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The explosion in cryptocurrencies: a black hole analogy

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Abstract

Using an analogy between finance and astrophysics, this study aims to investigate whether there exists a mechanism that can describe the explosive increase in the number of traded cryptocurrencies and the cryptocurrency market in general. In physics, the Schwarzschild radius indicates that black holes are constantly expanding because of their mass increase. Enriching this analogy, we consider the cryptocurrency market as a self-gravitational body whose mass is denoted by (1) the number of traded cryptocurrencies and (2) in terms of increasing market capitalization for a given number of traded cryptocurrencies. By analyzing weekly snapshot data of all traded cryptocurrencies from January 4, 2009, to June 14, 2020, we find evidence that the above-mentioned mechanism exists. The results clearly indicate the self-gravitational property of the cryptocurrency market, which is direct evidence toward the hypothesis that the changes in the traded cryptocurrencies are a positive function of the previous period's number of traded cryptocurrencies.

Keywords: Bitcoin, Cryptocurrencies, Econophysics, Negative specific heat, Thermodynamic disequilibrium

JEL Classification: G14, G15, G23

Introduction

The financial market universe comprises a wide set of assets that offer potential investors almost countless investment opportunities. New financial assets and instruments are formulated or developed periodically, which ultimately attracts capital and attention. The latest example is the cryptocurrency market, which started in 2009 with the then exotic, relative, and mysterious—but now well-known—Bitcoin (Nakamoto 2008). The emergence of the cryptocurrency market has merited a rapidly growing and robust academic literature, as shown by the systematic analysis of Xu et al. (2019). However, this study does not focus on the standard research issues relevant to the cryptocurrency market because they tend to overlook other equally important phenomena. Corbet et al. (2019) outlined that both quantitative and non-quantitative research on the cryptocurrency market is available, with the latter mostly focusing on regulation (Böhme et al. 2015; Hendrickson and Luther 2017), cybercriminality (Chao et al. 2019; Li et al. 2020; Vandezande 2017), and efficiency (Roth 2015). Regarding the quantitative analyses, as shown by Corbet et al. (2019), many extant studies on cryptocurrencies have

concentrated on market efficiency (Urquhart 2016; Vidal-Tomás and Ibañez 2018; Wei 2018; Neves 2020) and asset pricing bubbles (Cheah and Fry 2015; Corbet et al. 2018). Furthermore, other research areas, such as unusually high returns and the high volatility of the cryptocurrency market (Feng et al. 2018; Katsiampa 2017; Jalali and Heidari 2020), along with the herding behavior (Bouri et al. 2019; Vidal-Tomás et al. 2019; Ballis and Drakos 2020) and contagion (Antonakakis et al. 2019) related to it, are generally well-known in both academia and practice.

However, nonprofessionals are most likely not aware of the exponential expansion of the number of traded cryptocurrencies. To gauge this expansion, the following can be considered. At the birth of the cryptocurrency market, the number of cryptocurrencies was equal to one and remained at that level until April 17, 2011. Subsequently, the number of traded cryptocurrencies started to soar, reaching the value of 50 on August 4, 2013, while it increased to 500 by October 26, 2014, and further increased to 1500 by February 25, 2018; it currently (as of June 14, 2020) stands at 2,670 traded cryptocurrencies (source: CoinMarketCap). In other words, since its birth, the cryptocurrency market has exhibited a 266,900% increase in terms of the number of traded currencies. It is difficult to think of another economic and/or financial phenomenon with an equivalent increase rate over a decade, possibly with the exceptions of the Tulip Mania (1619–1622) and the Mississippi Bubble (1716–1719).

Therefore, our focus is on the mechanism that can describe the observed behavior of the explosive increase in the number of traded cryptocurrencies using an analogy between finance and astrophysics, where the new cryptocurrency market is considered to represent a celestial body belonging to the universe of financial assets. According to Newton's universal gravitation law, in physical systems, a body exerts a gravitational force to its surroundings that is proportional to its mass (i.e., bodies with greater mass exhibit higher gravity). A certain class of bodies, known as self-gravitational bodies, has the natural tendency to be in thermodynamic disequilibrium owing to their negative specific heat status (Thirring 1970; Zia et al. 2002); thus, their gravitational force increases, leading to a spiral where increases in the mass further reinforce the gravitational force.

For instance, a similar phenomenon is observed for black holes. When a star dies, it collapses inward rapidly. The fact that the radiation in its core ceases to exist leads to gravity pushing in extreme volumes. Consequently, the star explodes into a supernova (Woosley and Weaver 1986), which is a catastrophic expulsion of its outer material (Lohnes 2018), leading the dying star into a continuum of collapse until it becomes a singularity (zero volume, infinite density). These singularities are the dead centers of black holes leading them to be “objects” with extreme gravity volumes that can even bend spacetime (Hawking 1975). At the edge of a black hole, or the event horizon (Hawking 1973), as it is called, an astronomical time deceleration is present. Karl Schwarzschild (1916) identified the limit at which gravity triumphs over the other physical forces, creating a black hole. Today, we call this number the Schwarzschild radius, which is expressed as

$$R_s = \frac{2GM}{c^2},$$

where G is the gravitational constant, M is the mass of the black hole, and c is the speed of light. The Schwarzschild radius indicates that black holes are constantly expanding because of the mass increase.

For celestial bodies, the definition of mass is clear. However, from a financial/economics perspective, defining the appropriate measure of mass is not a straightforward exercise. Therefore, we consider the cryptocurrency market as a self-gravitational body. Our initial conjecture was considering the notion of mass based on the number of traded assets, which corresponds to the extensive margin in economics terminology and measures horizontal market expansion. However, it is plausible that the gravitational force may not solely lead to the creation of new cryptocurrencies, but instead attract more capital toward the already existing traded cryptocurrencies.¹ To operationalize this notion, we consider a different potential proxy for mass in terms of increasing market capitalization for a given number of traded cryptocurrencies. The rationale is that, apart from a horizontal expansion, a vertical expansion might also exist. To capture this vertical expansion, we resort to the intensive margin at any given point in time, defined as the total market capitalization divided by the total number of traded assets.

If the cryptocurrency market exhibits increasing entropy due to its negative specific heat, there exists a testable implication in its behavior. In particular, the mass of the cryptocurrency market, as captured by the number of traded cryptocurrencies (according to our first hypothesis regarding the definition of mass) at a point in time, determines its gravitational force. Then, the testable hypothesis is that, as the mass of the market (the number of traded cryptocurrencies) increases, the gravitational force increases, and, consequently, more cryptocurrencies are born (traded) in the next period. Accordingly, the same notion and testable hypothesis apply to the second definition of mass, denoted by the intensive margin.

Despite the rapidly growing academic literature on cryptocurrencies, to the best of our knowledge, such a phenomenon has not been formally investigated. This is exactly the gap of the academic literature that our analysis aims to fill, by investigating and measuring whether there exists a mechanism that can describe the explosive increase in the number of traded cryptocurrencies. The remainder of the paper is structured as follows. “[Data and empirical methodology](#)” section describes the dataset and provides a review of the models deployed in the analysis. “[Empirical results](#)” section presents and discusses the empirical findings. Finally, “[Conclusions](#)” section concludes.

Data and empirical methodology

The data are weekly snapshots of all traded cryptocurrencies from January 4, 2009, to June 14, 2020 (source: CoinMarketCap), for a total of 598 observations. Since April 17, 2011, when the second cryptocurrency made its appearance, the number of traded cryptocurrencies started to increase, as depicted in Fig. 1.

M_t denotes the number of cryptocurrencies traded at time t , where t spans the period from 2009 to 2020 at weekly intervals, and ΔM_t represents the change in the number of cryptocurrencies.

¹ We would like to thank one of the anonymous referees for pointing out this issue.

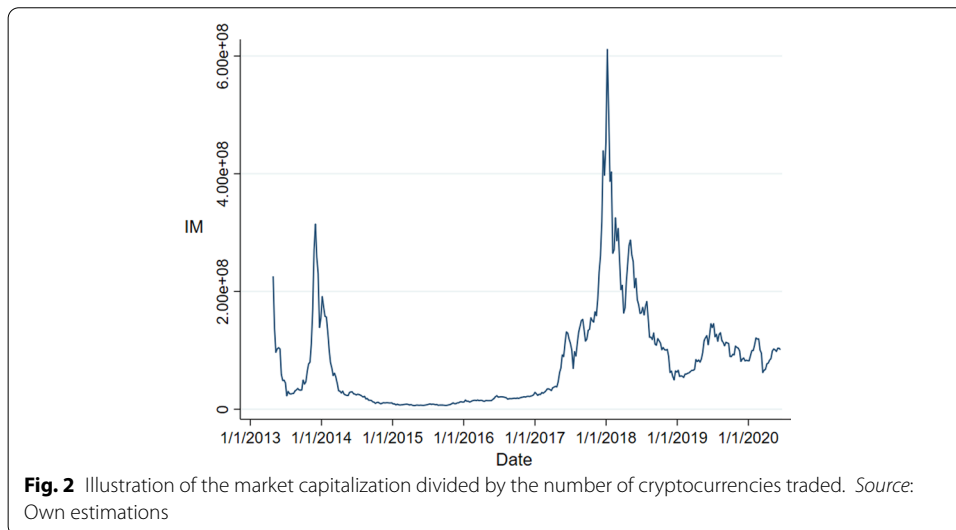
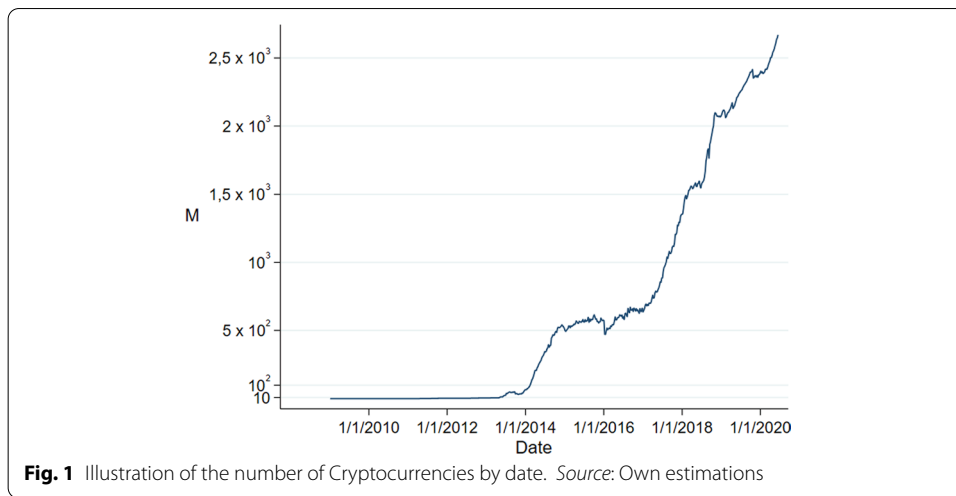


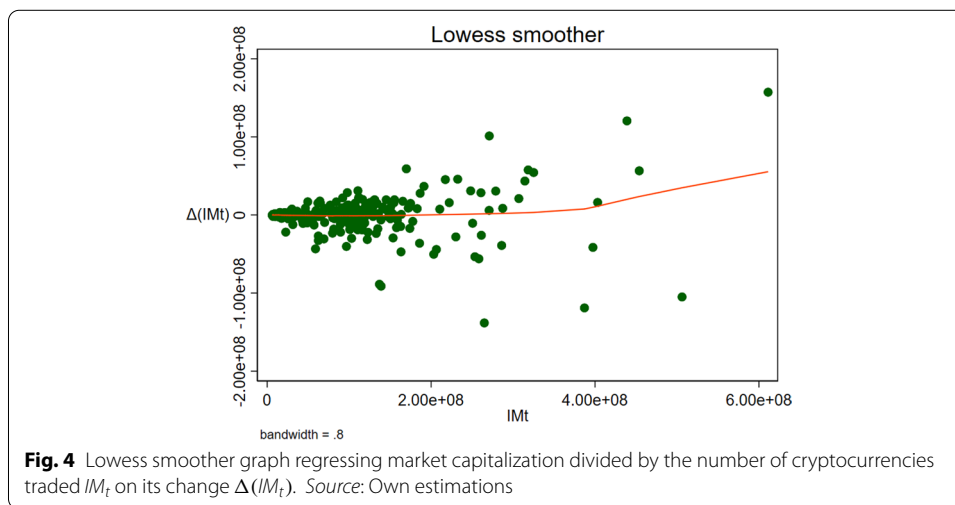
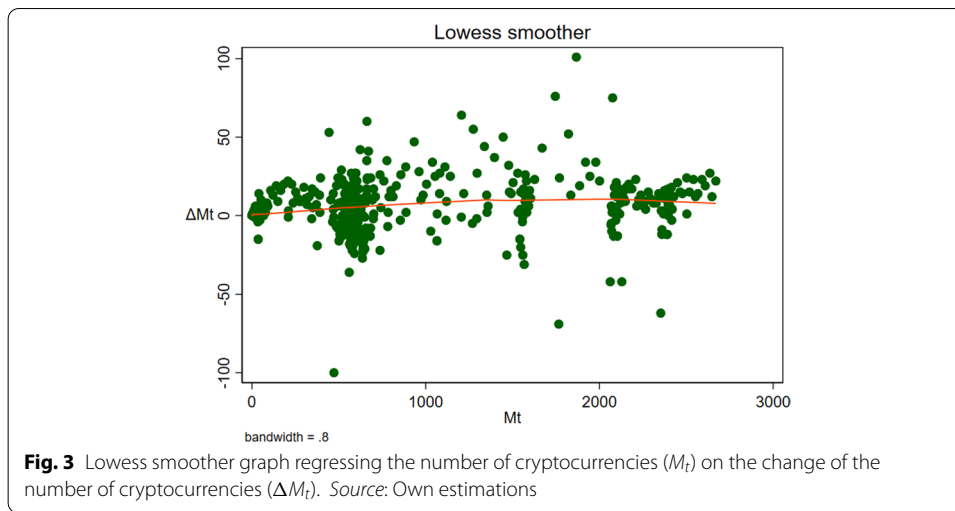
Figure 2 depicts the intensive margin, as market capitalization divided by the number of traded cryptocurrencies.

IM_t denotes the market capitalization divided by the number of cryptocurrencies traded at time t , where t spans the period from 2013 to 2020 at weekly intervals, and $\Delta(IM_t)$ is the change.

In Figs. 3 and 4, the lowess smoother graphs show a positive relationship between the above-mentioned parameters.

If the cryptocurrency market possesses a self-gravitational property, we expect that its gravitational force increases with mass. This behavior translates in a testable hypothesis, where the change (ΔM_t) in the number of traded cryptocurrencies should be a positive function of the previous period's number of traded cryptocurrencies (M_{t-1}):

$$\Delta M_t = a + \beta * M_{t-1} + u_t, \quad (1)$$



where a and β are the estimable parameters and u_t is a well-behaved disturbance term. Furthermore, our prior compatible with the self-gravitational property is that $\beta > 0$. Therefore, the testable hypothesis is formulated as

$$H_0 : \beta = 0,$$

$$H_1 : \beta > 0.$$

Accordingly, the second testable hypothesis is that the change $\Delta(IM_t)$ in market capitalization divided by the number of traded cryptocurrencies should be a positive function of the previous period (IM_{t-1}):

$$\Delta(IM_t) = \gamma + \delta * IM_{t-1} + u_t, \quad (2)$$

where γ and δ are the estimable parameters and u_t is well-behaved disturbance term. In this case, the testable hypothesis is formulated as

Table 1 Estimation results of $\Delta M_t = \alpha + \beta * M_{t-1} + u_t$

	α	β
Coef	1.5751* (0.7609)	0.0044*** (0.0007)
t-statistic	2.07	6.06
p value	(0.039)	(0.000)
Obs	R-squared	Adj R-squared
597	0.0581	0.0565

(***), (**), (*) denotes that the coefficient is significant at the 1%, 5%, 10% level

Table 2 Estimation results of $\Delta(IM_t) = \gamma + \delta * IM_{t-1} + u_t$

	γ	δ
Coef	2,531,778 (1,545,242)	-0.0356** (0.013)
t-statistic	1.64	-2.74
p value	(0.102)	(0.006)
Obs	R-squared	Adj R-squared
372	0.0199	0.0172

(***), (**), (*) denotes that the coefficient is significant at the 1%, 5%, 10% level

$$H_0 : \delta = 0,$$

$$H_1 : \delta > 0.$$

Here, $\beta = 0$ implies that the growth of traded cryptocurrencies does not depend on the past number of traded cryptocurrencies. If $\beta > 0$, the growth increases as the number of previous period's cryptocurrencies is higher. The same applies for the second notion regarding mass and $\delta = 0$ and $\delta > 0$.

The estimation of and inference for the above unknown parameters is a straightforward exercise provided that the variables are stationary. However, from the previous section, M_t and IM_t are clearly non-stationary; therefore, the standard asymptotic theory does not apply. Coincidentally, the models above [Eqs. (1) and (2)] are identical to the standard Dickey–Fuller formulation (Dickey and Fuller 1979).

Empirical results

Equations (1) and (2) were used to assess whether the cryptocurrency market possesses a self-gravitational property. If so, as previously stated, it is expected that the market's gravitational force will tend to increase with its mass. Tables 1 and 2 report the results for our models using ordinary least squares estimations.

In the first specification, where ΔM_t is the dependent variable, we find that the main parameter of interest (β) is positive and statistically significant at the 1% level.

In the second specification, where $\Delta(IM_t)$ is the dependent variable, we find that the main parameter of interest (δ) is negative and statistically significant at the 5% level.

Based on Eq. (1), which allows to draw conclusion about the stationarity of M_t , our findings show that the past level of M_t exerts a positive impact on the change in the number of cryptocurrencies (ΔM_t). By contrast, the results of Eq. (2) suggest that the past level of IM_t does not only exert a positive impact but also exerts a negative

impact on $\Delta(IM_t)$ based on the point estimates. Therefore, based on our empirical findings, even if the notion examined above is plausible, it is not in operation. Furthermore, the negative sign indicates that the intensive margin does not only act as a gravitational force in the sense that more capital goes toward existing cryptocurrency assets. However, even if more capital is attracted, it is diffused over a growing number of assets. Insofar, the number of traded currencies is a manifestation of mass, meaning our results are compatible with the notion that the cryptocurrency market possesses a self-gravitational property.

Conclusions

This study aimed to assess for the first time, to the best of our knowledge, whether a mechanism exists that can describe the observed behavior of the explosive increase in the number of traded cryptocurrencies. The testable hypothesis was that, as the mass of the market [number of traded cryptocurrencies in Eq. (1) and market capitalization in Eq. (2)] increases, more cryptocurrencies are created (traded) in the next period [Eq. (1)], and more money are attracted onto the market [Eq. (2)]. The analysis was based on weekly data of the number of existing cryptocurrencies, along with their market capitalization.

From our results, we can infer that such a mechanism exists. This study identified a statistically significant positive β (0.0044) coefficient, indicating a self-gravitational property, which is direct evidence toward the hypothesis that the change (ΔM_t) in the number of traded cryptocurrencies is, in fact, a positive function of the previous period's number of traded cryptocurrencies (M_{t-1}). Additionally, we found a statistically significant negative δ (-0.0356); this indicates that not only does the intensive margin act as a gravitational force of the additional capital toward existing cryptocurrency assets but also is a clear indicator that new capital is diffused over a growing number of assets. One possible explanation is that market capitalization and, subsequently, IM_t are only demand driven, whereas the number of cryptocurrencies—denoted as M_t —considers both demand and supply. In summary, these results are in agreement with our initial analogy that the cryptocurrency market is in a state of thermodynamic disequilibrium.

A fruitful and promising expansion of these results relates to improving the measurement of thermodynamic disequilibrium by the direct usage of entropy measures.

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Authors' contributions

AB: conceptualization, formal analysis, writing, review and editing, data curation, software. KD: conceptualization, formal analysis, writing and editing, project administration, supervision. Both authors read and approved the final manuscript.

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Availability of data and materials

The selected database to be considered by the model was built with data found in CoinMarketCap (<https://www.coinmarketcap.com>). The data on which this study is based refer to weekly snapshots of all traded cryptocurrencies from January 4, 2009 to June 14, 2019.

Competing interests

The authors declare that they have no competing interests.

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