

# Wavelet Analysis of Bitcoin Price and Twitter-Based Economic Uncertainty Index

Weike Yang<sup>1</sup>, Zheng Tao<sup>2\*</sup>

<sup>1</sup>College of Business and Public Management, Wenzhou-Kean University, Wenzhou 325000, Zhejiang Province, China

<sup>2</sup>Department of Statistic and Data Science, National University of Singapore, 10 Kent Ridge Crescent 119077, Singapore

\*Corresponding author: Zheng Tao, e0729756@u.nus.edu

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**Abstract:** In this paper, we analyze the time-series graphs of Bitcoin price and Twitter-based economic uncertainty index over the past two years and use a wavelet coherence graph to determine their relationship. We found a causal relationship between Bitcoin (BTC) and Twitter-based economic uncertainty (TEU) index in different frequency bands, which would help predict Bitcoin price movements in the future. Our study provides reference to academics and investors.

**Keywords:** Wavelet; Bitcoin; Twitter; Time series

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## 1. Introduction

Digital currencies have developed rapidly in this era. Bitcoin plays an increasingly prominent role in the economy. Hence, the development of digital economy has had a certain impact on Bitcoin <sup>[1]</sup>. As a result, there are fluctuations in the economic environment, be it small or large. From the beginning of the 21st century, digital currency began playing a huge role in the market, and Bitcoin, which is one of the most popular kinds of digital currency, was introduced in 2008 <sup>[2]</sup>. The currency has been used since 2009, and it can be transferred through the bitcoin network. In the year 2021, the price of each bitcoin rose to 68,000 dollars.

On March 24, 2021, following the announcement by Tesla that bitcoin would be accepted for vehicle purchases, Bitcoin price soared; on May 13, Musk tweeted that Bitcoin mining is a waste of energy, and therefore stopped accepting bitcoin as payment. The tweet sent Bitcoin plummeting, with nearly 300,000 people exploding their holdings in 24 hours. With Musk's help, Bitcoin hit a three-month high in a week. On August 23, Bitcoin rose above \$50,000 in sub-market trading and pre-European trading, breaking that threshold for the first time in three months. Bitcoin hit a high of \$64,000 in April, and then nearly halved in mid-to-late May. Since late July, Bitcoin has gradually regained its upward momentum, breaking the technical levels of \$47,000 and \$48,000 in a row.

Twitter is a software that was invented in the United States in 2006. Twitter users are spread across the globe, with as many as 396.5 million people using Twitter in 2021 <sup>[3]</sup>. The Twitter-based economic uncertainty (TEU) index consists of the total number of daily English-language tweets containing both "uncertainty" terms as well as "economy" terms. A large group of data are concluded into the index to determine the economic relationship <sup>[4]</sup>. We construct daily, weekly, and monthly Twitter-based economic uncertainty (TEU) indicators from 2011 onwards according to the counts of tweets about "economy" and "uncertainty" <sup>[5]</sup>.

In this article, our exploration embodies the relationship between Bitcoin and Twitter-based economic uncertainty index. First, we discuss the relationship and research background between Bitcoin and Twitter in blockchain technology and introduce the relationship between Bitcoin and Twitter-based economic uncertainty index. We then analyze the characteristics of Bitcoin and Twitter to prepare for the experimental analysis that follows. The third section is a discussion of our research method. We use Bitcoin price change and the change of uncertainty index for analysis. We also use R data for analysis, and two graphs that reveal the relationship between TEU-ENG and Bitcoin are shown. The fourth section embodies the experimental analysis. Based on the time-series graphs, we first perform a simple data analysis of the data components and data sources. Subsequently, we describe the relationship between Bitcoin and Twitter-based economic uncertainty by analyzing the wavelet correlation between the two based on the graph's information.

## 2. Bitcoin price, social media, and wavelet coherence

In recent years, Bitcoin's price volatility has garnered widespread attention from both academic researchers and investors. Many studies are currently trying to find a way to predict volatility. Roy *et al.* <sup>[6]</sup> proposed the use of time series to predict the price of Bitcoin. They collected the daily market capitalization, trading volume, and opening and closing prices of Bitcoin from July 2013 to August 2017, and applied the processed data to the autoregressive integrated moving average (ARIMA) model, autoregressive (AR) model, and moving average (MA) model to predict the price of Bitcoin for the next 10 consecutive days. In another study, Karalevicius *et al.* <sup>[7]</sup> used sentiment analysis to predict price movements. They used various Bitcoin-related news portals to conduct sentiment analysis experiments and data preprocessing and fed the data into a sentiment analyzer. They used a lexicon-based approach to observe how sentiment changes over time.

Some academics have found a potential interaction between social media discussions and bitcoin prices. According to Mai *et al.* <sup>[8]</sup>, the majority of users, as the silent majority, contribute little, while a small group of highly active users contribute the most and are more influential sources of information. They also mentioned that in-depth discussions carried out on internet forums can paint a more comprehensive picture of participants and are therefore more likely to trigger final adoption or purchase decisions. A study based on Twitter sentiment, collecting a total of 92,550 tweets over 60 days, found a strong correlation between Bitcoin percentage change and Twitter sentiment <sup>[9]</sup>.

Time and frequency are important for studying Bitcoin price dynamics; wavelet coherence can be used to locate correlations between sequences and evolutions in time and across scales. In Kristoufek's study <sup>[10]</sup>, a wavelet coherence analysis of Bitcoin price and some possible drivers was conducted separately; the correlation and lead-lag relationship between them were evident. In Phillips and Grose's study, the use of wavelets showed consistency between cryptocurrencies and online factors among different cryptocurrencies <sup>[11]</sup>. These previous studies fully demonstrate the practical significance of wavelet analysis.

## 3. Data and methodology

The data used in this study comprises Bitcoin (BTC) and Twitter-based economic uncertainty index (TEU-ENG). We sourced the data on BTC from Yahoo Finance and gathered information about TEU-ENG from the Economic Policy Uncertainty website. The period of collected data is from January 1, 2020, to June 1, 2022, yielding 883 valid pieces of data. We chose this period because we want to reduce the interference of the COVID-19 pandemic on this study.

### *The wavelet coherence*

Time series was used when analyzing BTC and TEU separately. In order to analyze the correlation between BTC and TEU, we took into account of widely implemented methods, thus wavelet coherence was used.

According to Torrence and Compo <sup>[12]</sup>, the cross-wavelet transform can be represented by two-time series  $a(t)$  and  $b(t)$  as follows:

$$N_{ab}(p, q) = N_a(p, q)N_b^*(p, q) \tag{1}$$

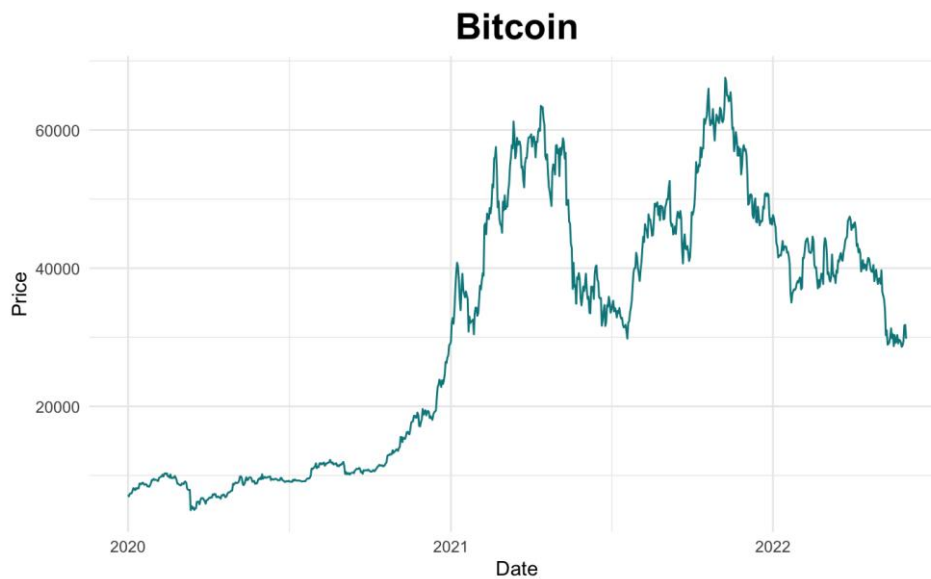
In the formula,  $N_a(p, q)$  and  $N_b(p, q)$  are the two continuous transformations of  $a(t)$  and  $b(t)$ ,  $p$  is the position index,  $q$  is the measure, and the asterisk (\*) represents the composite conjugate. As for the equation of the coefficient of adjusted wavelet coherence, Torrence and Webster <sup>[13]</sup> stated that:

$$W^2(p, q) = \frac{|M(M^{-1}Nab(p, q))|^2}{M(M^{-1}|N_a(p, q)|^2)M(M^{-1}|N_b(p, q)|^2)} \tag{2}$$

$M$  is the smoothing mechanism, and  $0 \leq W^2(p, q) \leq 1$ . This interval is the squared range of wavelet coherence coefficients. Close to 1 indicates high correlation, whereas close to zero indicates a lack of correlation.

#### 4. Empirical analysis

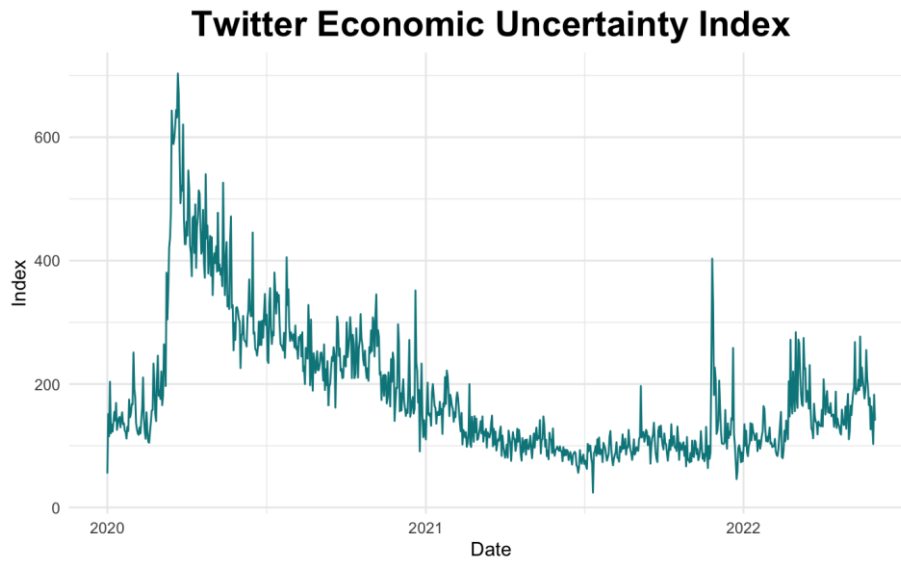
We analyze the time-series graph of Bitcoin price, as shown in **Figure 1**.



**Figure 1.** Bitcoin price from January 1, 2020, to June 1, 2022

The analyzed period began with a value of approximately \$7,200 per bitcoin and ended at approximately \$30,000. That price has more than quadrupled in less than 30 months. Moreover, there were two periods in 2021 when Bitcoin traded above \$60,000.

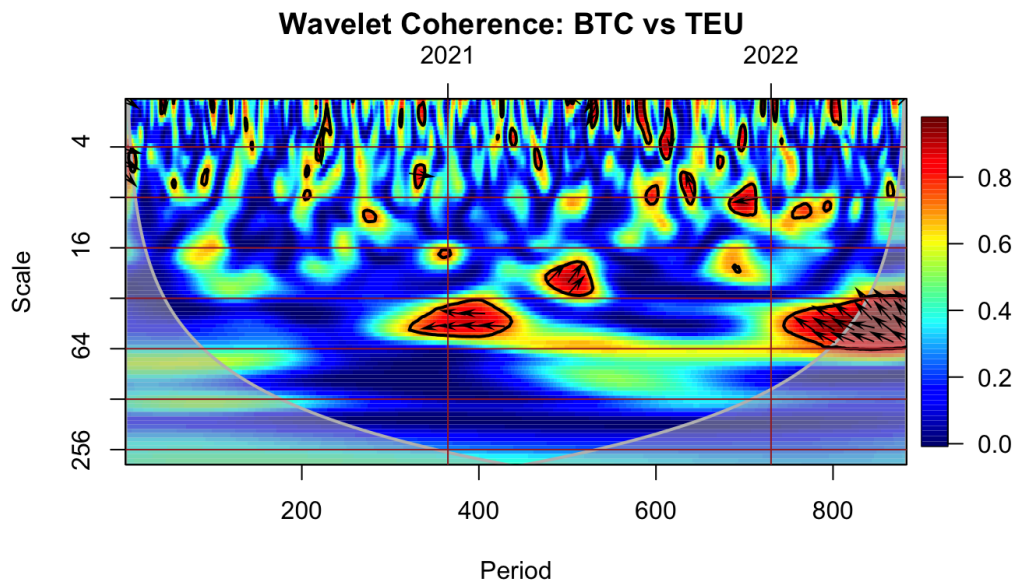
We analyze the time-series graph of Twitter-based economic uncertainty index, as shown in **Figure 2**.



**Figure 2.** Twitter-based economic uncertainty index

We use TEU-ENG data, which consist of all tweets in English. The TEU-ENG index increased sharply in March 2020, and the peak index was close to 650, just as COVID-19 was raging around the world. Thereafter, the overall trend of the index dropped.

The wavelet coherence between BTC and TEU is shown in **Figure 3**.



**Figure 3.** Wavelet coherence: BTC versus TEU

There are some prominent warm areas in the graph, which are located in the first half of 2021 and 2022. They indicate strong dependency over the 16–64 days frequency bands for the corresponding sample period. For the larger red island in 2022, the arrow points upward and to the left, indicating that BTC guides the rise of TEU and is negatively correlated with TEU. The conflict between Ukraine and Russia in 2022 exacerbated this change and affected the volatility of the crypto market. In 2021, two hot red zones can be seen, indicating strong dependence between two variables. For the red island over the 32–64 days frequency

bands, the arrows point upwards-left and downwards-left, suggesting that BTC and TEU affect each other and are negatively correlated. For the other smaller island, the arrow points upwards and to the right, indicating that TEU is leading BTC during this period, and the two are positively correlated. In February 2021, Tesla's CEO Elon Musk revealed Tesla's \$1.5 billion investment in Bitcoin. This revelation prompted a short-term surge in demand for bitcoin. There are many smaller red areas in the 0–16 frequency bands, and their arrows point differently. BTC and TEU have mutually bidirectional causality in the low-frequency segment. Briefly, BTC and TEU show bidirectional causality in the low-frequency interval from 0–64 days, but there is no dependence between them in the high-frequency interval (64–256 days).

## 5. Conclusion

In this study, we collect the daily data of BTC and TEU in the recent two years, analyze the time-series graphs, and use a wavelet coherence graph to analyze the interactive guided-lag interactions in the time-frequency domain. We conclude that BTC and TEU show bidirectional causality in the frequency interval from 0–64 days, with no dependence between them in the high-frequency interval (64–256 days). We also found that geopolitical conflicts, such as the Russia-Ukraine war in 2022, also affect Bitcoin's price volatility. These findings are useful for predicting Bitcoin price trend.

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## Disclosure statement

The authors declare no conflict of interest.

## Author contributions

Z.T. conceived the idea of the study. W.Y. wrote the abstract, literature review, data and methodology, empirical analysis, and conclusion.

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