Canan Eryiğit* - Mehmet Eryiğit†

THE DIFFUSION PROCESS OF BITCOIN

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Abstract

This article reports the results of an investigation of the diffusion of cryptocurrencies. The Bass diffusion model is used to estimate the diffusion patterns of Bitcoin. In addition, the size and time intervals of adopter categories are examined. The unit of analysis is quarterly data of new wallets. The data covered 37 quarterly observations for the periods from the last quarter of 2011 to the second quarter of 2020. The parameters of the Bass model are estimated through Ordinary Least Squares (OLS) estimations. The diffusion curve of Bitcoin is developed based on the estimated parameters. The results indicate that the diffusion of Bitcoin has passed early adoption and takeoff periods and is close to maturity. The estimated diffusion process indicates that innovators, early adopters, early majority, late majority, and laggards had adopted Bitcoin. The findings may guide communication decisions with different types of investors and government regulation plans.

JEL CLASSIFICATION: G40; M30; O16; O30.

KEYWORDS: INNOVATION DIFFUSION; CRYPTOCURRENCY; BITCOIN; BASS MODEL; ADOPTER CATEGORIES.

* Hacettepe University, Department of Business Administration, Hacettepe University, Ankara, Turkey. Email canand@hacettepe.edu.tr.
† Bolu Abant Izzet Baysal University Department of Business Administration, Bolu Abant Izzet Baysal University, Bolu, Turkey. Email: eryigit_m@ibu.edu.tr.
1. Introduction

Blockchain technology has changed the financial system and business operations through the creation of cryptocurrencies. Cryptocurrencies have garnered the attention of investors (Giudici et al., 2020) by offering an alternative to existing payment and saving methods. Accordingly, the cryptocurrencies market has reached $194 billion market capitalization by 2020. There were 412 wallets in January 2012, whereas almost 46 million wallets existed by March 2020.1

The literature on cryptocurrency has been increasing, mainly focusing on Bitcoin (Giudici et al., 2020). However, the cryptocurrency research field is regarded as being in the early stages of growth (Caporale & Plastun, 2019; Park & Park, 2020). Generally, studies have focused on the following issues: price and volatility of cryptocurrencies (Caporale & Plastun, 2019; Ciaian et al., 2016; Li and Wang, 2017; Salamat et al., 2020), relationships across cryptocurrencies (Dey et al., 2020; Ji et al., 2019; Kyriazis, 2019; Yi et al., 2018), security, and regulations (Andriole, 2020; Grobys et al., 2020). An examination (Giudici et al., 2020) of the Scopus database showed that the studies on cryptocurrencies are primarily from the areas of computer science, engineering, and mathematics. The share of the studies in the areas of social sciences (Economics, Econometrics & Finance and Business, Management & Accounting) is lower. Therefore, the literature mostly focused on the technical side of cryptocurrencies.

However, understanding the characteristics of the market and users in the market is essential for developing regulations and expansion plans for cryptocurrency. Regarding this notion, there are a few studies (Mazambani & Mutamba, 2019; Zhao et al., 2020) examining the diffusion process and the factors affecting the adoption of cryptocurrencies. Most of these studies were conducted at the individual level as they focus on the adoption behavior of individual investors. However, a market-level understanding of the development of cryptocurrencies is essential. Estimating the diffusion rate and trends is important in assisting critical decisions, such as the timing of technology modification, appropriate communication channels with potential investors, and the cost of mining. In addition, digital currencies create value; only people are willing to use them for transactions and exchange purposes (Mas & Chuen, 2015). Accordingly, understanding the adoption of cryptocurrencies is crucial.

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1 www.coinmarketcap.com, accessed April 16, 2020
cryptocurrencies and how it is diffused in the market is crucial for valuation. However, we were unable to identify an empirical study presenting a comprehensive view of the market. Park & Park (2020) also supported this gap, indicating the lack of a holistic picture of the market with quantitative data.

Based on these points, this study aims to investigate the diffusion process of Bitcoin through innovation diffusion models. Thus, the remainder of the article is organized as follows. In the following section, we examine the cryptocurrency market and innovation diffusion models, along with a review of empirical studies. Afterwards, the methodology of the study with the details of the model and data is examined. The findings of the study are presented and discussed in the last section, which concludes the article.

2. Conceptual Framework

2.1. Cryptocurrencies

"Cryptocurrencies are peer-to-peer electronic cash systems that allow online payments to be sent directly from one party to another without going through a financial institution" (Corbet, Lucey, Urquhart, & Yarovaya, 2019:182). In other words, cryptocurrencies are peer-to-peer digital transfers without any certification of third-party institutions (Giudici et al., 2020). In total, 12 cryptocurrencies (such as Ripple, Litecoin, EOS) currently have market capitalization values greater than $170 billion. Those currencies, in total, constitute 89% of the total cryptocurrency market. However, more than five thousand cryptocurrencies exist. The prices of those cryptocurrencies have ranged from $0.000085 (the price of WİNq on 15.04.2020) to $6794 (the price of Bitcoin on 15.04.2020). These cryptocurrencies can be traded in over twenty thousand different markets². BTC is the leading cryptocurrency. Hence, the market capitalization of Bitcoin is $124 billion by 2020, representing 64% of the total market. Ethereum is the second-largest cryptocurrency, representing 9% of the overall market with a market capitalization value of $17 billion. Bitcoin, a type of cryptocurrency, is defined as a "purely digital record of ownership over a certain quantity of monetary value" (Mas & Chuen, 2015). Bitcoin (BTC) represents value as it

² www.coinmarketcap.com, accessed April 16, 2020
is tradable through a Bitcoin network (Mas & Chuen, 2015).

Despite this growth in the market, it is stated that the adoption of cryptocurrencies remains in its infancy due to technological, societal, and governmental barriers (Schipor, 2019). The regulations and market penetration of cryptocurrencies constitute severe uncertainties (Hui et al., 2020).

On the other hand, cryptocurrencies may be regarded as safe heavens due to the following characteristics: independence from monetary policy, a role as a store of value, and limited correlation with traditional assets (Conlon & McGee, 2020). Additionally, BTC provides some benefits to users. It offers fast transactions at lower costs, even for cross-border transfers (Nian & Chuen, 2015). In addition, BTC transactions are more secure due to transaction verification. The systematic verification process eliminates the chances of disputes occurring (Salamat et al., 2020). Accordingly, BTC transactions are irreversible, which also prevents fraud in the chargeback process. In addition, Bitcoin prevents identity theft because transactions do not require personal information. On the other hand, there is a likelihood of private key theft. BTC is also accepted to have the potential for future innovations (Nian & Chuen, 2015).

2.2. Innovation Diffusion Models

The diffusion of innovation has been defined as "the process by which that innovation is communicated through certain channels over time among the members of a system" (Rogers, 1983). In other words, "the theory of diffusion of innovations explains how, why, and at what rate new ideas and technology gains momentum and diffuses through a social system" (Vincent & Evans, 2019:261). Innovation diffusion models can be used to identify the adoption rate and to forecast the future adoption of an innovation. Additionally, these models are used to develop adopter categories that are generated based on consumers' time of adoption (Rogers, 1983).

The Bass (1969) diffusion model has been widely used to forecast the adoption of new products (Kavak & Demirsoy, 2009). According to the model, the probability of the adoption of a new product at time \( t \) is an increasing linear function of the number of previous adopters. The Bass diffusion model proposes that potential adopters of an innovation are influenced by two means of communication: mass media communication and word of mouth communication. Accordingly, the model categorizes adopters
into two categories: innovators who are affected by mass media communication and imitators who are influenced by word of mouth communication. In the model, the coefficient of innovation measures the effect of mass media communication, and the coefficient of imitation measures the impact of word of mouth communication (Bass, 1969; Bass & Bultez, 1982).

The other widely used diffusion model is the model offered by Rogers (1983). The Rogers diffusion model assumes that diffusion of a new product follows a normal distribution. It is possible to determine five adopter categories, namely, innovators, early adopters, early majority, late majority, and laggards, by using the mean and standard deviation of the distribution (Rogers, 1983). Mahajan, Muller, & Srivastava (1990) combined Bass and Rogers models to generate adopter categories. Many studies (Adams et al., 2019; Bridges, E., & Ellis, 1997; Mahajan et al., 1990; Martínez & Polo, 1996; Reinhardt & Gurtner, 2015) have been devoted to identifying and describing adopter categories. Those studies examined various variables to understand the characteristics of adopters, such as demographic variables, socioeconomic variables, product-specific variables, and personality values (Kavak & Demirsoy, 2009).

Diffusion models have been applied to various product categories from tangibles to services, as well as financial innovations. Studies have generally investigated the diffusion process of durable innovations, such as electric vehicles (Li et al., 2017; Massiani & Gohs, 2015), medicines (Dunn et al., 2012), consumer durables (Martínez & Polo, 1996), automobiles (Meir, 1981; Xia, 2017), and personal computers (Mahajan et al., 1990). The validity of the Bass model was also supported for services, such as mobile communication and mobile services (Chandra & Yadav, 2013; Kumar et al., 2007) and health services (Bridges, E., & Ellis, 1997). Moreover, studies have employed various types of diffusion models to estimate adoption levels, such as compartmental diffusion models, microlevel models, and technology substitution models (Abedi, 2019; Kumar, 2015; Laciana et al., 2013).

Diffusion models have also been validated for financial innovations in a few studies. For instance, Kavak & Demirsoy (2009) studied the diffusion of online banking in Turkey and showed that the Bass model fits well with the data. Similarly, Srivastava et al. (1985) used diffusion models to forecast the adoption of investment alternatives. The diffusion pattern of investment funds
was also examined using diffusion models (Marszk et al., 2017). In addition, Marszk & Lechman (2018) investigated the diffusion of exchange-traded funds (ETFs) in Japan and South Korea using diffusion models. They extended their study to 32 emerging and developed countries in their further research (Marszk & Lechman, 2019). Another study (Mare et al., 2019) investigated the diffusion process of life insurance among Romanian consumers.

There are also studies focusing on the adoption and diffusion of blockchain technology or cryptocurrencies. For instance, Janssen et al. (2019) investigated the factors affecting the adoption of cryptocurrencies. Their review of 31 papers showed three main factors influencing the adoption of cryptocurrencies, namely, institutional factors, technical factors, and market factors. Institutional factors are norms and culture, regulations and legislation, and governance. Technical factors include information exchange and transactions, distributed ledgers, and shared infrastructure. Market factors affecting the adoption of cryptocurrencies cover market structure, contracts and agreements, and business process. Mazambani & Mutambara (2019) investigated the factors that influence the intention to adopt cryptocurrencies in accordance with the theory of planned behavior. The study was conducted on 269 students who are regarded as potential users of cryptocurrency. The results indicate that attitude and perceived behavioral control significantly positively influence adoption intention, whereas subjective norms have an insignificant negative effect. Zhao et al. (2020) investigated the adoption of blockchain technology in China with the use of online resources and interview methods. The study covered various types of investors ranging from Bitcoin investors to financial companies and governments. The results revealed that blockchain technology had evolved three stages of technology adoption: embryonic, early growth, and growth. Another study (Wang et al., 2016) investigated the blockchain maturity model and its adoption process and offered a three-stage adoption model, including feasibility study, development and operation phases.

The studies mentioned above examined the individual adoption behavior of cryptocurrency or blockchain technology. Thus, they provided evidence for individual-level adoption. Research on Bitcoin development and diffusion at the market level is lacking. Accordingly, this study aims to examine the diffusion process of Bitcoin. Regarding the studies (Kavak & Demirsoy, 2009; Mare et al., 2019; Marszk & Lechman, 2019; Srivastava et al., 1985) that applied diffusion models to financial innovations, diffusion of Bitcoin can be
estimated with the use of diffusion models.

3. Analytical Expressions

We defined the diffusion process of cryptocurrencies based on the Bass model and estimated the model by employing the following formulas (Schmittlein & Mahajan, 1982). Accordingly, the adoption rate at time \( t \) can be expressed as follows:

\[
f(t) = \frac{dF(t)}{dt} = [p + qF(t)] [1 - F(t)]
\]

(1)

\( F(t) \): the cumulative fraction of adopters at time \( t \), \( f(t) \): the noncumulative fraction of adopters at time \( t \), \( p \): the coefficient of innovation, \( q \): the coefficient of imitation.

\[
n_t = \frac{dN(t)}{dt} = p[m - N_t] + \frac{q}{m} N_t[m - N_t]
\]

(2)

\( N(t) = mF(t) \): cumulative number of adopters at time \( t \), \( n(t) = mf(t) \): noncumulative number of adopters at time \( t \), \( m \): potential number of adopters

\[
n(t) = pm + (q - p)N_{t-1} - \frac{q}{m} N_{t-1}^2
\]

(3)

\[
n_t = \alpha_1 + \alpha_2 N_{t-1} + \alpha_3 N_{t-1}^2
\]

(4)

\[
\alpha_1 = pm
\]

(5)

\[
\alpha_2 = q - p
\]

(6)

\[
\alpha_3 = -\frac{q}{m}
\]

(7)

The Bass model proposes that “the probability that an initial purchase will be made at \( T \) given that no purchase has yet been made is a linear function of the number previous buyers” (Bass, 1969:216). Accordingly, the adoption rate and the number of adopters can be estimated via equations (1) and (2). Rearrangement of equation (2) yields equations (3 - 4). Regression analysis is used to estimate the regression coefficients \( \alpha_1, \alpha_2, \) and \( \alpha_3 \) in equation 4. After regression coefficients are identified, \( p, q, \) and \( m \) can be estimated (Mahajan et al., 1990) using equations (8-10).

4. Data
The unit of analysis in diffusion models is the first purchase of the new product. In other words, adoption is measured as the first purchase (Bass & Bultez, 1982). Concerning this information, the study used the number of new wallets at a specific period as the first purchase. "Bitcoin wallets are software applications that facilitate the process of buying, selling, and managing one's Bitcoins" (Mas & Chuen, 2015). In other words, a user needs to store his Bitcoin in a wallet to be able to buy and sell them (Nian & Chuen, 2015). An individual holding a new wallet can be regarded as adopting the cryptocurrency since wallets function as storage of cryptocurrencies. Accordingly, the number of adopters equals the number of new wallets in each period.

We used the data for the new wallets of Bitcoin. Although different currencies are present in the market, these currencies were introduced to the market at different times. Thus, they are in different stages of diffusion (Papadimitriou, 2019).

The quarterly data was gathered from quandl.com. Thus, we used the new wallets assigned every three months. The data covered 37 quarterly observations for the periods of the last quarter of 2011 to the second quarter of 2020.

5. Results

The parameters of the Bass diffusion model were estimated by employing formulas 2 - 4. The ordinary least squares (OLS) estimation of equations 2 - 4 yielded the results presented in Table 1. According to the results (see Table 1), the Bass diffusion model has a satisfactory fit with an $R^2$ value of 0.76. Accordingly, $a_1 = 4.26E+04$, $a_2 = 0.2207585$, $a_3 = -3.78E-09$. 

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The diffusion process of bitcoin

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Table 1. OLS Estimation of the Bass Diffusion Model

<table>
<thead>
<tr>
<th>Coef.</th>
<th>Std. Err.</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_1$</td>
<td>4.26E+04</td>
<td>.23</td>
<td>.817</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>0.2207585</td>
<td>8.32</td>
<td>.000</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td>-3.78E-09</td>
<td>-6.45</td>
<td>.000</td>
</tr>
</tbody>
</table>

Sources: developed by the authors

Regression coefficients of $\alpha_1$, $\alpha_2$, and $\alpha_3$ can be used to estimate parameters $p$, $q$, and $m$.

\[
p = \frac{\alpha_1}{m}
\]

\[
q = -m\alpha_3
\]

\[
m = \frac{-\alpha_2 - \sqrt{\alpha_2^2 - 4\alpha_1\alpha_3}}{2\alpha_3}
\]

Employing these formulas resulted in the following parameter estimates:

$\ p$ (the coefficient of innovation) = .00073,

$\ q$ (the coefficient of imitation) = .2115.

The estimated values of $p$ and $q$ indicate that the adoption of Bitcoin is internal-dominant given that $q > p$ (Dunn et al., 2012). According to the estimated parameters of the model, the cumulative adopter distribution for Bitcoin is presented in Figure 1.

Figure 1. Cumulative Adopter Distribution

Sources: developed by the authors
As shown in Figure 1, the diffusion of Bitcoin is consistent with the general S-shaped diffusion pattern. The general pattern of diffusion constitutes a period of slow increase at the beginning, which is called the early adoption or incubation period. This period is followed by more rapid growth, which is referred to as the take-off period. Afterwards, the number of adopters increases at a decreasing rate due to growth slowdown. This period is followed by maturity and saturation or plateau (Lechman 2015 as cited in Marszk & Lechman, 2019). According to Figure 1, Bitcoin has passed early adoption and takeoff periods. The diffusion is close to the maturity period, indicating that the rapid improvement has ended and that growth has slowed down.

We also estimated the size and time interval for adopter categories by employing the following formulas (Mahajan et al., 1990):

\[ F(T^*) = \frac{1}{2} \cdot \frac{p}{2q} \]  
\[ F(T_1) = F(T^*) - \frac{1}{\sqrt{12}}x \left( 1 + \frac{p}{q} \right) \]  
\[ F(T_2) = F(T^*) + \frac{1}{\sqrt{12}}x \left( 1 + \frac{p}{q} \right) \]  
\[ T_1 = -\frac{1}{p + q} \ln \left( \frac{1}{(2 + \sqrt{3}) \frac{p}{q}} \right) \]  
\[ T_2 = -\frac{1}{p + q} \ln \left( \frac{1}{(2 + \sqrt{3}) q} \right) \]  
\[ T^* = -\frac{1}{(p + q)} \ln \left( \frac{p}{q} \right) \]  

Then, the size of adopter categories can be calculated as follows (Mahajan et al., 1990):

Innovators = \( p \)  
Early adopters = \( F(T_1) - p \)  
Early majority = \( F - F \)  
Late majority = \( F - F \)  
Laggards = \( 1 - F \)

Estimated time intervals and sizes of adopter categories are presented in Table 2 and Figure 2. Accordingly, up to \( t_{19.8} \), the number of adopters increased rapidly, and this increase continued until \( t_{25.7} \). In other words, the market grew
at an increasing rate until $t_{25.7}$. Later, the market increased slowly, and the number of adopters decreased at a decreasing rate.

### Table 2. Estimated Time Intervals and Size of Adopter Categories

<table>
<thead>
<tr>
<th>Adopter Category</th>
<th>Time Intervals</th>
<th>Size of Adopter Category (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovators</td>
<td>$T_0$ to $T_1$</td>
<td>$0$ to $19.8$</td>
</tr>
<tr>
<td>Early adopters</td>
<td>$T_1$ to $T^*$</td>
<td>$19.8$ to $25.7$</td>
</tr>
<tr>
<td>Early majority</td>
<td>$T^*$ to $T_2$</td>
<td>$25.7$ to $31.7$</td>
</tr>
<tr>
<td>Late majority</td>
<td>Beyond $T_2$</td>
<td>Beyond $31.7$</td>
</tr>
<tr>
<td>Laggards</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: developed by the authors

According to the sizes of adopter categories presented in Table 2 and Figure 2, innovators constitute a minor share in the market (.073%). The early adopters who adopted cryptocurrencies until $t_{25.7}$ represent approximately 21% of the market. The early majority constituted approximately 29% of the market.
market and adopted cryptocurrencies between \( t_{25.7} \) and \( t_{31.7} \). The late majority also constituted approximately 29% of the market, and these investors adopted cryptocurrencies after \( t_{31.7} \). The laggards started to invest in cryptocurrencies after \( t_{31.7} \) and covered almost 21% of the market.

6. Conclusion

In this study, the diffusion process of Bitcoin was analyzed employing the diffusion of innovation models. For this purpose, diffusion patterns, time intervals, and the size of adopter categories were identified for the quarterly data covering 2011-2020.

The estimation of the Bass diffusion model revealed that Bitcoin diffusion has passed the takeoff period, and market growth has slowed down. Accordingly, the diffusion of Bitcoin is close to the maturity period and market saturation. Then, less volatility in Bitcoin prices may be expected in the near future given that the more familiar is, the greater the likelihood of a less volatile Bitcoin value (Nian & Chuen, 2015).

Based on the phase of the diffusion process, different categories of adapters ranging from early adopters up to laggards are currently investing in the market. The estimated diffusion process of 37 periods indicated that innovators, early adopters, early majority, late majority, and laggards had adopted Bitcoin.

Consequently, interpersonal interaction has a prominent role in the diffusion process. However, estimated coefficients showed that Bitcoin is an internal-dominant innovation. Therefore, the likelihood of adopting cryptocurrencies independently from other investors is low. The internal-dominant characteristic of Bitcoin is consistent with the uncertainty associated with Bitcoin (Hui et al., 2020) and herding behavior. In herding, investors watch and imitate better-informed investors when high uncertainty is present (Giudici et al., 2020).

Thus, Bitcoin is adopted and grows by word of mouth communication. Accordingly, the increasing number of investors in cryptocurrencies and the higher earnings of those investors may encourage imitators who are risk averse. This notion is consistent with the view that a "fear of missing out," which is relevant for conventional assets, may also be valid for Bitcoin (Bouri et al., 2019). Consequently, positive posts on social media may play an essential role in the diffusion rate. Previous studies have suggested that the words and emotional content of social media influence investors (Nguyen et
al., 2020) and cryptocurrency prices and volumes (Burnie & Yılmaz, 2019; Wolk, 2019). In addition, social media users are interested in the currency exchange system and favor technology application issues (Park & Park, 2020).

The internal-dominant nature of the cryptocurrency may be due to illegal circulation and speculative actions. For instance, one-half of Bitcoin transactions (46%) are associated with illegal activity (Foley et al., 2019). Therefore, regulations ensuring cyber safety may diminish the perceived risk and may subsequently increase the rate of diffusion. However, laws and treatment toward cryptocurrencies vary across countries. Some countries consider cryptocurrencies as digital money, and others treat them as commodities. On the other hand, some countries forbid cryptocurrencies (Janssen et al., 2020).

Thus, the diffusion process is sensitive to government actions. Acceptance of cryptocurrency as an official transaction method may create a new peak or takeoff phase in the diffusion curve. Additionally, strict regulations on capital flows may lead people to Bitcoin to move money out of the country (Shahzad et al., 2019). Therefore, governments may have a positive role as regulators of the rate of speed of adoption. This notion is consistent with continual cocreation, indicating that innovation occurs through multiple cycles of diffusion and institutionalization (Vargo et al., 2020).

The study is not without limitations. Diffusion models use first purchases as a unit of analysis. Thus, we used the new wallets as first purchases. However, the same investor may have a new wallet in a different exchange market. It is not possible to discover the repetitiveness with the existing, reachable data sources. Additionally, the study focused on the diffusion, not the market growth, of Bitcoin. Accordingly, it should be noted here that the number of new wallets is not a predictor of the trade volume and market size. Future studies may examine market growth by estimating the product life cycle of Bitcoin. Thus, the growth of new wallets at a decreasing rate does not represent the trends in market size. In addition, the present study focused solely on the diffusion process of Bitcoin. Since Bitcoin is the leading currency and cryptocurrencies are highly correlated (Papadimitriou, 2019), this study findings may be generalized for cryptocurrencies. However, the diffusion process of other cryptocurrencies may still be examined in future studies. Moreover, the factors affecting the diffusion rate may be examined in future studies. Some of these factors may include social media, governmental
actions, and return on cryptocurrency.

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