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Abstract

This paper deals with explosiveness of four leading cryptocurrency prices: Bitcoin, Ether, XRP, and Litecoin. The main contribution is that this paper not only analyses the prices of these cryptocurrencies expressed in US Dollars, but also the price of the latter three expressed in Bitcoin. Evidence of explosive periods is found not only in all cryptocurrency prices in US Dollars, but also when XRP and Ether are expressed in Bitcoin. These latter periods, however, are found to be in the first half of 2016 and 2017, respectively, but not during the price peak period of Bitcoin exhibited around the turn of the year 2017/2018. Whether or not these explosive periods can be interpreted as cryptocurrency bubbles requires a sufficient understanding of the fundamental value of cryptocurrencies. This paper draws a parallel to the discussion on the fundamental value of fiat money according to which it is essential whether or not money is used for transactions or as speculative object. As long it is unclear what fundamental value of cryptocurrencies is, the term bubble should be used with more caution.

Keywords: Cryptocurrencies, Bubbles, Explosiveness, Fundamental value, Intrinsic value, Fiat money

JEL-Classification: C12, C22, E42, E52, G12

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1 Introduction

Motivated by frequent enormous price increases cryptocurrencies such as Bitcoin exhibit, a lively debate emerged whether or not there are cryptocurrency bubbles. This paper contributes to this discussion by applying a popular test for (temporary) explosiveness. In addition to testing for explosiveness in the prices of the leading cryptocurrencies Bitcoin, Ether, XRP, and Litecoin expressed, as conventional, in US Dollars, this paper also analyses the price of the latter three currencies expressed in terms of Bitcoin.[1] Thus, this paper also investigates whether or not a stable relationship exists between prices of different cryptocurrencies; or, in other words, if prices changes of the different currencies follow the same pattern and extent. The results can be summarised as follows: First, evidence for temporary explosiveness is found in prices of all currencies under consideration expressed in US Dollars. This finding is largely in line with the existing literature. However, the price of both Ether and XRP is also found to be temporarily explosive even if expressed in terms of Bitcoin. This means that the price changes of these two cryptocurrencies are disproportionally larger than changes in Bitcoin prices in the respective periods. It is worth highlighting that this feature is only observed during earlier cryptocurrency episodes in the first half of 2016 and 2017, respectively, but not during the price peak period of Bitcoin exhibited around the turn of the year 2017/2018. The price of Litecoin expressed in Bitcoin, in contrast, does not show this peculiar behaviour.

[1] Ether and XRP are the cryptocurrencies generated by the platforms Ethereum and Ripple, respectively.

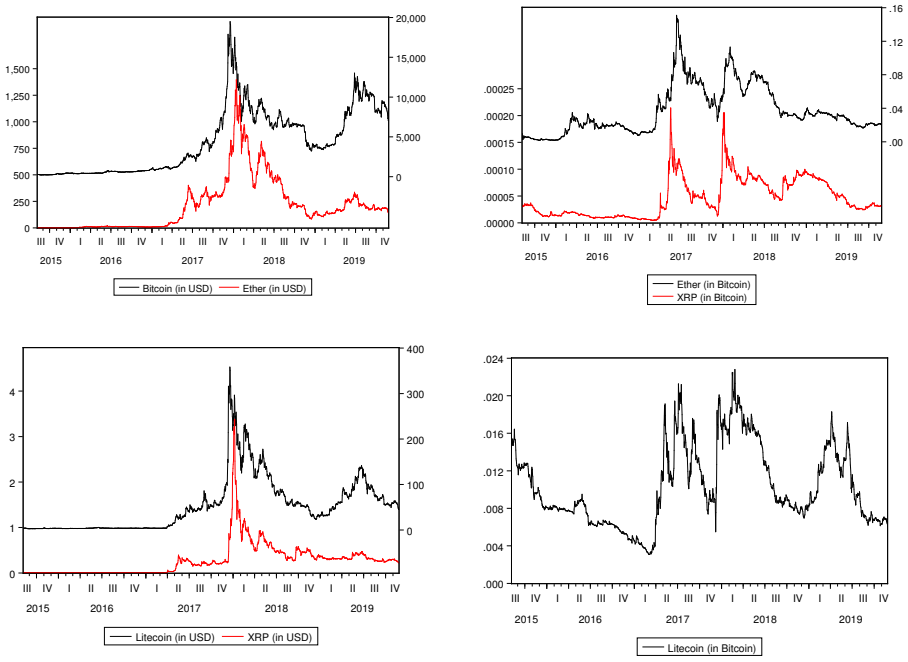
This paper also discusses what this analysis allows one to say regarding bubbles in cryptocurrencies. As a bubble is conventionally defined as an asset price that diverges from its fundamental value (Diba and Grossman, 1988), the essential question in this context is the following: what is the fundamental value of a cryptocurrency? This question has been insufficiently addressed in the existing literature. However, as cryptocurrencies share with fiat money the feature of having a value despite the fact that their respective intrinsic values are zero, a parallel can be drawn to the discussion on the fundamental value of money. According to Tirole's (1985), "fundamentalist view", for instance, money must be a store of value if it is used for transactions. Thus, it is essential whether or not a cryptocurrency is used for transaction or speculative purposes. However, Bolt and van Oordt (2019) state that not much is known about the actual number of payments in cryptocurrencies for goods and services. The implication of this is that, unless a better understanding of the fundamental value of cryptocurrencies has been achieved, the term bubble should be used with more caution.

2 Testing for explosiveness

Bitcoin emerged in 2009; followed by various other cryptocurrencies. Drastic increases in the value of many of these cryptocurrencies occur very frequently. Figure 1a presents the prices of Bitcoin, Ether, XRP, and Litecoin; all expressed in US Dollars.[2] This phenomenon motivated many to empiri-

[2]Period of observation: 07/08/2015-25/11/2019; all data from www.coinmarketcap.com.

Figure 1: Cryptocurrency prices expressed in US Dollars and in Bitcoin



(a) Cryptocurrency prices in US Dollars

(b) Cryptocurrency prices in Bitcoin

cally test for the existence of bubbles in cryptocurrency prices.[3]

Carefully inspecting Figure 1a yields that price hikes of these currencies seem to occur simultaneously. This is not surprising insofar as cryptocurrencies are largely considered speculative assets, and, thus, all price changes follow the same overall pattern. For this reason it would not be implausible to assume that there is a more or less stable relationship between these price series. However, Figure 1b vividly illustrates that this is not the case.

[3]See e.g. Cheung et al. (2015). See Section 3 for a delailed discussion of this literature. It is an offshoot of a recently emerged enormous empirical literature on Bitcoin and other cryptocurrencies; see Gronwald (2019) for one of the most recent contributions. That paper also provided a comprehensive overview of the literature.

Presented are the price of XRP, Ether, and Litecoin expressed in terms of Bitcoin.[4] It is evident that these price series is far from stable. There are certainly rather horizontal movements in some periods such as 2016 and the second half of 2018, but also drastic changes in these series. These changes occurred during similar periods as those the cryptocurrencies expressed in US Dollar exhibited drastic increases. To summarize, even though the pattern of the price changes is overall similar, there are considerable differences in their extent across cryptocurrencies. These price series are now analysed using Phillips et al.'s (2011) well-established SADF test. Hence, this paper's analysis of the relationship between cryptocurrency prices contributes to an offshoot of the cryptocurrency literature which so far has has focussed on issues such as volatility spillovers and volatility connectedness; see e.g. Yi et al. (2018).

This standard procedure consists of a forward recursive application of an augmented Dickey-Fuller unit root test. The null of a unit root is tested against the alternative of an explosive root. Thus, the following equation is estimated:

$$x_t = \mu_x + \delta x_{t-1} + \sum_{j=1}^{J} \phi_j \Delta x_{t-j} + \epsilon_{x,t}, \quad \epsilon_{x,t} \sim \text{NID}(0, \sigma_x^2). \tag{1}$$

The hypothesis H_0: $\delta = 1$ is tested against the alternative H_1: $\delta > 1$.[5] Initially, a subset of the sample with $\tau_0 = nr_0$ observations is used. In each

[4] By expressing Ether, XRP, and Litecoin in terms of Bitcoin, it is assumed that the most polular and oldest cryptocurrencies, Bitcoin, is the leading cryptocurrency.

[5] Note that this is a standard unit root test except for the formulation of the alternative hypothesis. Rather than testing the null of a unit root against a stationary alternative, the alternative in this case is explosive.

subsequent regression, this subset is supplemented by successive observations, giving a sample of size $\tau = nr$ for $r_0 \leq r \leq 1$. This procedure yields a sequence of t-statistics with corresponding p-values. These sequences are used to identify origination $\hat{r}_e$ and collapse dates $\hat{r}_f$ of explosive behavior in the data:

$$\hat{r}_e = \inf_{s \geq r_0} \{s : \mathrm{ADF}_s > \mathrm{cv}_{\beta_n}^{\mathrm{adf}}(s)\}$$

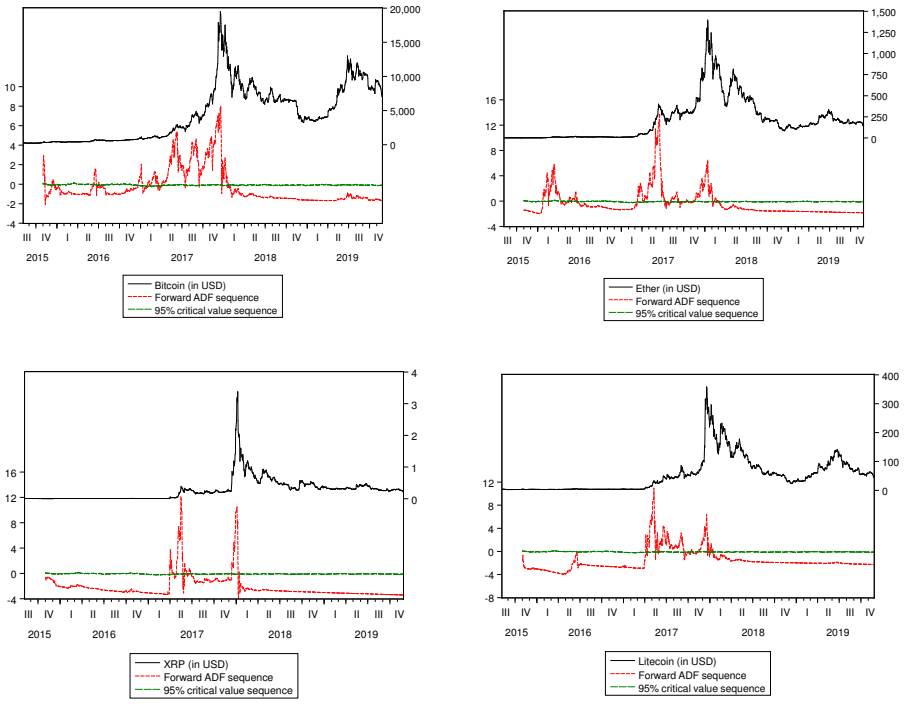
$$\hat{r}_f = \inf_{s \geq \hat{r}_e} \{s : \mathrm{ADF}_s < \mathrm{cv}_{\beta_n}^{\mathrm{adf}}(s)\}$$

where $\mathrm{cv}_{\beta_n}^{\mathrm{adf}}(s)$ stands for the critical value.[6]

Figures 2 and Figure 3 present the results. Each panel displays the ADF sequence as well as the critical values for a cryptocurrency quoted in US Dollars (Figure 2) and in Bitcoin (Figure 3). It is evident that all cryptocurrency prices expressed in US Dollars exhibit temporary phases of explosiveness, in particular in 2017. This finding is generally consistent with the extant literature. What is more, evidence of temporary explosiveness is also found in the prices of XRP and Ether expressed in Bitcoin. However, these periods are found to be only in early stages of 2017, and, in addition, in early 2016, but not during the price peak period of Bitcoin at the turn of the year 2017/2018. The interpretation is the following: the prices of XRP, Ether and Bitcoin are generally following the same pattern; however in certain periods the prices of XRP and Ether are explosive even if expressed

[6] In the empirical application, the critical values are simulated usung the Monte Carlo technique; see Phillips et al. (2011).

Figure 2: Tests for explosiveness: Bitcoin, Ether, XRP, and Litecoin expressed in USD

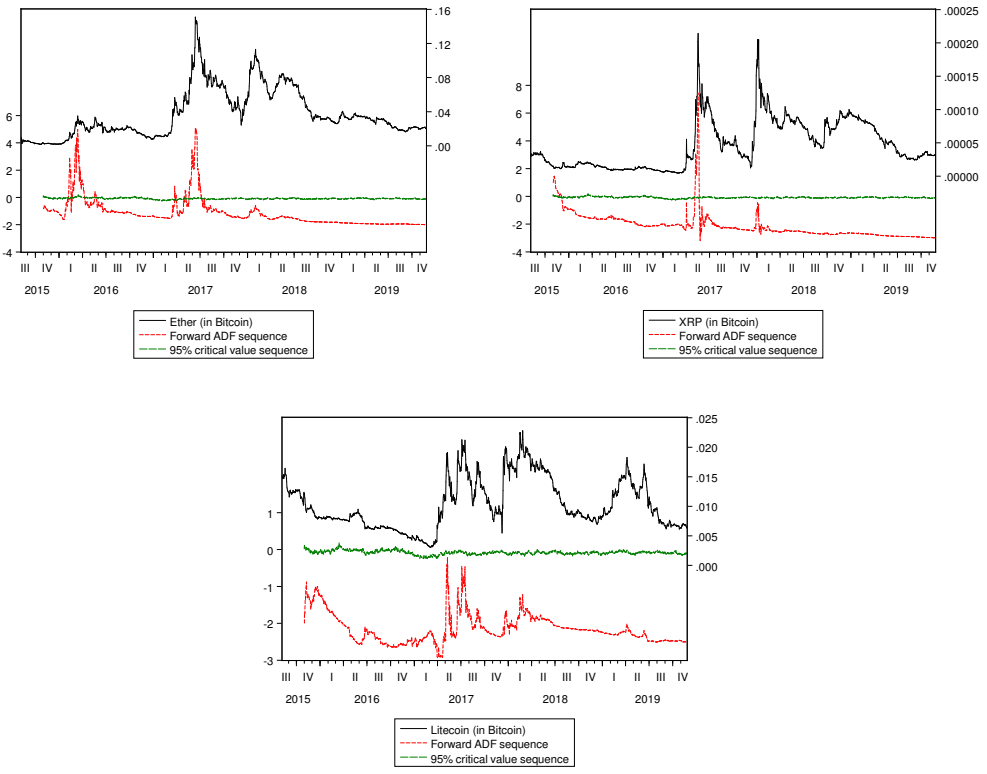


in terms of Bitcoin. This reflects that in these periods the change in XRP as well as Ether prices are disproportionally larger than change in Bitcoin prices. It is worth highlighting that the price of Litecoin does not exhibit this idiosyncratic behaviour.

3 Discussion

This section discusses to what extent the findings obtained in Section 2 allow one to draw conclusions regarding the existence of cryptocurrency bubbles. Centre stage in this discussion takes the notion that any analysis of an as-

Figure 3: Tests for explosiveness: Ether, XRP, and Litecoin expressed in Bitcoin



set price bubble requires sufficient knowledge about the fundamental value of the respective asset. It has been asserted above that the existing literature on cryptocurrency bubbles insufficiently addresses this issue. The following two examples further illustrate this. The early contribution by Cheung et al. (2015) also applies Phillips et al.'s (2011) popular procedure and finds evidence of a cryptocurrency bubble. The essential question of the fundamental value is addressed in this paper but circumvented by referring to the common assumption that explosiveness is a key feature of price

bubbles. This procedure ignores the possibility that also the fundamental value of an asset can change drastically; see e.g. Gronwald's (2016) analysis of the crude oil market. Phillips et al. (2011) themselves highlight that explosive price behavior can be caused by "rational responses to economic fundamentals". Cheah and Fry (2015) also find evidence of cryptocurrency bubbles. In addition, they employ an empirical procedure to estimate the fundamental value of Bitcoin and find that this value is equal to zero. This is problematic insofar as this fundamental value is derived from observed prices and not based on any economic theory. It should also be noted that some papers are more careful in this regard. Corbet et al. (2018), for instance, undertake the attempt to explicitly take the fundamental value into account; their approach is based on blockchain position, hashrate, and liquidity. They construct three measures that are supposed to capture "key theoretical components of cryptocurrency pricing structures". Bouri et al. (2018), in addition, emphasize that, due to the lack of clarity in this issue, an analysis if a cryptocurrency is not possible; they focus only on explosiveness. The innovative aspect of that paper is that they analyse so-called co-explosivity between Ether and Bitcoin prices.

This literature in specific and the literature on asset price bubbles in general goes back to Diba and Grossman (1988). These authors define a bubble as a deviation of an observed price from its market fundamental. Diba and Grossman (1988) are concerned with stock market bubbles and follow the notion that discounted stream of expected future dividends reflects the fundamental value of stock prices. In empirical studies such as Phillips et al. (2011), actual dividend data is used. In other words, the fundamental

value is not only based on economic theory, it is also measurable using financial market data.[7]

As asserted above, cryptocurrencies share with fiat money the feature that both have a positive value despite the fact that their respective intrinsic values are zero. Most of the studies cited above acknowledge that. This essentially reflects Ali et al.'s (2014) assertion that "digital currencies have meaning only to the extent that participants agree that they have meaning". Hence, a parallel can be drawn to the discussion about the fundamental value of money. Tirole's (1985) seminal paper, for instance, states that the market fundamental of money is equal to the present discounted value of transaction savings, and is, thus, based on theoretical economic considerations. Tirole (1985) summarises his discussion in the so-called fundamentalist view: if money is used for transactions, it must be a store of value, and, in that case, there is no bubble on money. Starr (1974) offers an alternative view by stating that money is needed to pay income tax and, thus, there cannot be a bubble on money. Tirole (1985) and also Stiglitz (1990) certainly also state that, if money is only held for speculative purposes and not for transactions, there is a bubble in money.[8] Some of these arguments reappear in the recent paper by Bolt and van Oordt (2019). They show that the value of cryptocurrencies is determined by three components two of which

[7] It is important to note that Diba and Grossman (1988) discuss two empirical procedures to identify (rational) bubbles: one is based on the order of integration and, thus, statistical properties of observed prices; the other on testing for cointegration between observed price and fundamental value. However, also the former is based on the fundamental equation that observed prices consists of a fundamental component as well as a bubble component.

[8] Tirole (1985) discussion of Flood and Garber (1980) shows that bubbles in money are difficult to detect.

are the value of transactions in that currency and decisions by forward-looking investors (that affect supply of the currency).[9] They, however, also state not much is known about the actual number of payments in virtual currency for goods and services. Worth highlighting is Bolt and van Oordt's (2019) "hypothetical Bitcoin exchange rate in the absence of speculation". The finding that this rate substantially deviates from the actual exchange rate should be seen as evidence of a Bitcoin bubble. It should also be noted, however, that this hypothetical exchange rate exhibits steep increases resembling those in the actual exchange rate. As Bolt and van Oordt (2019) themselves acknowledge, more research in this area is required; however this is certainly an interesting starting point.[10] In a nutshell, it seems to be difficult to determine the fundamental value of cryptocurrencies. As long this is not changing, the term bubbles should be used with caution.

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[9] The third is "the elements that jointly drive future consumer adoption and merchant acceptance of virtual currency".

[10] See Appendix A in Bolt and van Oordt (2019) for a critical discussion of this hypothetical exchange rate.

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