quotation by a local spokesman of communist party in the city of Pilsen (May 29, 1953) (Ule 1965)

> Our currency is firm. Trust the party, Comrades. The rumors about a reform have no justification…

followed the next day by the official public announcement of currency reform on May 30th, 1953, which largely deprived the population of cash and bank savings and resulted in local rebellions against the regime. The conversion rates of the old currency to the new one varied from 1:5 to 1:50, based on the amount; the government also realized a bankruptcy as the obligation from all government bonds to their holders was cancelled.

Since currency reforms feature nonlinear conversion between the old and new currency based on the deposited amount leading to arbitrary relocation of financial resources (Krishna and Leukhina 2019), they are popular with totalitarian regimes such as the one during the socialist regime period in Czechoslovakia. Similar loss of savings occurred in Russia during the currency reform of the summer 1993 which wiped out the value of savings of general population using a combination of conversion restrictions with high rate of inflation (cf. Desai 2005).

The global financial crisis of 2008 has resulted in trillion dollar losses all over the world, be it in the house value and related personal mortgage bankruptcies when the US housing bubble burst; or the evaporated retirement savings of US citizens; the extreme losses of European Banks that naively propelled the sub-prime mortgage financial derivative prices; in brief the whole world sank into an aftermath, a recovery from which has been particularly long and painful in Europe (cf. Farmer 2012).

The above-mentioned currency reforms and financial crises serve us here to claim that the probability of major disruption in the time value of fiat currencies, even if it were to be once in a lifetime—is not negligible. Times of hyperinflation, such as the current one in Venezuela, attest to the loss of public trust in the official currency, and the need for an alternative solution—be it a foreign currency, a commodity, or, as we discuss in the next section—perhaps even a cryptocurrency.

2 Algorithmic Innovations in Digital Finance

Money in the world moves to the cyberspace by getting digital form. The consequences of such a change include detailed expenditure and revenue traces in databases of financial institutions, and the shift towards the cashless society, a trend especially pronounced in Scandinavian countries such as Sweden, where cards and mobile apps in smartphones are by far the most common means of payment. Proposals for citizen accounts directly with the central bank are also popular as discussed in the following.

2.1 Fiat Currencies—Pros and Cons

When a fiat currency goes completely digital, which has not yet occurred in the world nevertheless, the central financial institution gains the technical means to cut each individual off the economic system. They also gain the full financial record of individual behavior. Information has become the most valued commodity of our times and its possession results in power. This asymmetric relation of an individual and the financial institution may be convenient when privacy is protected, and general security measures function but turns to a disaster in cases of successful cyberattacks. It is in the very nature of the trusted bookkeeping party that digital money cannot be proved completely secure. Technically, redistribution of financial wealth can easily be implemented by altering the financial records according to any algorithm deemed as legal, be it for instance (nonlinear) negative interest rates to fight deflation in the form of instantaneous currency reforms using central bank digital currency (Bindseil 2019). As the sophistication of the digital financial systems increases, the risks associated with the malfunction of the centralized financial system gradually deepen.

2.2 Cryptocurrencies—Pros and Cons

The year 2008 is not only known for the Great Recession; it is the year when a breaking article entitled "Bitcoin: A Peer-to-Peer Electronic Cash System" published under the name of Satoshi Nakamoto appeared (Nakamoto 2008). The work solved the double spending problem of digital money—how to guarantee that digital money is not spent several times—by publishing the ever-growing entire record of all transactions protected by encryption in the form of blockchain. According to Nakamoto, "The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work". Incentive to maintain the cryptographic integrity of the blockchain is given by rewarding the creator of the new block with a fixed amount of Bitcoin (mining process) or by using transaction fees. As long as the majority of the computational nodes participates in the blockchain consensus mechanism,

the system is robust to attackers possibly attempting to alter the blockchain records (Nakamoto 2008). The distinguishing features of Bitcoin as cryptocurrency are the lack of any regulatory financial institution, fixed supply of coins, and availability of the complete record of all transactions among (in principle anonymous) addresses.

Bitcoin has found its place in the alternative financial system and remains the leading cryptocurrency. As of January 26, 2020, the price of Bitcoin in USD is about 8367 and the market capitalization is 152 billion USD, out of 230 billion for the entire cryptocurrency market with thousands of altcoins (Coinmarketcap 2020). The major reservation against Bitcoin and cryptocurrencies based on the same concept is that they do not have any underlying economic value unlike from fiat currencies. In other words, the lack of trust in the financial system of fiat currencies which are prone to political etc. interventions should not necessarily imply trust in such an ad hoc built digital asset. The highly fluctuating values of Bitcoin prices over time and various cryptocurrency exchanges attest to the fact that Bitcoin intrinsic value is not in the goods and services available in an economy for which it would be a legal tender. To date, the decentralized nature of Bitcoin has yet to gain its broader acceptance among the public. Cryptocurrencies also face the environmental problem of enormous power consumption for the hash calculations that bear a substantial carbon footprint. The criticisms as well as expectations can be summarized in the following two quotations on Bitcoin (CNBC 2018, 2019).

> Bitcoin has no unique value at all.
>
> —Warren Buffet

> There will be one online equivalent to gold, and the one you'd bet on would be the biggest.
>
> —Peter Thiele

This book treats various aspects of cryptocurrency markets, ranging from efficiency, proportion of informed traders, arbitrage opportunities in short- and long-time span, predictability with machine learning algorithms, causality in the cryptocurrency exchange rate time series, etc. We purposefully leave the issue of the social acceptance of Bitcoin and cryptocurrencies in general open to the future.

2.3 Time Series Analysis of Fiat Currencies and Crypto Assets

In order to analyze dynamics of asset prices, including digital assets, the available theoretical models typically rely either on statistics (econometric algorithms, cf. (Martin et al. 2012), such as the GARCH model of volatility (Bollerslev 1986)) or more recently booming methods of machine learning in data science. These algorithms, such as the Elman Recurrent Neural Network in the past (Elman 1990), or more recently Long Short-Term Memory Network (LSTM) (Hochreiter and Schmidhuber 1997) and its derivatives are motivated from the developments in the field of Natural Language Processing (cf. Sagheer and Kotb 2019). Predictions beyond the

level of random coin tossing can then be used in algorithmic trading, for instance for dynamic portfolio management. A recent hot topic, focused on the spatial structure of the underlying economic subjects, such as banks or firms, is network science (cf. Barabási 2016), which builds on the network structure models and algorithms for sets of objects connected by edges. Such a formalism allows to study the propagation of initial network shocks, or estimate parametric features distinguishing the behavior of various groups in the economic models. The next section provides examples of such approaches in the following chapters of this book.

3 Financial Technologies and Cryptocurrency Markets

In the first part of the book, there are four chapters related to general financial topics, such as portfolio selection, asset price prediction, and network structure of default risk among financial institutions.

Jun Sakazaki and Naoki Makimoto in Chapter "Financial Contagion Through Asset Price and Interbank Networks" study propagation of shocks caused for instance by regulatory effects through different topologies of network structures. They vary the composition of banks' portfolio and observe its effects upon outbreaks and spreads of a financial contagion.

Adeola Oyenubi in Chapter "Optimal Portfolios on Mean-Diversification Efficient Frontiers" uses genetic algorithm, an evolutionary computing method, for obtaining mean-variance efficient frontiers and portfolios that optimize the trade-off between returns and risk measures.

Ken Matsumoto and Naoki Makimoto in Chapter "Time Series Prediction with LSTM Networks and Its Application to Equity Investment" use the Long and Short-Term Memory algorithm from among the recent recurrent neural network methods to conduct an empirical stock return prediction study for TOPIX Core 30 with applications to portfolio selection problem.

Masato Hisakado and Takuya Kaneko in Chapter "A Response Function of Merton Model and Kinetic Ising Model" consider the contagious defaults of banks created by a network structure based on lending and borrowing relations. In their mathematical description built on a model originating from physics they show that the thermodynamic notion of temperature can be attributed to asset volatility.

The second part of the book contains eight chapters related to crypto-assets, and Bitcoin in particular, focusing on features ranging from security and major player identification through the analysis of crypto-asset forks, cointegration models of crypto-currency time series, triangular arbitrage, estimates of proportion of informed traders, and other advanced topics.

Naoyuki Iwashita in Chapter "Bitcoin's Deviations from Satoshi's World" examines the reasons why Bitcoin has not yet become a major means of payment, focusing on the security issues, and making the point of the difficulty that that ordinary investors cannot manage their secret keys in a secure way.

Yoshi Fujiwara and Rubaiyat Islam in Chapter "Hodge Decomposition of Bitcoin Money Flow" study how money flows among users of Bitcoin based on an algorithm that partially identifies anonymous users from addresses, and construct a dynamic directed graph of Bitcoin transaction flow. Graph theory then serves them as a tool understand the dynamics on the complex network of Bitcoin transactions, including some indirect consequences on Bitcoin price in the exchange markets.

Takeshi Yoshihara et al. in Chapter "Time Series Analysis of Relationships Among Crypto-asset Exchange Rates" investigate market efficiency (Fama 1970, 1991) in crypto-asset exchange rates through the application of several kinds of unit root tests and the Johansen procedure. They also elucidate the causal relation between the cryptocurrency exchange rates and the foreign exchange rates.

Zheng Nan and Taisei Kaizoji in Chapter "The Optimal Foreign Exchange Futures Hedge on the Bitcoin Exchange Rate: An Application to the U.S. Dollar and the Euro" propose the use of FX futures to hedge the risk of currency exchanges based on the bitcoin exchange rate. The time-dependent optimal hedge ratio for the resulting portfolio is calculated from the conditional covariance matrix of the two returns.

Lukáš Pichl et al. in Chapter "Time Series Analysis of Ether Cryptocurrency Prices: Efficiency, Predictability, and Arbitrage on Exchange Rates" compute the Hurst exponent for Ether(eum) related time series, explore the predictability margin of daily returns with Support Vector Machine based techniques, and compute the triangular arbitrage characteristics between Ether and fiat currency pairs selected from among USD, JPY, GBP, EUR, CNY, and CAD.

Ping Chen Tsai and Shou Huang Dai in Chapter "Estimating the Proportion of Informed Traders in BTC-USD Market Using Spread and Range" identify a proxy—a spread-to-range ratio—for the unobserved proportion of informed traders in a market based on the classic Glosten-Milgrom model. They show that for a USD-BTC market the proportion of the informed traders can be as high as 6%.

Vasily Derbentsev et al. in Chapter "Forecasting of Cryptocurrencies Prices Using Machine Learning" use the machine learning algorithms of Binary Auto Regressive Trees, Random Forests, and Artificial Neural Network for short-term prediction of three crypto-assets with major capitalization.

Walter Bazán-Palomino in Chapter "Bitcoin and Its Offspring: A Volatility Risk Approach" examines the risk-return relationship between the return on Bitcoin and the returns on its forks (Litecoin, Bitcoin Cash, Bitcoin Gold, Bitcoin Diamond, and Bitcoin Private). He provides the evidence that there is a transmission of the risk from Bitcoin forks to Bitcoin.

4 Summary and Outlook

In this book, we have collected a number of articles from finance with a focus on the recently trending topic of crypto-currencies or crypto-assets. We believe these are of broad general readership interest. The future will show whether crypto-assets are a

viable option to fiat currencies, or rather an obscure portfolio diversification complement, or even a dead-end outcry of blockchain technology. Nevertheless, given the excitement, tensions and controversies that recently accompanied the announcement of planned introduction of the Facebook's Libra digital currency or the project of digital yuan in China, we feel the time is ripe for further substantial breakthrough brought by information technology-based innovations in finance.

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