LUNDS UNIVERSITET

Master Thesis II

Bitcoin's Response to U.S. Monetary Policy Easing Announcements

by Emilia Alarcón

Supervisor: Anna Grodecka-Messi
Lund University
Department of Economics
Lund, Sweden
2021

Abstract

This paper aims to evaluate the effect of the U.S. monetary policy on the bitcoin price. In particular, how monetary policy easing affects the bitcoin returns. One of the main tenets of bitcoin is that it is a hedge against inflation caused by a large increase in the money supply. Inspired by that idea, this study intends to analyze bitcoin's instant response to the Federal Reserve's monetary policy easing announcements using an event study methodology and intraday data. For this, the impact of the Federal Reserve Open Market Committee (FOMC) easing announcements on the bitcoin returns is analyzed. The studied period starts 10 minutes before each announcement and finishes 45 minutes after the announcement. For robustness, the relationship between changes in the federal funds futures rate and the bitcoin returns is evaluated. It was found that the U.S. monetary policy easing announcements does not affect the bitcoin returns in the studied period. Furthermore, the results suggest that U.S. monetary policy easing announcements and bitcoin returns do not have a significant and instant relationship.

Contents

List of Abbreviations

U.S.	United States
FOMC	Federal Open Market Committee
CPI	Consumer Price Index
Covid-19	Coronavirus disease of 2019
AR	Abnormal Returns
AAR	Abnormal Average Returns
CAR	Cumulative Abnormal Returns
CAAR	Cumulative Abnormal Average Returns
MP	Monetary Policy Surprise Variable

1. Introduction

The exponential growth characterizing the cryptocurrency market in recent years has promoted many discussions about their role in the modern economy. Cryptocurrencies are a type of digital currency that applies cryptography principles to enable secure and decentralized economic transactions (Vejacka, 2014). Their development can be linked to a potential alternative to fiat currencies and a profitable investment that is thought to be uncorrelated with some macroeconomics indicators (Alarcón, 2020; Pyo & Lee, 2020). As their popularity and trading volume rise, cryptocurrencies develop a global market with low transaction costs and easy access that is open 24 hours a day. At the time of collecting data for this study, there exist about 10,115 different cryptocurrencies. Among these, the first and largest cryptocurrency regarding market capitalization is bitcoin.

Bitcoin was created by Satoshi Nakamoto in 2008 and is defined by its creator as a peer-to-peer electronic cash alternative (Nakamoto, 2008). Despite high volatility, the price of bitcoin has followed an upward trend preserving the interest in the digital currency and attracting new investors. The importance of bitcoin is undeniable. For instance, financial institutions, as Morgan Stanley & Co. Llc. and Goldman Sachs Group Inc., announced to begin offering exposure to bitcoin funds to their wealthy clients (Taub & Wells, 2021). Companies as Tesla Inc. and MicroStrategy Incorporated have added significant holdings of bitcoin to their balance sheets (McCormick, 2021). And most recently, El Salvador has declared bitcoin a legal tender (Jagtani & McDonald, 2021), an initiative that might be followed by other countries. Thus, bitcoin's importance, unique features, and controversial role in the modern economy make it relevant to study its economic behavior.

Many studies have analyzed the role of bitcoin in the monetary system, see for example Yermack (2015), Fernández-Villaverde (2018) and Söderbeg, (2018). In contrast, this study intends to analyze the effect of the U.S. monetary policy easing on the bitcoin price. One of the main tenets of bitcoin is that it is a hedge against inflation caused by a large increase in the money supply. However, in order to empirically explore the argument that a large increase in money supply creates inflation and inflation can be hedged by bitcoin, some limitations need to be taken into consideration.

Firstly, there might not be accurate measures of inflation. Common inflation measures, such as the Consumer Price Index (CPI), are based on a basket of consumer goods and services and might not consider all goods and services in the economy. Moreover, a liquidity trap and a decline in money velocity might hinder prices from raising even if the money supply is largely increased. Secondly, economists use the term inflation to refer to a general increase in consumer price, however, bitcoin supporters tend to use the term inflation to mean an increase in the money supply (Handagam, 2021). Thirdly, the variables and data to be analyzed need to be collected in high frequency. The use of monthly, weakly, or daily data is not optimal as changes in the asset price could be responding to other news that was released earlier in the period (Gürkaynak, et al., 2005). Kuttner (2001) estimated the impact of monetary policy actions on bond yields using daily data and found that daily data may still capture noise from other financial market developments that happened during the day. Finally, a lot of research about the determinants of the bitcoin price has been done, however, there is no consensus about the factors that influence the bitcoin price which makes it difficult to control for other determinants that might affect its price.

In order to overcome these issues, this study intends to analyze the perception that bitcoin is a hedge against monetary debasement by evaluating bitcoin's immediate response to the Federal Reserve monetary policy easing communications. In this regard, this paper does not intend to solve the debate on whether bitcoin is a hedge against inflation, but to provide empirical evidence that can contribute to the debate.

Accordingly, bitcoin's immediate response to the Federal Reserve monetary policy easing communications is studied using an event study methodology. The event is defined as the Federal Reserve Open Market Committee (FOMC) announcements where the federal funds target rate was lowered. Since the development of bitcoin, there have been five occasions when the federal funds target rate was reduced. In that sense, the impact of the FOMC monetary policy easing announcements on bitcoin returns is analyzed for these specific dates in an event period that goes from 10 minutes before the announcement to 45 minutes after the announcement. The use of intraday data is motivated to avoid other noise and by the price action observed a few minutes after social media activity of influential people, such as Elon Musk, suggesting that information can be processed quickly in the bitcoin market (Ante, 2021). To confirm the robustness of the results, changes in the federal funds futures rate are captured by a monetary policy surprise variable around the events. Then, the relationship between the monetary policy surprise variable and the bitcoin returns is evaluated. The results of the event study show that there is no abnormal performance. This implies that there is no significant difference between the expected returns and the actual returns in the period that starts 10 minutes before the announcement and finishes 45 after the announcement. Thus, the U.S. monetary policy easing announcement does not influence the bitcoin price in the studied period. Furthermore, the robustness tests support this finding suggesting that U.S. monetary policy easing announcements and bitcoin returns do not have a significant and instant relationship.

The remainder of the paper is structured as follows. A theoretical framework about monetary policy is presented in section 2. The financial use of bitcoin as a hedge against inflation is discussed in section 3. The methodology is described in Section 4 and the results are presented in Section 5. Lastly, Section 6 concludes and provides recommendations for future research.

2. Monetary policy

In order to analyze the effects of monetary policy easing on the bitcoin price, some features of monetary policy need to be described.

2.1 Money

Money is usually defined in relation to its functions: money is a unit of account, a medium of exchange, and a store of value. As a unit of account, money is the criterion used to measure economic transactions. All prices and all contracts are denominated in terms of money (Williamson, 2018). As a store of value, money is an instrument to transfer purchasing power from the present to the future (Mankiw, 2013). As a medium of exchange, money is what we use to buy and sell goods and services (Mankiw, 2013). The last feature, medium of exchange, distinguishes money from other assets, e.g., stocks or housing. Other assets might serve as a store of value but can hardly function as standard mediums of exchange. Money, in contrast, is the most liquid medium of exchange given that it is the asset most easily traded for any good or service (Mankiw, 2013).

Throughout history, money has taken different forms. Thousands of years ago, commodities with some intrinsic value, such as gold, silver, and copper, were used as money, i.e., commodity money. However, in order to avoid purity verifications during trade, metals were turned into coins minted by governments and became widely recognized because of their guaranteed purity and weight (Mankiw, 2013). Hundreds of years later and as production costs remained high, gold-backed paper currencies were introduced, that is, pieces of paper issued by governments and redeemed for the same amount of gold (Mankiw, 2013). These gold-backed government bills eventually became the monetary standard: the gold standard. The connection between money and gold gave confidence about the currency's value, however, the gold standard collapsed between 1920 and 1970 due to the financing of the World Wars and because the worldwide production of gold did not keep pace with economic growth (Yermack, 2015).

Since then, all the currencies of the world have entered the era of fiat money. The value of fiat currency relies upon the fact that it can be exchanged for consumable goods and its acceptance is determined by the belief that others will accept it for consumable goods in the future (Williamson, 2018).

2.2 Money Supply and Monetary Policy

The quantity of money available in an economy is known as money supply (Mankiw, 2013). Money supply is the total amount of money in circulation, and it can commonly be defined as a group of safe assets that households and firms use to make payments or hold as short-term investments (Board of Governors of the Federal Reserve System, 2015). As different kinds of assets can be used for transactions and short-term investments, e.g., cash, bank deposits and saving accounts, it can be difficult to determine a general measure for money supply. Thus, distinct measures of money supply are used according to different purposes of analysis. In the U.S., some standard measures of money supply are M0, M1, and M2. Namely, M0 is known as the monetary base, M1 is a measure of assets most widely used for transactions by the private sector, and M2 includes assets that are not directly used in transactions but are easily exchanged for mediums to be used in transactions (Williamson, 2018). The components of these standard measures of money supply for the U.S. are presented in Table 1.

M0	Currency in circulation and reserve balances. Reserve balances are deposits held by banks and other depository institutions in their accounts at the Federal Reserve.
M1	Currency held by the public and transaction deposits at depository institutions such as commercial banks, savings and loan associations, savings banks, and credit unions.
M2	M1 plus saving deposits, small-denomination time deposits, and retail money market mutual fund shares.

Table 1. Standard measures of Money in the United States
Source: Federal Reserve, https://www.federalreserve.gov/faqs/money_12845.htm

The quantity of money in circulation is regulated through monetary policy. Monetary policy refers to the actions taken to control the level and growth rate of the money supply in order to pursue macroeconomic goals (Williamson, 2018). Monetary policy is usually conducted by central banks. In the United States, monetary policy is determined by the Federal Reserve, also known as the Fed. The Fed conducts monetary policy in order to achieve three goals set by Congress: maximum employment, moderate long-term interest rates, and stable prices, given the inflation objective of two percent (Board of Governors of the Federal Reserve, 2016). Decisions about monetary policy are determined by the Federal Open Market Committee (FOMC).

The Fed communicates its monetary policy by lowering or raising the target of the federal funds rate (Board of Governors of the Federal Reserve, 2016). In that sense, lowering the federal funds target represents an “easing” of monetary policy while increasing the federal funds target implies a “tightening” of monetary policy (Board of Governors of the Federal Reserve, 2016)

The federal funds, or fed funds, are excess reserves, i.e., reserves that banks and depository institutions hold above the reserve requirement established by the Fed (Board of Governors of the Federal Reserve, 2016). The federal funds can be lent within financial institutions to meet short-term reserve and business needs. These loans are usually done on an overnight period and using a low-interest rate called the federal funds rate. The FOMC determines a target for the federal funds rate about every six weeks. The federal funds target rate has a big influence over the economy as it is a benchmark for all other short-term interest rates paid by borrowers and earned by savers and the overall economy (Williamson, 2018). Thus, changes in the federal funds target rate are normally followed by changes in other interest rates. These changes will then influence spending decisions, of households and businesses, and have implications for economic growth, employment, and inflation (Board of Governors of the Federal Reserve, 2016).

Furthermore, the most common instruments used by the Fed to implement its monetary policy are open market operations, discount window lending, and reserve requirements. The open market operations, and discount window lending, influence the supply of balances in the federal funds market, while the reserve requirements influence the demand for balances in the federal funds market (Board of Governors of the Federal Reserve, 2016).

Open market operations, which are purchases and sales of securities issued or backed by the government, are the policy instrument that is most commonly used by the Fed to keep the fed funds rate near the target (Board of Governors of the Federal Reserve, 2016). This is known as conventional monetary policy. However, in response to the global financial crisis 2007-2009, the Fed lowered the target for the federal funds rate near to zero and began to use non-traditional monetary instruments, also known as unconventionally monetary policy. In the following, the difference between the two approaches of monetary policy is explained.

2.4 Conventional and unconventional monetary policy

2.4.1 Conventional Monetary Policy

The modern era of monetary policy started with Paul Volcker, the Chair of the Federal Reserve during 1979-1987 (Williamson, 2018). Paul Volcker implemented the ideas of monetarists, such as Milton Friedman, who argued that the best way of controlling inflation is through money supply (Williamson, 2018). The idea is described as follows.

Inflation is commonly defined by economists as an increase in the average price of goods and services in terms of money (Romer, 2019). Hence, in order to control inflation, the money market needs to be analyzed. The condition for the equilibrium in the money market is given by equation (1), where *M* is the money supply, *P* is the price level, and the right-hand side, $L(i,Y)$, represents the demand for money which decreases in the nominal interest rates *i* and increases in real income *Y*, i.e., $L_i < 0, L_y > 0$ (Romer, 2019). This equilibrium condition implies that the price levels are determined as shown in equation (2).

$$\frac{M}{P} = L(i,Y) \tag{1}$$

$$P = \frac{M}{L(i,Y)} \tag{2}$$

Accordingly, equation (2) shows that there could be many potential sources of inflation, i.e., the price level could rise due to an increase in money supply, increase in interest rates, decrease in output, or decrease in money demand for a given *i* and *Y*. However, empirical evidence showed that money supply can grow at any rate, while variations in the interest rate are limited, and long-term declines in output, as well as large falls in money demand given *i* and *Y*, are unlikely (Romer, 2019). Therefore, persistent increases in the price level, i.e., inflation over the long run, can only be determined by money supply growth (Romer, 2019).

This is also seen in the quantitative equation given by equation (3) where *V* denotes the money velocity with which money changes hands. As shown in equation (4), if money velocity and real income remain constant, the price level is only affected by money supply.

$$P \times Y = M \times V \tag{3}$$

$$P = \frac{M \times V}{Y} \tag{4}$$

The relationship between inflation and money supply is known as money neutrality. Money neutrality implies that changes in money supply cause inflation but have no real effects on the economy in the long run, i.e., consumption, investment, output, employment, the real interest rate, and economic welfare are unaffected (Williamson, 2018). In the early 1980s, Volcker, inspired by this idea, reduced inflation by reducing the money supply (Williamson, 2018). This approach was initially based on money growth targeting but then switched to a corresponding federal funds targeting procedure, although the change was never formally announced (Thornton, 2006).

Under conventional circumstances, e.g., before the global financial crisis, the Fed uses mainly open market operations to maintain the fed funds rate near its target. That is, the Fed buys and sells securities, issued by the U.S. government, through dealers in the securities market. This is done by crediting and debiting the reserve accounts of the dealer's bank. As a result, open market purchases increase reserve balances and push the federal funds rate down, as in such cases banks will lend their excess funds at lower rates (Board of Governors of the Federal Reserve, 2016). In contrast, open market sales reduce reserve balances and push the federal funds rates up (Board of Governors of the Federal Reserve, 2016). The daily quantity of open market operations to maintain the fed funds near its target is determined considering banks' reserve and funding needs (Board of Governors of the Federal Reserve, 2016). Thus, under conventional circumstances, the Fed communicates its monetary policy by lowering or raising the target of the federal funds rate, and open market operations are the policy instrument most commonly used to keep the fed funds rate near the target.

2.4.2 Unconventional Monetary Policy

Unconventional monetary policy refers to actions taken by central banks for supporting macroeconomic goals when the effectiveness of conventional tools appears exhausted (Williamson, 2018). Under certain circumstances, conventional monetary instruments can be ineffective and non-traditional tools instruments are needed. This was the case during the financial crisis of 2007-2009 and its later recession. In order to respond to the crisis and stimulate the economy, the Fed lowered the short-term interest rates by continuously reducing the federal funds target rate from 5.25 in 2007 to a target range of 0 - 0.25 by December 2008. By doing this, the interest rates approximated what some economists called the zero-lower bound, i.e., when the nominal short-term interest rate equals zero.

Krugman (1998) developed a model that demonstrates singularities in the economy when the zero lower bound is approximated. The model shows that when the nominal interest rate is positive, the increase in money supply has the conventional effect of reducing the interest rate and rising prices. However, when the nominal interest rate is zero, the increase in money supply does not affect prices, conventional monetary tools are ineffective, and the economy is in a liquidity trap.

Nevertheless, not all monetary policy actions are ineffective when the economy is at the zero-lower bound (Romer, 2019). Another experiment done by Krugman (1998) shows that an increase in expectations of future money supplies raises the expectation of future price levels and this results in an increase in current prices (Romer, 2019). Thus, in order to raise expected inflation when the economy is in a liquidity trap, the expectations of future money supplies and future monetary policy have to be influenced. This is usually done using quantitative easing and forward guidance.

Quantitative easing refers to buying a large number of long-term government securities, which mature in more than a year, to substantially increase the monetary base, apply downward pressure on long-term interest rates and affect expectations of future money supply (Mankiw, 2013). Thus, if expectations of future money stocks are high, the expectation of future price levels are raised, and expected inflation increases today (Romer, 2019). During 2008-2014, the Fed did extensive quantitative easing by buying long-maturity Treasury securities, mortgage-backed securities, and swaps of shorter-maturity Treasury securities for longer-maturity securities (Williamson, 2018).

On the other hand, in forward guidance the Fed affects expectations of future monetary policy by communicating its outlook for the federal funds rate and the economy (Board of Governors of the Federal Reserve, 2016). In that sense, plans to keep the interest rate low might raise expected inflation (Romer, 2019). Forward guidance is done through the Fed’s assessments about the economic outlook and its intentions concerning the federal funds rate (Board of Governors of the Federal Reserve, 2016). For instance, in December 2008, when the FOMC lowered the target for the federal funds rate near to zero, it communicated in its post-meeting statement that it expected that “weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time” (Board of Governors of the Federal Reserve, 2016). During the period of the financial crisis and its resulting recession, 2008-2014, the wording used by the Fed to communicate its intentions has evolved, but its intentions to affect expectations about future monetary policies remained the same.

2.5 Monetary Policy after 2015

After some years near the zero-lower bound with a target range of 0 - 0.25, in December 2015 the Fed raised the federal funds target by 25 basis points resulting in a new target of 0.25 - 0.50 (see Figure 1). The FOMC supported its decision on the improvement in the labor market during 2015 and confidence that inflation, which has been below the inflation goal, would reach two percent in the medium term (Board of Governors of the Federal Reserve, 2016). This represented the start of a normalization period that implied steps to return to more normal levels of short-term interest rate and reduction of the size of the Fed's balance sheet that notably increased due to quantitative easing (Board of Governors of the Federal Reserve, 2016). After that, the FOMC continued to raise its target range, reaching 2.25 - 2.5 from December 2018 to July 2019, and continued to communicate its policy through this rate.

Nevertheless, in July 2019, the Fed started lowering the federal funds rate due to slow global growth and uncertainty from the economic conflicts with China. In this month, the federal funds rate was reduced by 25 basis points to a target range of 2.00 – 2.25. This was followed by two further reductions of 25 basis points in September and October 2019.

The federal funds target range determined in October 2019, i.e., 1.5 -1.75, remained unchanged until the Covid-19 pandemic outbreak at the begging of 2020. As the Covid-19 pandemic spread through the world and countries declared a state of emergency, the FOMC decided to lower the target range 50 basis points on March 3, 2020, and 100 basis points on March 15, 2020. With this reduction, the federal funds rate went back to the 0 - 0.25 range that was in place during and after the financial crisis. Thus, the zero-lower bound has been approximated again and unconventional monetary policy tools became relevant again.

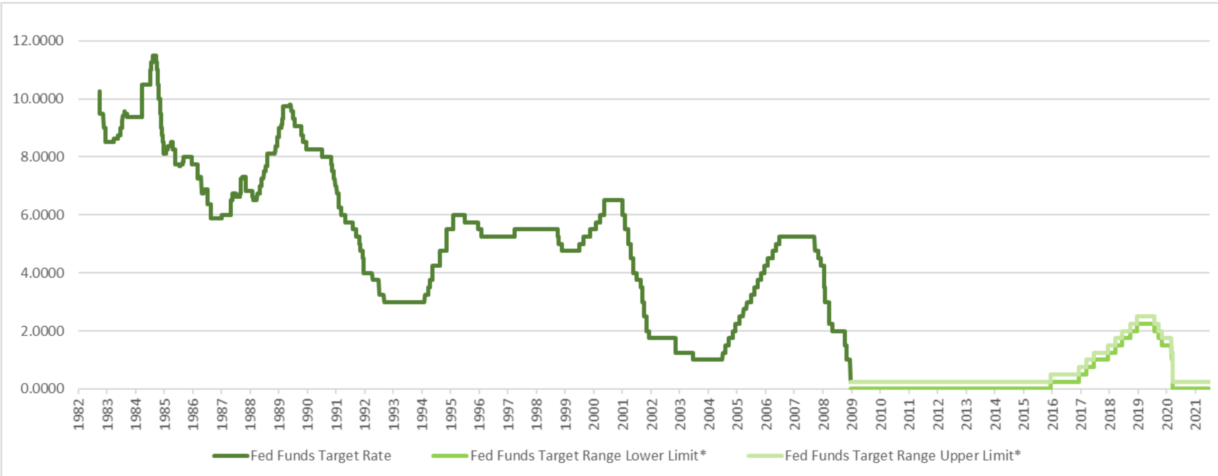

Figure 1. Federal Funds Target Rate and Range 1982-2021

*On the 16th of December 2008, the Federal Reserve started using the federal funds target range instead of the target rate.

Source: Own elaboration with data from Federal Reserve Bank of St. Louis

As a possible result of the Fed's quantitative easing in 2020, money supply, quantified by the commonly used measure M2, has increased by 24.91%. This is the largest one-year increase in M2 since 1959, i.e., since the history of the data. In the previous unconventional monetary policy period, 2008-2014, money growth increased 6.53% on average each year. Large increases are also observed in M0 and in particular in M1 during the year 2020.

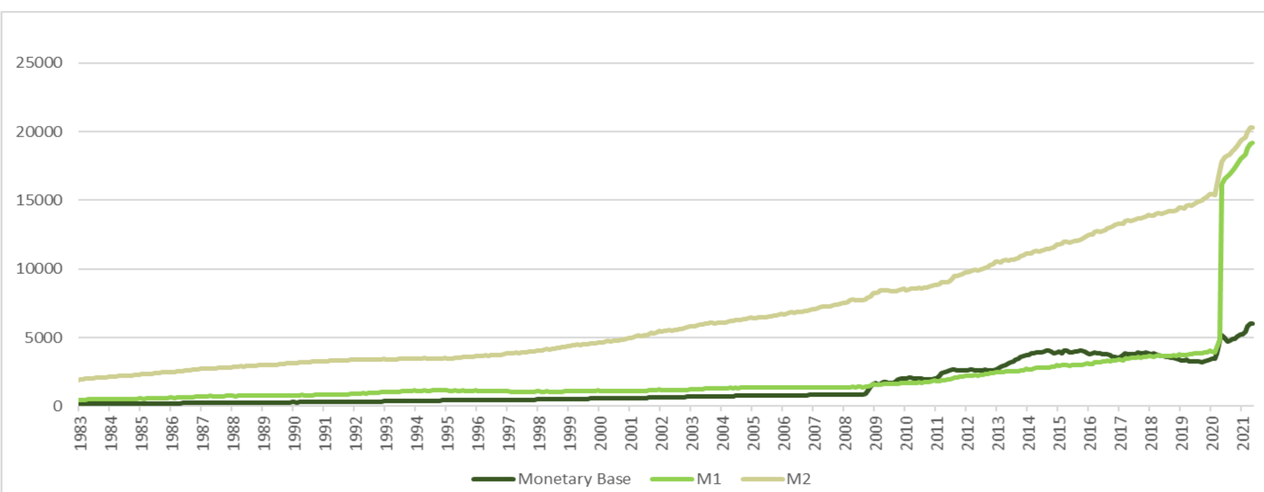

Figure 2. Monetary Base, M1 and M2 in billions of dollars

Source: Own elaboration with data from Federal Reserve Bank of St. Louis

After having described some features of monetary policy that are relevant for this study, the topic of bitcoin is developed in the following section. Accordingly, some arguments in support and opposition to the tenet that bitcoin is a hedge against inflation caused by a large increase in money supply are presented.

3 Bitcoin

The development of cryptographic algorithms combined with high-speed internet has allowed the appearance of cryptocurrencies (Fernández-Villaverde, 2021). Private cryptocurrencies, such as bitcoin, are considered decentralized digital assets. Among all cryptocurrencies, the first and largest cryptocurrency regarding market capitalization is bitcoin. The revolutionary features of bitcoin are probably bigger than any other innovation in the monetary field since the collapse of the gold standard (Fernández-Villaverde, 2021).

Despite global economic contraction due to the Covid-19 pandemic, the year 2020 presented a favorable scenario for bitcoin as the monetary policy procedures that induced Satoshi Nakamoto to create bitcoin were in place again. These are quantitative easing, sometimes referred to as 'money printing', and near-zero interest rate policy (Bartlett, 2020). Bitcoin was meant to be a reliable store of value that amends modern monetary policy (Nakamoto, 2008). Bitcoin tries to overcome the weakness of some fiat currencies that seem to have an infinite supply, by having a deterministic supply tied to Nakamoto's scheme, i.e., bitcoin supply growth slows asymptomatically to zero and will reach zero the year 2140 when the total 21 million units will be mined. Thus, its circulations cannot be affected by monetary policy in a way that the Federal Reserve controls the growth of the money supply (Yermack, 2015).

Regarding its nature, some studies indicate that bitcoin is far from behaving like a currency (see for example Yermack, 2015). According to the three functions that money has, medium of exchange, unit of account, and store of value, bitcoin has some challenges to overcome in order to be considered a currency. These challenges are described in the following paragraphs.

As a medium of exchange, bitcoin can be accepted as a form of payment, but its worldwide commercial use remains small (Yermack, 2015). Some people might consider that an obstacle for bitcoin becoming a widely used medium of exchange is obtaining bitcoin, given that users must get it from online exchanges and store it securely. Thus, customers must possess bitcoins before buying goods and services from a merchant. Also, bitcoins transactions require that merchants and customers go through a verification process that can last from a few seconds to 3-5 minutes (Ante & Fiedler, 2021)

Regarding the role of the unit of account, for a currency to be used as a unit of account consumers must be able to compare the prices of alternative retail goods. In that sense, bitcoin's extreme volatility might be a problem as retailers would have to recalculate prices frequently (Yermack, 2015). Furthermore, the diversity of market prices in different platforms and the high price of bitcoin, compared to ordinary products and services, would lead to the use of four or more decimals when converting prices which might create confusion among consumers.

For a currency to be a store of value, the owner of currency has to spend it and receive the same or higher economic value that the currency was worth when acquiring it. Bitcoin must be held in digital wallets which might force the customer to bear the cost of evaluating security, given that hacking attacks, and security-related problems challenge bitcoin as a store of value (Yermack, 2015). Moreover, customers must also manage the risk arising from bitcoin's price volatility as holding bitcoin even for short periods is quite risky (Yermack, 2015).

As the debate about bitcoin continues, the perspective around these arguments has evolved having some important figures as the Federal Reserve Bank of Dallas' President, Robert Kaplan, affirming that bitcoin is clearly a store of value, and it could potentially transform into a medium of exchange (Damanick, 2021). Bitcoin has reached the mainstream and the interest of once-skeptical investors from Wall Street has notably increased. Some companies, as Tesla Inc. and MicroStrategy Incorporated, have added significant holdings of bitcoin to their balance sheets, while other companies have begun facilitating transactions in cryptocurrencies, e.g., Square Inc. and PayPal Holdings Inc. (McCormick, 2021). Furthermore, financial institutions as Morgan Stanley Morgan Stanley & Co. LLC and Goldman Sachs Group Inc. have announced to begin offering exposure to bitcoin funds to their wealthy clients (Taub & Wells, 2021).

As bitcoin reaches the mainstream and cryptocurrencies start taking an important role in financial markets, the debate of bitcoin's financial use as a hedge against inflation caused by a large increase in money supply becomes more relevant. The arguments that support and reject this idea are developed as follows.

3.1 Arguments that support bitcoin as a hedge

A central argument that endorses bitcoin as a hedge against inflation, caused by a large increase in the supply of money, is that bitcoin's limited and diminishing supply prevents it to be devalued by a government or central bank. Bitcoin investors see the increase in money supply as a debasement in the value of money. In contrast, bitcoin has a fixed pre-determined supply of 21 million coins which permits it to maintain the value over time. The argument implies that if there are changes in the relative quantity of two goods, the one that increases in quantity tends to get cheaper. Thus, as bitcoin has limited supply and as central banks have significantly increased the money supply during the Covid-19 pandemic, the U.S. dollar might depreciate relative to bitcoin.

Moreover, despite stable inflation in 2020, expectation about inflation is still high. Bitcoin supporters tend to use the term inflation to mean an increase in the money supply, however, economists use the term inflation to refer to a general increase in consumer price (Handagam, 2021). Thus, bitcoin supporters argue that while the value of money is going down, the prices of assets with limited supply such as bitcoin, real estate, or stocks are moving up. For instance, the stock market ended 2020 with record-high gains, and bitcoin price gains were more than 250% by the end of 2020 (Handagam, 2021). Furthermore, it is suggested that as the economy reopens and spending prices go up, maintaining inflation would be a big challenge for the Federal Reserve.

Another argument that supports this idea is the fact that there is no accurate measure of inflation. The Consumer Price Index (CPI) includes a basket of goods and services, however, some articles such as stocks are not included. According to Fisher (1920), the price index should consider everything purchased and purchasable, including securities, labor, services rendered by corporations, and commodities. Thus, it should be kept in mind that inflation includes more than good and services that are considered in the CPI, that is, inflation could be higher than what it is captured by the CPI or other inflation measures.

Furthermore, bitcoin's halving in May 2020, an event when the reward for coding bitcoin transactions is cut by 50%, showed that the blockchain network was working as designed. Also, it presented an opposite scenario to the Fed´s monetary policy showing its potential against the debasement of fiat currencies (Keoun, 2020). The halving will continue to occur every four years until the supply cap is 21 million bitcoin is reached. As bitcoin has a limited and diminishing supply curve, it attracts investors worried about the debasement of the U.S. dollar and other currencies during the Covid-19 pandemic.

Finally, prominent investors such as Elon Musk, CEO of Tesla Inc, invested in bitcoin and advised that people should look for alternatives to government bonds, whose yields do not match the CPI inflation expectation, suggesting that despite its volatility, bitcoin is a better store of value than the 10-year treasury note (Tully, 2021).

3.2 Arguments against bitcoin as a hedge

Arguments that refute the idea of bitcoin being an inflation hedge, sustain that cryptocurrency's history is too short to provide evidence of being an inflation hedge and that bitcoin's volatility during its short life has not been related to inflation. Since January 2021, the 10-Year Breakeven Inflation (BEI) has been increasing and bitcoin prices followed an upward trend, however, when the BEI reached a two-year peak the price of bitcoin dropped almost 20% (Tully, 2021). Moreover, it might be that inflation causes the opposite effect on bitcoin, that is, if inflation creates a recession, investors could step away from riskier assets as cryptocurrencies (Hajric, 2021). This happened in February 2021 when investors' concerns about inflation pushed the 10-year Treasury yield up from 1.34% to 1.62% and bitcoin prices crashed (Hajric, 2021). It may be possible that inflation and bitcoin move in the same direction, but it does not mean that these are connected (Hajric, 2021).

Furthermore, other arguments for bitcoin not being an inflation hedge are endorsed by comments made by Federal Reserve Chairman, Jerome Powel, who said that the increase in money supply has no implications for the economic outlook, i.e., inflation. Despite having more money in the economy, money velocity has dropped. And even if velocity would increase there are disinflationary forces, such as the aging population and digital technology, which could push the prices down (Hajric, 2021). Accordingly, the Federal Reserve Chairman might imply that the economy is in a liquidity trap.

In 2020, the money supply in the U.S increased as a result of measures taken to face the Covid-19, however, inflation did not rise. The Federal Reserve inflation target for 2020 measured by the Consumer Price Index (CPI) was 2%, however, the actual rate of inflation at the end of the year was 1.36%. This can be due to money velocity which quantifies how fast money changes hands. If the amount of money in the economy increases but is not spent quickly, inflation can remain constant. At the begging of the pandemic, household spending decreased in many countries as lockdowns reduced the demand for some goods and services (Handagam, 2021). For instance, global energy demand dropped by 4% in the first half of 2020, being the biggest drop since World War II, and lower oil prices pushed consumer price inflation down (IEA, 2021) Thus, declining money velocity caused prices not to increase dramatically in the economy in 2020.

Finally, it is suggested that defenders of bitcoin as an inflation hedge, might have been looking at other countries where an increase in money supply led to hyperinflation as Argentina or Venezuela (Handagam, 2021). However, the reality in these hyperinflationary countries is different from other countries, as there could be other contributing factors as foreign debt, war, or other political problems that relate the supply of money to inflation (Handagam, 2021).

As the debate of bitcoin as a hedge against inflation caused by a large increase in money supply continues, some empirical research is needed. Therefore, in order to contribute to this debate, the instant response of the bitcoin returns to monetary policy easing is evaluated in the remaining part of this study. In the next section, the methodology and data used are presented. Firstly, the impact of the monetary policy easing announcements on the bitcoin returns is analyzed using an event study methodology. Then, to confirm the robustness of the results, changes in the federal funds futures contracts around the events are captured by a monetary policy surprise variable, and its relationship with the bitcoin returns is assessed.

4. Methodology and data

4.1 Event Study

The response of the bitcoin price to monetary policy easing is evaluated using an event study methodology. The event is defined as monetary policy easing announcements done by FOMC through its post-meeting statement from July 2019 to March 2020. Most central banks' main monetary policy instrument is a safe short-term interest rate rather than the quantity of money (Romer, 2019). As seen in Part 2, the Fed communicates its monetary policy using the federal funds rate. Lowering the federal funds target represents an easing of monetary policy (Board of Governors of the Federal Reserve, 2016). Thus, the events for this study are the FOMC announcements where the federal funds target was lowered. This has happened on five occasions since the development of bitcoin which defined the studied period from July 2019 to March 2020. The events were retrieved from the Federal Reserve webpage and are presented in Table 2.

Date	Time	Change	New target range
07/31/2019	2:00 PM	-0.25	2.00 - 2.25
09/18/2019	2:00 PM	-0.25	1.75 - 2.00
10/30/2019	2:00 PM	-0.25	1.5 - 1.75
03/03/2020	10:00 AM	-0.50	1.00 - 1.25
03/15/2020	5:00 PM	-1.00	0.00 - 0.25

Table 2. Negative changes in federal funds target since the development of bitcoin
Source: Own elaboration with data from Federal Reserve Bank of St. Louis

Event studies have been widely applied to analyze the dispersion of assets returns around information events. In the same way, in recent years the event study methodology has been employed to analyze cryptocurrencies' response to different events. Azouzi & Echchabi (2018) analyzes the impact of the Libra announcement on the Bitcoin price and found that the announcement does not affect the price of bitcoin. Hashemi Joo, et al. (2020) and Li, et al. (2021) examine some cryptocurrencies' reactions to major news and found high abnormal returns on the event day. Ante (2021) analyzes if Elon Musk's Twitter activity moves the cryptocurrency market and identifies significant abnormal returns and trading volume minutes after the event. Ante & Fiedler (2021) studies bitcoin reaction to large transfers on the bitcoin blockchain and concluded that the nature of the transfer is recognized and priced in new information.

Regarding monetary policy announcements, some previous studies have analyzed the effects of FOMC announcements on Bitcoin obtaining diverse conclusions. Jarboui & Mnif (2021) evaluates the effect of the Federal Reserve monetary policy on bitcoin focusing on the FOMC announcement on March 3rd, 2020. Contrary to usual results that abnormal returns are larger on the event date than other days, they found that the event does not generate significant abnormal returns until 4 days after the event date. Pyo & Lee (2020) and Cordet, et al. (2020) studied bitcoin's reaction to FOMC announcements via an event-driven regression and a GARCH based approach respectively. Pyo & Lee (2020) found Bitcoin as vulnerable to monetary and fiscal policies, while Cordet, et al. (2020) concluded that bitcoin is immune to an FOMC announcement when it is considered as a protocol-based asset. Besides the methods, a reason for diverse conclusions can be that the event periods analyzed, i.e. 13, 6, and 50 days respectively, might include other noise that could have affected the results.

Some recent event studies use intraday data rather than daily data to control for other events or news affecting the returns (see for example, Ante, 2021; Ante & Fiedler, 2021; Kocenda & Moravcova, 2018; Ghadhad, 2018; and Wójtowicz, 2016). The results show that price behavior can be affected by events already some minutes after the event. For instance, Busse & Green (2002) found that analysts' views about individual stocks broadcasted on TV are fully incorporated in price within one minute. Wongswan (2009) found that equity markets in Asia, Europe, and Latin America react to information from U.S. monetary policy surprises within 15 min after the FOMC announcement. Rogers, et al. (2017) analyzes the Securities and Exchange Commission (SEC) filings publication and found that price responds to news contained in the fillings 30 seconds before public posting and that trading profits can be found over an 81 second period.

Marshall, et al. (2019) points out that the popularity of intraday event studies has increased because: 1) intraday datasets are more accessible than in the past, 2) there is evidence of markets becoming more efficient as information is processed more quickly, and 3) analyzing an event around the specific time of the event reduces the risk of capturing the effect of other features that might affect the asset's price. Siegel & McWilliams (1997) explains that as the event window becomes longer it is more difficult for researchers to affirm that they have controlled confounding events. Furhtermore, Marshall, et al. (2019) investigates the specification and power of intraday event study test statistics and found that the mean, market, and matched firm models generate well-specified results. They further suggest that researchers using intraday return event studies can be confident in their robustness.

Following a similar approach as previous studies, such as Wójtowicz (2016), and Kocenda & Moravcova (2018), Ante (2021), and Ante & Fiedler (2021), this study analyzes intraday data around the event. A high-frequency analysis was selected in order to ensure that the bitcoin price was not influenced by other noise. The specific time of the event is the time of the FOMC announcement's press release, usually pre-scheduled at 2 p.m. on the second day of the FOMC meeting. The event window starts 10 minutes before the announcement and finishes 45 minutes after the announcement as shown in Figure 3. The estimation window starts 250 minutes before the event and finishes 10 minutes before the event. One minute bitcoin price data is retrieved from the Bloomberg terminals. Log returns are calculated for each minute of the event and estimation window. The returns in the event window are called the 'real returns' and the returns in the estimation window are used to calculate the 'expected normal returns'.

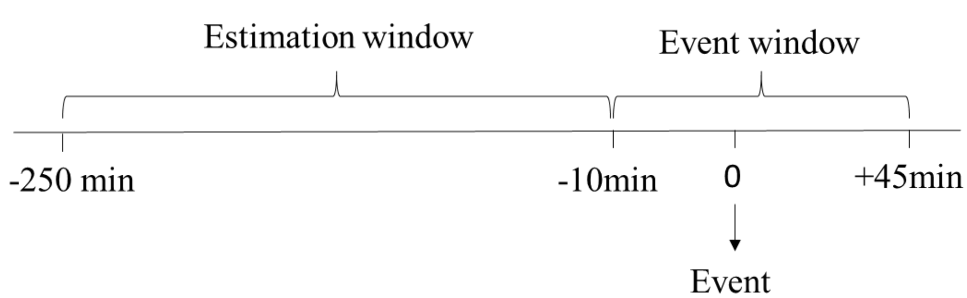

Figure 3: Timeline for the event study
Source: Own elaboration

The expected normal returns are estimated using the Constant Mean Model which is found to provide similar results to more complex asset pricing models (Brown & Warner, 1980). Previous event studies on the bitcoin market also employ the Constant Mean Model (see for example Jarboui

& Mnif, 2021; Ante, 2021; Kocenda & Moravcova, 2018; Hashemi Joo, et al., 2020; and Ante & Fiedler, 2021). The mean reason for this is because there is not an appropriate cryptocurrency market index to use in other pricing models, e.g., the Market Model. Bitcoin not only dominates the cryptocurrency market but also influences the price movements of other cryptocurrencies.

The Constant Mean Model calculates the mean return over the estimation window which is used as a baseline expected normal return $E(R)$. The abnormal returns, AR_t, are calculated as the difference between the real returns, R_t, and the expected normal return as shown in equation (5).

$$AR_t = R_t - E(R) \tag{5}$$

The abnormal returns of the N events *i* are averaged (AAR) for each minute t of the event window as observed in equation (6). The abnormal returns are also aggregated into the cumulative abnormal returns (CAR) from t_1 to t_2 and averaged into the cumulative average abnormal return (CAAR) as shown in equation (7) and equation (8). The CARs and CAARs are calculated for different intervals in the event window going from $(t_1 = -10, t_2 = 45)$ to $(t_1 = -5, t_2 = 5)$.

$$AAR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{i,t} \tag{6}$$

$$CAR_i = \sum_{t=t_1}^{t_2} AR_{i,t} \tag{7}$$

$$CAAR = \frac{1}{N} \sum_{i=1}^{N} CAR_i \tag{8}$$

The null hypothesis that the CAARs have a zero mean, that is, that event has no impact on the mean returns, is tested. As the variance of the cumulative abnormal returns is unknown, the literature suggests using the residual variance (MacKinlay, 1997). In order to test the null hypothesis that the FOMC monetary policy easing announcements have no impact on bitcoin mean returns, a traditional t-test is calculated. The traditional t-test assumes normality and its estimation follows equations (9) and (10).

$$var(CAAR) = \frac{1}{N^2} \sum_{i=1}^{N} \sigma^2{}_{CAR_i} \tag{9}$$

$$t_{CAAR} = \frac{CAAR}{var(CAAR)^{1/2}} \tag{10}$$

Furthermore, two non-parametrical t-tests that do not require any assumptions about the shape of the distribution are calculated, namely the Corrado-Zivney rank test and the Wilcoxon sign rank test. The Corrado-Zivney test is performed on the abnormal returns. This test considers increased volatility of abnormal returns after the event (Corrado, 2011) and follows the approach proposed by Corrado & Zivney (1992). Corrado's early work in 1989 evidenced that the rank test outperforms the t-test and does not require symmetry in cross-sectional return distributions for the correct specification (Hashemi Joo, et al., 2020). The Wilcoxon sign rank test is performed on the CAARs. The Wilcoxon sign rank test considers the sign and the magnitude of the abnormal returns and follows the method proposed by Wilcoxon (1945).

4.2 Robustness

Robustness in the results is verified in two ways. Firstly, two other estimation windows of 2 hours and 1 day before the event are applied to calculate the baseline-mean return for the Constant Mean Model. Then, the process as described in the methodology part is repeated using the resulting expected returns for each new estimation window.

Secondly, the relation between bitcoin and the FOMC monetary policy easing announcements is evaluated by regressing a monetary policy surprise variable on the bitcoin price. The monetary policy surprise variable is based on changes in federal funds futures contracts. As stated before, lowering the federal funds target represents an easing of monetary policy while increasing the federal funds target implies a tightening of monetary policy (Board of Governors of the Federal Reserve, 2016).

This approach is applied by other authors as Kuttner (2001), Gürkaynak, et al., (2005), Jarocinski & Karadi, (2020) and Gürkaynak, et al., (2021). In these studies, changes in the implied rate of the federal funds contracts around the FOMC announcements are used to calculate a monetary policy surprise variable. As proposed by Gürkaynak, et al., (2005), Jarocinski & Karadi, (2020) and Gürkaynak, et al., (2021), the monetary policy surprise variable is defined as the 30-minutes change in the current-month federal funds futures contract, that is, the change in the period that starts 10 minutes before the announcement and finishes 20 minutes after. This variable is further adjusted to account for the timing of the FOMC meeting within the month. The calculation is shown in equation (11), where mp_i is the monetary policy variable at event i, ff_{t+20} is the federal funds futures rate 20 minutes after the event, ff_{t-10} is the federal funds futures rate 10 minutes before the event, D denotes the number of days in the month and d corresponds to the day when the FOMC meeting announcement takes place.

$$mp_i = (ff_{t+20} - ff_{t-10}) \frac{D}{D - d} \tag{11}$$

Then, changes in bitcoin price are also calculated for the 30-minutes interval around the event. The relationship between these variables is analyzed by regressing the monetary policy surprise variable to the change in bitcoin price as shown in equation (12). In this equation, $\Delta\, b_t$ denotes the 30-minutes change in the bitcoin price, i.e., 10 minutes before and 20 minutes after the event, $\alpha \; and \; \beta$ are the coefficient estimates, and ε_t is the stochastic error.

$$\Delta\, b_t = \alpha + \beta\, mp_t + \varepsilon_t \tag{12}$$

In order to have more observations to regress the monetary policy surprise variable on the bitcoin price and evaluate its relationship, the studied period is extended. As stated before, the federal funds target has been lowered on only 5 occasions since the development of bitcoin. Considering all FOMC announcements from October 2015 to April 2021, 49 events are obtained. These events include reduction, increase, and no change in the federal funds target, i.e., monetary policy easing, tightening, and no change. The studied period was extended to October 2015 because earlier intraday data for bitcoin could not be obtained. Data for the monetary policy surprise variable from November 2018 to April 2021, was calculated by the author of the present study following equation (12). For the period from October 2015 to October 2018 the monetary policy surprise variable data was collected from the replication data provided by Gürkaynak, et al., (2021). In general, the data of the federal funds futures contracts and bitcoin price was retrieved from the Bloomberg terminals.

The idea of this approach is to test if bitcoin returns have an inverse relationship with the monetary policy surprise variable. If monetary policy easing is announced by the FOMC, the federal funds futures rate should be lowered around the event time. Then, a negative change in the monetary policy surprise variable is expected and a positive change in bitcoin returns. This should hold if bitcoin is a hedge against monetary debasement and if bitcoin has an instant response to monetary policy easing announcements.

5. Results

5.1 Event Study

As shown in Table 2, there have been 5 occasions since the development of bitcoin when monetary policy easing was announced by the FOMC by lowering the federal funds target. The real returns during the estimation and event period are presented in Figure 4. It can be seen that following the announcement done in October 2019 volatility increases on the 27^{th} minute after the event (minute 14:27). This increase in volatility lasts 9 minutes (until 14:36) and then goes back to more normal movements. The other events do not present such a different behavior compared to the estimation period.

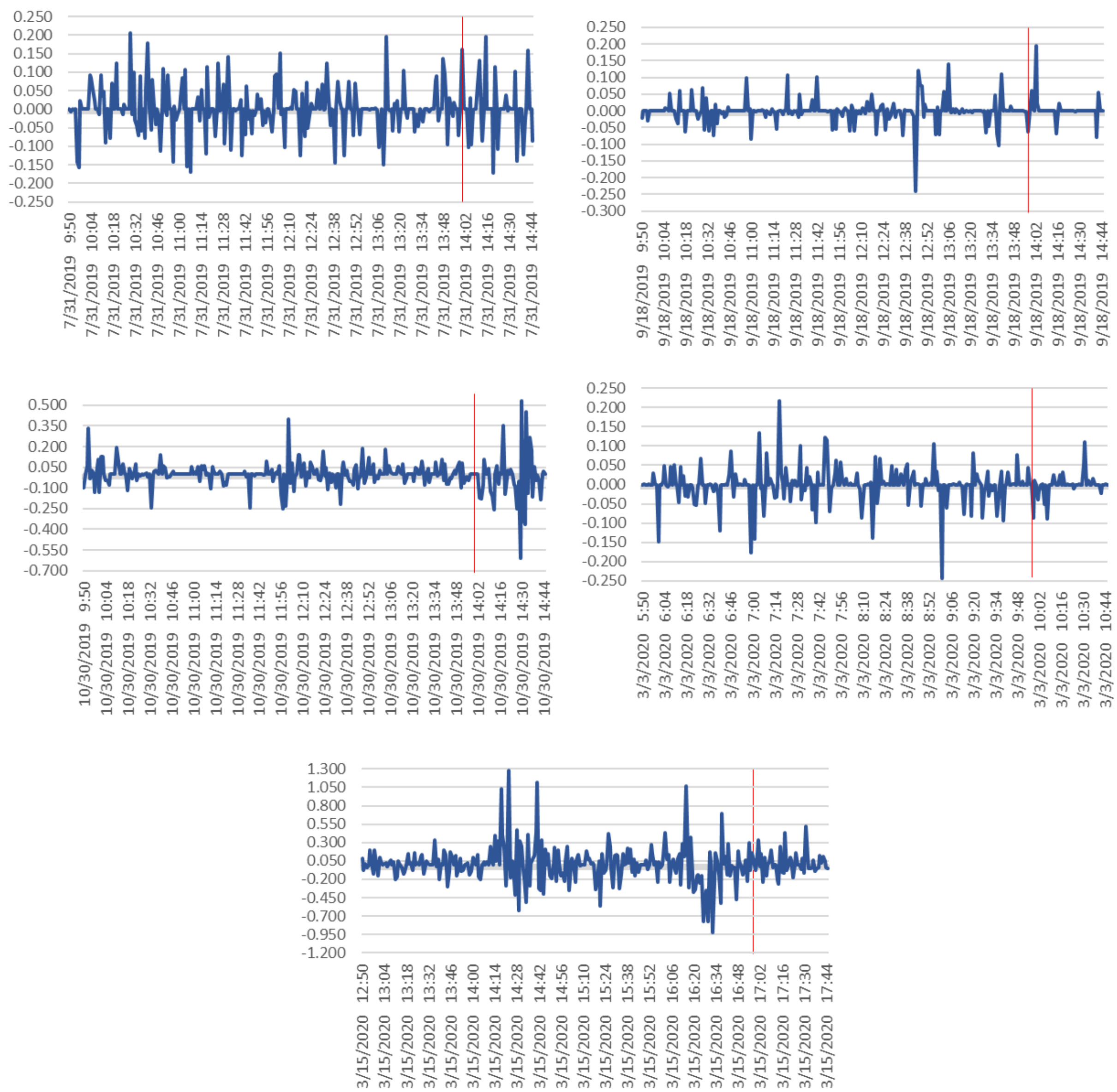

Figure 4: Real returns around the time of FOMC monetary policy easing announcements. On the vertical axis bitcoin log returns in percentage and on the horizontal axis the event date and time, in red the specific time of the event.
Source: own elaboration with data from Bloomberg terminals

The constant mean models were estimated for each event in order to calculate the expected normal returns. Then, the abnormal returns, i.e., the difference between the real returns and the expected returns, were estimated and averaged. The descriptive statistics for the average abnormal returns (AARs) are presented in Table 3. The mean value is -0.003%, the minimum is -0.106%, and the maximum is 0.157%.

Mean	-0.0037
Standard Error	0.0065
Median	-0.0034
Standard Deviation	0.0485
Sample Variance	0.0024
Range	0.2644
Minimum	-0.1068
Maximum	0.1577
Sum	-0.2096

Table 3: Descriptive statistics of the abnormal returns
Source: Own elaboration

The null hypothesis that the FOMC monetary policy easing announcements have no impact on the bitcoin returns is tested by the traditional t-test, the Corrado-Zivney rank t-test, and the Wilcoxon sign rank t-test as explained in the methodology section. The results of the Corrado-Zivney rank test on the AARs are presented in Appendix I. In this test, the null hypothesis of no abnormal performance is tested for every single minute in the event window. The null hypothesis of no abnormal performance is rejected at a 5% significance level in only one single-minute test, i.e., minute 21 on the event window. In all the other single-minute tests the null hypothesis of no abnormal performance could not be rejected at a 1%, 5%, and 10% level of significance.

Figure 5 shows the CARs and CAARs for the whole event window. For this figure, the aggregation is done each minute. The CARs and CAARs fluctuate close to zero for each event except for the event in October 2019 where the CARs follow a downwards trend. As previously seen in Figure 4, in this event there is an increase in volatility on the 27^{th} minute which lasts until the 36^{th} minute after the event.

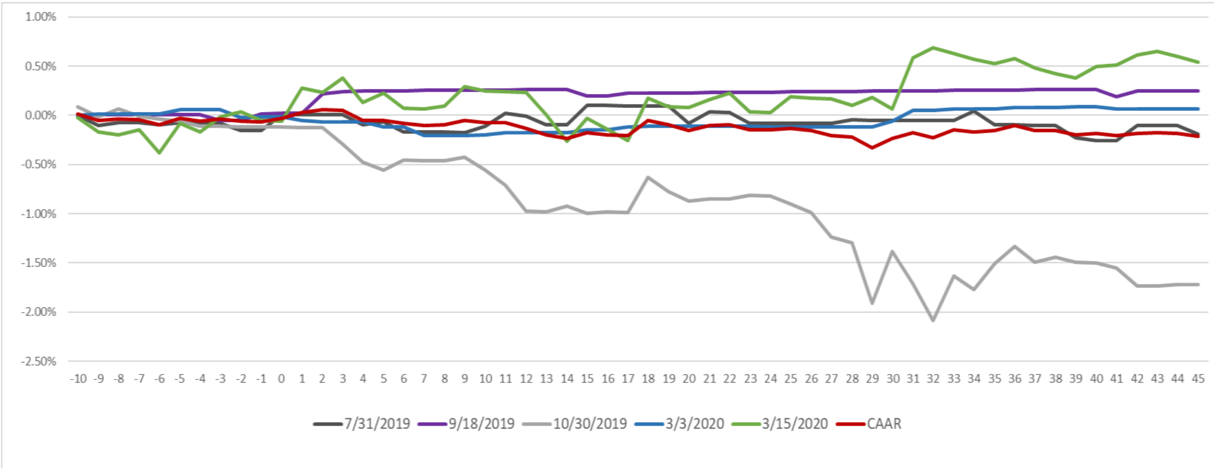

Figure 5. Cumulative abnormal returns and cumulative average abnormal returns aggregated each minute. On the vertical axis, the log returns. On the horizontal axis, the event period
Source: Own elaboration

The CARs and CAARs were obtained for intervals going from $(t_1 = -10, t_2 = 45)$ to $(t_1 = -5, t_2 = 5)$. The CAAR analysis provides an aggregate assessment of those intervals. The results of the traditional t-test and Wilcoxon sign rank t-test on the CAARs are presented in Table 4. Accordingly, it is found that the null hypothesis of no abnormal performance cannot be rejected for all intervals analyzed in the event window at a 1%, 5%, and 10% level of significance. These results are found in both the traditional t-test and the Wilcoxon t-test.

	CAR							
	7/31/2019	**9/18/2019**	**10/30/2019**	**3/3/2020**	**3/15/2020**	**CAAR**	**T-test p-value**	**Wilcoxon test p-value**
-10,45	-0.19%	0.25%	-1.72%	0.07%	0.54%	-0.21%	0.619	0.364
-10,40	-0.26%	0.27%	-1.50%	0.08%	0.49%	-0.18%	0.626	0.344
-10,30	-0.05%	0.25%	-1.38%	-0.06%	0.07%	-0.24%	0.457	0.241
-10,20	-0.08%	0.23%	-0.87%	-0.11%	0.08%	-0.15%	0.461	0.327
-10,10	-0.11%	0.26%	-0.55%	-0.20%	0.25%	-0.07%	0.655	0.794
-5,20	0.01%	0.22%	-0.84%	-0.13%	0.46%	-0.05%	0.814	0.534
-5,15	0.19%	0.19%	-0.95%	-0.16%	0.35%	-0.08%	0.758	0.715
-5,10	-0.02%	0.25%	-0.51%	-0.22%	0.63%	0.03%	0.899	0.796
-5,5	0.02%	0.24%	-0.52%	-0.13%	0.60%	0.04%	0.828	0.700

Table 4: CAR and CAAR for all events in percentage. P-values for the T-test and Wilcoxon test
Source: Own elaboration

Thus, the tests performed on the average abnormal returns and the cumulative average abnormal returns cannot reject the null of no abnormal performance. That is, the FOMCs monetary policy easing announcements have no impact on the bitcoin returns in the studied period and there is no significant difference between the real returns and the expected returns during this period. This implies that bitcoin is not affected by U.S. monetary policy easing announcements in the period that goes from 10 minutes before the announcement to 45 minutes after. The results are in accordance with Jarboui & Mnif (2021), who analyzing daily data found that the monetary policy easing announcement on March 3rd, 2020 does not generate significant abnormal returns on bitcoin until 4 days after the event date.

5.2 Robustness

As a first robustness test other estimations windows were used, namely 2 hours and 1 day before the event. This was motivated by the high volatility commonly experienced in the cryptocurrency market. The previous results are robust for estimation windows of 2 hours and 1 day before the event. The null hypothesis of no abnormal performance cannot be rejected by the Corrado-Zivney rank t-test, the traditional t-test, and the Wilcoxon sign rank t-test. Thus, the FOMC monetary policy easing announcements have no impact on the bitcoin returns during the event window and there is no significant difference between the real returns and the expected returns. The results are presented in Appendixes II and III.

For a second robustness test, a monetary policy surprise variable is calculated using the current-month federal funds futures contracts for all the FOMC announcements from October 2015 to April 2021. As explained in the methodology section, this variable is then regressed in the bitcoin returns to evaluate their relationship. Table 5 shows the results of various regressions where the statistical significance of changes in the monetary policy surprise variable (MP) on the bitcoin returns is tested. Searching for significance, some control variables are included in the regressions. For instance, a dummy variable is included when the federal funds target is at the zero-lower bound. Also, dummy variables are used to control for monetary policy changes, i.e., monetary policy easing, tightening, and no change. When heteroscedasticity is found the p-values with corrected standard error are presented.

	1	2	3	4	5	6	7
Intercept	-0.0005 (0.4710)	0.0000 (0.9572)	0.0000 (0.9850)	-0.0004 (0.6792)	-0.0004 (0.6269)	-0.0004 (0.7482)	0.0011 (0.5070)
MP	-0.0158 (0.2798)	-0.0206 (0.1895)	-0.0148 (0.3358)	-0.0167 (0.2692)	-0.0161 (0.4682)	-0.0162 (0.4673)	-0.0227 (0.1628)
Dummy MP zero		-0.0007 (0.5867)	-0.0008 (0.5469)	-0.0009 (0.5189)			-0.0007 (0.6277)
Dummy zero lower bound			-0.0003 (0.8651)		-0.0004 (0.7603)	-0.0005 (0.7516)	-0.0004 (0.8088)
Dummy easing		-0.0030 (0.2357)					-0.0043 (0.1609)
Dummy Tightening				0.0015 (0.3747)			
Dummy no change			0.0000 (0.9954)			0.0001 (0.9712)	-0.0012 (0.5088)

Table 5: Testing the significance of the MP in various linear regression.
The data correspond to coefficient estimates and (p-values). Heteroscedasticity is found in regressions 5 and 6, p-values with corrected standard errors are presented for these regressions.
Source: Own elaboration

The results in Table 5 show that the coefficient estimates that explain the relationship between the MP and the bitcoin returns have the expected sign, that is, there is an inverse relationship between the monetary policy surprise variable and the bitcoin returns. If the FOMC announces monetary easing, federal funds futures contracts rates are expected to fall creating a negative change in the MP. As a result, bitcoin prices and returns should rise. Although the sign of the coefficient estimates is consistent in all the regressions, the p-values show that the null hypothesis that the coefficient estimates are zero cannot be rejected at any commonly used level of significance, that is, the relationship between the monetary policy surprise variable and the bitcoin returns is not statistically significant. Thus, there is insufficient evidence to conclude the changes in the federal funds rate, captured by the monetary policy variable, affect the bitcoin returns at the population level.

This result is in accordance with the results from the event study performed in the previous section. That is, the FOMC monetary policy easing announcements have no significant impact on bitcoin returns 10 minutes before the announcement and 45 after the announcement.

6. Conclusions

One of the main tenets of bitcoin is that it is a hedge against inflation caused by a large increase in the money supply. This study intended to contribute to the debate around this tenet by evaluating how bitcoin immediately responds to U.S. monetary policy easing announcements using an event study methodology and intraday data. The use of intraday data is motivated to reduce the risk of capturing other noise that might affect the price. Also, there is evidence of markets becoming more efficient as information is processed more quickly (Marshall, et al., 2019). In previous studies, immediate bitcoin price reaction can be observed a few minutes after some events take place. For instance, Ante (2021) showed that Elon Musk's Twitter activity results in significant cumulative abnormal returns 30 minutes after posting about bitcoin. Ante & Fiedler (2021) found that market participants immediately identify large transfers on the bitcoin blockchain and further adjust expectations and trading strategies some minutes after identification.

Thus, this study is meant to provide empirical evidence to the debate of bitcoin as a hedge against inflation by evaluating the immediate response of bitcoin returns to FOMC monetary policy easing announcements. The results of the event study show that there is no abnormal performance. That is, there is no significant difference between the expected returns and the actual returns in the period that starts 10 minutes before the announcement and finishes 45 after the announcement. Thus, bitcoin returns are not affected by U.S. monetary policy easing announcements at the time of the event. This finding is confirmed by the robustness tests. Firstly, the results are robust for different estimation windows. Secondly, monetary policy surprises, defined as changes in the federal funds futures rate, and bitcoin returns have an expected inverse relationship. However, the relationship between the two variables is not statistically significant suggesting that U.S. monetary policy easing announcements do not have a significant and instant relationship with bitcoin returns. Furthermore, the results are in accordance with Jarboui & Mnif (2021), who analyzing daily data found that the monetary policy easing announcement on March 3rd, 2020, does not generate significant abnormal returns on bitcoin until 4 days after the event date.

The results of this study can be explained by the fact that bitcoin might be detached or uncorrelated with some macroeconomics indicators (see for example, Alarcón, 2020; and Pyo & Lee, 2020,). Moreover, bitcoin promotes a decentralized alternative to Central Banking, and bitcoin supporters might not put a lot of attention to Central Banks' actions as they put to large transactions in blockchain, influential people’s activity on social media, and news about bitcoin fundamentals.

Further research could analyze bitcoins response to the U.S. monetary policy easing announcements comparing intraday and daily data while controlling for other noise. Also, bitcoin's instant response to different kinds of events can be further researched. In general, more academic research on bitcoin is needed in order to increase knowledge of this phenomenon that is becoming more and more important.

References

Alarcón, E., 2020. *Inference and Prediction of Cryptocurrency Market Returns,* Lund: LUP Student Papers. Available at: http://lup.lub.lu.se/student-papers/record/9023391

Ante, L., 2021. *How Elon Musk's Twitter activity moves cryptocurrency markets,* Hamburg, Germany: Blockchain Research Lab .

Ante, L. & Fiedler, I., 2021. Market reaction to large transfers on the Bitcoin blockchain - Do. *Finance Research Letters,* Volume 39.

Azouzi, D. & Echchabi, A., 2018. Libra Announcement: Does it have an impact on bitcoin's price?. *Journal of Innovation in Business and Economics,* 3(2), pp. 83-90.

Bartlett, M., 2020. What Happens To Bitcoin When The Money Printer Goes BRRR?. *Towards data science*, 30 March.

Board of Governors of the Federal Reserve System, 2015. *What is the Money Supply?.* [Online] Available at:https://www.federalreserve.gov/faqs/money_12845.htm
[Accessed 15 6 2021].

Board of Governors of the Federal Reserve, 2016. *The Federal Reserve System Purposes and Functions.* 11th Edition ed. Washington: Publications Fulfillment.

Brooks, C., 2014. *Introductory Econometrics for Finance.* 3rd ed. New York: Cambridge University Press.

Brown, S. J. & Warner, J. B., 1980. Measuring security price performance. *Journal of Finance and Economics,* 8(3), pp. 205-258.

Busse, J. A. & Green, T. C., 2002. Market efficiency in real-time. *Journal of Financial Economics,* Volume 65, pp. 415-437.

Cordet, S. et al., 2020. Cryptocurrency reaction to FOMC Announcements: Evidence of heterogeneity based on blockchain stack position. *Journal of Financial Stability*, Volume 46.

Corrado, C. J., 2011. Event Studies: A methodology Review. *Accounting and Finance,* Volume 51, pp. 207-234.

Corrado, C. J. & Zivney, T. L., 1992. The Specification and Power of the Sign Test in Event Study Hypothesis Tests Using. *The Journal of Financial and Quantitative Analysis,* 27(3), pp. 465-478.

Damanick, D., 2021. Bitcoin Is ‘Store of Value’ Though Not Yet ‘Medium of Exchange,’ Dallas Fed’s Kaplan Says. *Yahoo! Finance*, 16 4.

Fernández-Villaverde, J., 2018. Cryptocurrencies: A crash Course in Digital Monetary Economics. *University of Pennsylvania.*

Fernández-Villaverde, J., 2021. Fernández-Villaverde, Jesús, Cryptocurrencies and All That: Two Ideas from Monetary Economics (January 9, 2021). PIER Working Paper No. 21-009, Available at SSRN: https://ssrn.com/abstract=3790681

Fisher, I., 1920. *The Purchasing Power of Money: Its Determination and Relation to Credit, Interest and Crisis.* New York: Macmillan.

Ghadhad, I., 2018. Arbitrage opportunities and liquidity: An intraday event study on cross-listed stocks. *Journal of Multinational Financial Management,* Volume 46, pp. 1-10.

Gürkaynak, R., Sack, B. & Swason, E., 2005. Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements. *International Journal of Central Banking,,* Volume 1.

Gürkaynak, R. S., Kara, A. H., Kisacikoglu, B. & Lee, S. S., 2021. Monetary policy surprises and exchange rate behavior. *Journal of International Economics,* Volume 130.

Hajric, V., 2021. Don’t Count on Bitcoin to Be a Sure-Thing Inflation Hedge. *Bloomberg*, 17 March .

Handagam, S., 2021. Bitcoin and Inflation: Everything You Need to Know. *Coindesk,* 28 January.

Hashemi Joo, M., Nishikawa, Y. & Dandapani, K., 2020. Announcement effects in the cryptocurrency market. *Applied Economics,* 52(44), pp. 4797-4808.

IEA, 2021. Global Energy Review: CO2 Emissions in 2020. *IEA.*

Jagtani, S. & McDonald, M. D., 2021. ‘Laser Eyes’ El Salvador Leader Makes Bitcoin Legal Tender. *Bloomberg,* 9 June.

Jarboui, A. & Mnif, E., 2021. Cryptocurrency bubble risk and the FOMC. *Journal fo Investment Compliance,* 22(1).

Jarocinski, M. & Karadi, P., 2020. Deconstructing Monetary Policy Surprises - The Role of Information Shock. *American Economic Journal: Macroeconomics,* 12(2), pp. 1-43.

Keoun, B., 2020. Bitcoin Prices in 2020: Here’s What Happened. *Coindesk,* 30 December.

Kocenda, E. & Moravcova, M., 2018. Intraday effect of news on emerging European forex markets: An. *Economic Systems,* Volume 42, pp. 597-615.

Krugman, P. R., 1998. It's Baaack: Japan's Slump and the Return of the Liquidity Trap. *Brooking Papers of Economics,* Issue 2, pp. 137-205.

Kuttner, K., 2001. Monetary Policy surprises and interest rates: Evidence from Fed funds future markets. *Journal of Monetary Economics,* Volume 47, pp. 523-544.

Li, Z., Liming, C. & Dong, H., 2021. What are bitcoin market reactions to its-related events?. *International Review of Economics and Finance,* Volume 7, pp. 1-10.

MacKinlay, C., 1997. Event Studies in Economics and Finance. *Journal of Economic Literature,* 35(1), pp. 13-39.

Mankiw, N. G., 2013. *Macroeconomics.* 8th Edition ed. New York: Worth Publishers.

Marshall, B. R., Nguyen, N. & Visaltanachott, N., 2019. A Note on Intraday Event Studies. *European Accounting Review,* 28(3), pp. 605-619.

McCormick, E., 2021. Coinbase shares close 14% below opening price after trading debut. *Yahoo! Finance*, 14 April.

Nakamoto, S., 2008. A Peer-to-Peer Electronic Cash System.

Pyo, S. & Lee, J., 2020. Do FOMC and macroeconomic announcements affect Bitcoin. *Finance Research Letters,* Volume 37.

Rogers, J. L., Skinner, D. J. & Zechman, S. L. C., 2017. Run EDGAR run: SEC dissemination in a high-frequency world. *Journal of Accounting Research,* Volume 55, pp. 459-505.

Romer, D., 2019. *Advanced Macroeconomics.* 5th Edition ed. New York: McGraw-Hill.

Siegel, D. S. & McWilliams, A., 1997. Event studies in management research: Theoretical & empirical issues. *Academy of Management Journal,* 40(3), pp. 626-657.

Söderbeg, G., 2018. *Are Bitcoin and Other Crypto-assets money?,* Stockholm: Sveriges Riskbank.

Taub, D. & Wells, C., 2021. Goldman Close to Offering Bitcoin to Wealth Management Clients. *Bloomberg*, 31 March.

Thornton, D. L., 2006. When did the FOMC Begin Targeting the Federal Funds Rate? What the Verbatim Transcripts Tell Us. *Journal of Money,* 38(8), pp. 2039-2071.

Tully, S., 2021. Bitcoin is proving it's not the hedge against inflation that some boosters claim. *Fortune*, 24 February.

Vejacka, M., 2014. Basic Aspects of Cryptocurrencies. *Journal of Economy, Business and Financing,* 2(2), pp. 75-83.

Wilcoxon, F., 1945. Individual Comparisons by Ranking Methods. *Biometrics Bulletin 1,* 1(6), pp. 80-83.

Williamson, S. D., 2018. *Macroeconomics.* 6th Edition ed. United Kingdom: Pearson.

Wójtowicz, T., 2016. Intraday event study. The impact of US macroeconomic news on WIG20. *Studia Ekonomiczne,* Volume 295, pp. 109-118.

Wongswan, J., 2009. The response of global equity indexes to U.S. monetary policy announcements. *Journal of International Money & Finance,* Volume 28, pp. 344-365.

Yermack, D., 2015. Is Bitcoin a real currency? An economic appraisal. In: *Handbook of digital currency*. s.l.:Academic press, pp. 31-43.

Appendix I

Corrado-Zivney test – 4 hours estimation window

	Abnormal Returns						
	7/31/2019	**9/18/2019**	**10/30/2019**	**3/3/2020**	**3/15/2020**	**AAR**	**P-VALUE**
-10	-0.002%	0.002%	0.084%	0.001%	-0.023%	0.013%	0.37
-9	-0.098%	0.002%	-0.100%	0.010%	-0.145%	-0.066%	0.37
-8	0.029%	0.002%	0.077%	0.001%	-0.032%	0.015%	0.14
-7	-0.002%	0.002%	-0.070%	0.001%	0.054%	-0.003%	0.72
-6	-0.020%	0.002%	-0.031%	0.001%	-0.235%	-0.057%	0.39
-5	0.018%	-0.001%	-0.021%	0.045%	0.295%	0.067%	0.37
-4	-0.002%	0.001%	-0.050%	0.001%	-0.085%	-0.027%	0.21
-3	-0.002%	-0.060%	-0.002%	0.001%	0.158%	0.019%	0.66
-2	-0.073%	0.002%	-0.002%	-0.086%	0.046%	-0.023%	0.42
-1	-0.002%	0.062%	-0.002%	0.010%	-0.084%	-0.003%	0.66
0	0.160%	0.007%	-0.002%	0.001%	-0.006%	0.032%	0.28
1	0.003%	0.002%	-0.002%	-0.038%	0.331%	0.059%	0.58
2	-0.002%	0.197%	-0.002%	-0.015%	-0.038%	0.028%	0.49
3	-0.002%	0.024%	-0.173%	0.001%	0.142%	-0.002%	0.76
4	-0.105%	0.002%	-0.181%	0.001%	-0.245%	-0.105%	0.10
5	0.029%	0.002%	-0.082%	-0.051%	0.091%	-0.002%	0.99
6	-0.098%	0.002%	0.102%	0.001%	-0.153%	-0.029%	0.32
7	-0.002%	0.003%	-0.002%	-0.088%	-0.007%	-0.019%	0.41
8	-0.002%	0.002%	-0.002%	0.001%	0.032%	0.006%	0.35
9	-0.002%	0.002%	0.039%	0.001%	0.196%	0.047%	0.11
10	0.065%	0.001%	-0.130%	0.001%	-0.046%	-0.022%	0.33
11	0.131%	0.002%	-0.161%	0.025%	-0.006%	-0.002%	0.80
12	-0.028%	0.002%	-0.263%	0.001%	-0.007%	-0.059%	0.11
13	-0.088%	0.002%	-0.002%	0.001%	-0.225%	-0.063%	0.35
14	-0.002%	0.002%	0.058%	0.001%	-0.272%	-0.043%	0.76
15	0.195%	-0.068%	-0.071%	0.026%	0.235%	0.063%	0.60
16	-0.002%	0.002%	0.008%	0.001%	-0.111%	-0.020%	0.68
17	-0.002%	0.025%	-0.002%	0.032%	-0.117%	-0.013%	0.81
18	-0.002%	0.002%	0.354%	0.001%	0.433%	0.158%	0.44
19	-0.002%	0.002%	-0.147%	0.001%	-0.086%	-0.047%	0.44
20	-0.174%	0.002%	-0.095%	0.001%	-0.013%	-0.056%	0.17
21	0.113%	0.002%	0.027%	0.001%	0.087%	0.046%	**0.08**
22	-0.001%	0.002%	-0.002%	0.001%	0.060%	0.012%	0.31
23	-0.109%	0.002%	0.034%	0.001%	-0.185%	-0.052%	0.87
24	-0.002%	0.002%	-0.002%	-0.011%	-0.006%	-0.004%	0.31
25	-0.002%	0.002%	-0.082%	0.001%	0.155%	0.015%	0.73
26	-0.002%	0.002%	-0.087%	0.001%	-0.012%	-0.020%	0.70
27	-0.002%	0.001%	-0.254%	0.001%	-0.006%	-0.052%	0.26

28	0.037%	0.003%	-0.057%	0.001%	-0.066%	-0.016%	0.71
29	-0.007%	0.002%	-0.612%	0.001%	0.082%	-0.107%	0.17
30	0.004%	0.002%	0.529%	0.054%	-0.115%	0.095%	0.38
31	-0.002%	0.002%	-0.334%	0.111%	0.519%	0.059%	0.67
32	-0.002%	0.002%	-0.369%	0.001%	0.101%	-0.053%	0.38
33	-0.001%	0.002%	0.453%	0.013%	-0.062%	0.081%	0.43
34	0.100%	0.002%	-0.140%	0.001%	-0.059%	-0.019%	0.35
35	-0.142%	0.002%	0.266%	0.001%	-0.044%	0.016%	0.40
36	-0.001%	0.002%	0.173%	0.017%	0.050%	0.048%	0.15
37	-0.002%	0.002%	-0.165%	0.002%	-0.095%	-0.052%	0.51
38	-0.002%	0.002%	0.052%	0.000%	-0.053%	0.000%	0.97
39	-0.124%	0.002%	-0.049%	0.001%	-0.046%	-0.043%	0.33
40	-0.030%	0.002%	-0.008%	0.001%	0.116%	0.016%	0.59
41	-0.002%	-0.078%	-0.049%	-0.022%	0.019%	-0.026%	0.14
42	0.157%	0.058%	-0.184%	0.001%	0.099%	0.026%	0.57
43	-0.002%	0.002%	-0.002%	0.001%	0.038%	0.007%	0.35
44	-0.002%	0.002%	0.020%	0.001%	-0.051%	-0.006%	0.53
45	-0.086%	0.002%	-0.002%	0.001%	-0.056%	-0.028%	0.54

The null hypothesis of no abnormal performance is tested for every single minute in the event window. The null hypothesis is rejected at a 10% significance level in only one single minute test, minute 21 after the announcement. In all the other single-minute tests the null hypothesis of no abnormal performance could not be rejected at a 1%, 5%, and 10% level of significance.

Appendix II

Corrado-Zivney test – 2 hours estimation window

	Abnormal Returns						
	7/31/2019	**9/18/2019**	**10/30/2019**	**3/3/2020**	**3/15/2020**	**AAR**	**P-VALUE**
-10	-0.002%	0.004%	0.084%	0.002%	0.008%	0.019%	0.34
-9	-0.099%	0.004%	-0.100%	0.011%	-0.115%	-0.060%	0.36
-8	0.028%	0.004%	0.077%	0.002%	-0.001%	0.022%	0.12
-7	-0.002%	0.004%	-0.070%	0.002%	0.084%	0.004%	0.77
-6	-0.021%	0.004%	-0.031%	0.002%	-0.204%	-0.050%	0.39
-5	0.017%	0.001%	-0.021%	0.046%	0.326%	0.074%	0.26
-4	-0.002%	0.003%	-0.050%	0.002%	-0.055%	-0.020%	0.50
-3	-0.002%	-0.058%	-0.002%	0.002%	0.189%	0.026%	0.80
-2	-0.074%	0.004%	-0.002%	-0.084%	0.076%	-0.016%	0.34
-1	-0.002%	0.064%	-0.002%	0.012%	-0.054%	0.004%	0.60
0	0.160%	0.009%	-0.002%	0.002%	0.025%	0.039%	0.45
1	0.002%	0.004%	-0.002%	-0.037%	0.361%	0.066%	0.50
2	-0.002%	0.199%	-0.002%	-0.014%	-0.007%	0.035%	0.51
3	-0.002%	0.026%	-0.173%	0.002%	0.172%	0.005%	0.80
4	-0.105%	0.004%	-0.181%	0.003%	-0.214%	-0.099%	0.11
5	0.028%	0.004%	-0.082%	-0.050%	0.122%	0.004%	0.99
6	-0.098%	0.004%	0.102%	0.002%	-0.122%	-0.023%	0.32
7	-0.003%	0.005%	-0.002%	-0.086%	0.024%	-0.013%	0.56
8	-0.002%	0.004%	-0.002%	0.002%	0.063%	0.013%	0.29
9	-0.002%	0.004%	0.039%	0.002%	0.227%	0.054%	0.13
10	0.065%	0.003%	-0.130%	0.002%	-0.016%	-0.015%	0.40
11	0.131%	0.004%	-0.160%	0.027%	0.025%	0.005%	0.89
12	-0.029%	0.004%	-0.263%	0.002%	0.023%	-0.053%	**0.10**
13	-0.089%	0.004%	-0.002%	0.002%	-0.195%	-0.056%	0.44
14	-0.002%	0.004%	0.058%	0.002%	-0.242%	-0.036%	0.77
15	0.194%	-0.066%	-0.071%	0.028%	0.265%	0.070%	0.59
16	-0.002%	0.004%	0.008%	0.002%	-0.081%	-0.014%	0.73
17	-0.002%	0.027%	-0.002%	0.033%	-0.087%	-0.006%	0.65
18	-0.002%	0.004%	0.354%	0.002%	0.464%	0.164%	0.45
19	-0.002%	0.004%	-0.147%	0.002%	-0.056%	-0.040%	0.51
20	-0.174%	0.004%	-0.095%	0.003%	0.018%	-0.049%	0.11
21	0.112%	0.004%	0.027%	0.002%	0.117%	0.053%	0.12
22	-0.002%	0.004%	-0.002%	0.002%	0.090%	0.018%	0.28
23	-0.110%	0.004%	0.034%	0.002%	-0.155%	-0.045%	0.48
24	-0.002%	0.004%	-0.002%	-0.009%	0.025%	0.003%	0.91
25	-0.002%	0.004%	-0.082%	0.002%	0.185%	0.021%	0.74
26	-0.002%	0.004%	-0.087%	0.002%	0.018%	-0.013%	0.90
27	-0.002%	0.003%	-0.254%	0.002%	0.024%	-0.046%	0.27
28	0.036%	0.005%	-0.057%	0.002%	-0.036%	-0.010%	0.65
29	-0.007%	0.004%	-0.612%	0.002%	0.113%	-0.100%	0.29

30	0.003%	0.004%	0.529%	0.056%	-0.085%	0.101%	0.38
31	-0.002%	0.004%	-0.334%	0.112%	0.549%	0.066%	0.61
32	-0.002%	0.004%	-0.369%	0.002%	0.132%	-0.047%	0.38
33	-0.002%	0.004%	0.453%	0.014%	-0.031%	0.088%	0.45
34	0.099%	0.004%	-0.140%	0.002%	-0.029%	-0.013%	0.42
35	-0.142%	0.004%	0.266%	0.002%	-0.014%	0.023%	0.38
36	-0.002%	0.004%	0.173%	0.018%	0.081%	0.055%	0.16
37	-0.002%	0.004%	-0.165%	0.003%	-0.064%	-0.045%	0.53
38	-0.002%	0.004%	0.052%	0.001%	-0.023%	0.006%	0.45
39	-0.125%	0.004%	-0.049%	0.002%	-0.016%	-0.037%	0.12
40	-0.031%	0.004%	-0.008%	0.002%	0.146%	0.023%	0.60
41	-0.002%	-0.076%	-0.049%	-0.020%	0.050%	-0.020%	0.15
42	0.156%	0.060%	-0.184%	0.002%	0.129%	0.033%	0.65
43	-0.002%	0.004%	-0.002%	0.002%	0.069%	0.014%	0.29
44	-0.002%	0.004%	0.020%	0.002%	-0.021%	0.001%	0.42
45	-0.087%	0.004%	-0.002%	0.002%	-0.025%	-0.022%	0.65

The null hypothesis of no abnormal performance is tested for every single minute in the event window. The null hypothesis is rejected at a 10% significance level in only one single minute test, minute 12 after the announcement. In all the other single-minute tests the null hypothesis of no abnormal performance could not be rejected at a 1%, 5%, and 10% level of significance.

T-test and Wilcoxon test – 2 hours estimation window

	CAR							
	7/31/2019	**9/18/2019**	**10/30/2019**	**3/3/2020**	**3/15/2020**	**CAAR**	**T test p-value**	**Wilcoxon test p-value**
-10,45	-0.22%	0.36%	-1.72%	0.13%	2.25%	0.16%	0.810	0.832
-10,40	-0.28%	0.37%	-1.50%	0.14%	2.05%	0.16%	0.797	0.829
-10,30	-0.07%	0.33%	-1.38%	-0.01%	1.32%	0.04%	0.936	0.861
-10,20	-0.10%	0.29%	-0.87%	-0.08%	1.02%	0.05%	0.869	0.875
-10,10	-0.12%	0.30%	-0.55%	-0.18%	0.89%	0.07%	0.795	0.520
-5,20	0.00%	0.27%	-0.83%	-0.09%	1.25%	0.12%	0.740	0.990
-5,15	0.18%	0.23%	-0.95%	-0.14%	0.99%	0.06%	0.850	0.715
-5,10	-0.02%	0.28%	-0.51%	-0.20%	1.12%	0.13%	0.654	0.352
-5,5	0.02%	0.26%	-0.52%	-0.12%	0.94%	0.12%	0.652	0.278

The null hypothesis of no event effect cannot be rejected for all intervals analyzed in the event window at a 1%, 5%, and 10% level of significance. This result is found in both the traditional t-test and the Wilcoxon t-test.

Appendix III

<u>Corrado-Zivney test – 1 day estimation window</u>

	Abnormal Returns						
	7/31/2019	**9/18/2019**	**10/30/2019**	**3/3/2020**	**3/15/2020**	**AAR**	**P-VALUE**
-10	-0.002%	0.000%	0.088%	-0.002%	-0.015%	0.013%	0.67
-9	-0.099%	0.000%	-0.096%	0.007%	-0.138%	-0.066%	0.15
-8	0.029%	0.000%	0.081%	-0.002%	-0.025%	0.015%	0.91
-7	-0.002%	0.000%	-0.067%	-0.001%	0.061%	-0.003%	0.30
-6	-0.021%	0.000%	-0.028%	-0.002%	-0.227%	-0.057%	**<u>0.07</u>**
-5	0.017%	-0.002%	-0.017%	0.042%	0.303%	0.067%	0.47
-4	-0.002%	-0.001%	-0.047%	-0.001%	-0.078%	-0.027%	**<u>0.05</u>**
-3	-0.002%	-0.062%	0.001%	-0.002%	0.165%	0.019%	0.73
-2	-0.074%	0.000%	0.001%	-0.088%	0.053%	-0.023%	0.34
-1	-0.002%	0.060%	0.001%	0.008%	-0.077%	-0.003%	0.41
0	0.160%	0.005%	0.001%	-0.002%	0.001%	0.032%	0.26
1	0.002%	0.000%	0.001%	-0.041%	0.338%	0.059%	0.79
2	-0.002%	0.195%	0.001%	-0.018%	-0.031%	0.028%	0.74
3	-0.002%	0.022%	-0.170%	-0.002%	0.149%	-0.002%	0.88
4	-0.105%	0.000%	-0.177%	-0.001%	-0.238%	-0.105%	0.12
5	0.028%	0.000%	-0.079%	-0.053%	0.098%	-0.002%	0.56
6	-0.098%	0.000%	0.106%	-0.002%	-0.146%	-0.029%	0.36
7	-0.003%	0.001%	0.001%	-0.090%	0.001%	-0.019%	0.97
8	-0.002%	0.000%	0.001%	-0.002%	0.039%	0.006%	0.70
9	-0.002%	0.000%	0.043%	-0.002%	0.204%	0.047%	0.89
10	0.065%	-0.001%	-0.126%	-0.002%	-0.039%	-0.022%	0.34
11	0.131%	0.000%	-0.157%	0.023%	0.001%	-0.002%	0.34
12	-0.029%	0.000%	-0.260%	-0.002%	0.000%	-0.059%	0.33
13	-0.088%	0.000%	0.001%	-0.002%	-0.218%	-0.063%	0.15
14	-0.002%	0.000%	0.062%	-0.002%	-0.265%	-0.043%	0.43
15	0.195%	-0.069%	-0.068%	0.024%	0.242%	0.063%	0.67
16	-0.002%	0.000%	0.012%	-0.002%	-0.104%	-0.020%	0.20
17	-0.002%	0.023%	0.001%	0.029%	-0.110%	-0.013%	0.43
18	-0.002%	0.000%	0.357%	-0.002%	0.441%	0.158%	**<u>0.07</u>**
19	-0.002%	0.000%	-0.144%	-0.002%	-0.079%	-0.047%	0.11
20	-0.174%	0.000%	-0.091%	-0.001%	-0.006%	-0.056%	0.34
21	0.112%	0.000%	0.031%	-0.002%	0.094%	0.046%	0.44
22	-0.002%	0.000%	0.001%	-0.002%	0.067%	0.012%	0.74
23	-0.110%	0.000%	0.037%	-0.001%	-0.178%	-0.052%	0.26
24	-0.002%	0.000%	0.001%	-0.013%	0.001%	-0.004%	0.30
25	-0.002%	0.000%	-0.078%	-0.002%	0.162%	0.015%	0.43
26	-0.002%	0.000%	-0.083%	-0.002%	-0.005%	-0.020%	0.13
27	-0.002%	-0.001%	-0.251%	-0.002%	0.001%	-0.052%	0.20

28	0.037%	0.001%	-0.053%	-0.002%	-0.059%	-0.016%	0.86
29	-0.007%	0.000%	-0.609%	-0.002%	0.090%	-0.107%	0.80
30	0.003%	0.000%	0.533%	0.052%	-0.108%	0.095%	0.13
31	-0.002%	0.000%	-0.331%	0.108%	0.526%	0.059%	0.24
32	-0.002%	0.000%	-0.366%	-0.002%	0.109%	-0.053%	0.54
33	-0.002%	0.000%	0.457%	0.010%	-0.054%	0.081%	0.15
34	0.099%	0.000%	-0.137%	-0.002%	-0.052%	-0.019%	0.54
35	-0.142%	0.000%	0.269%	-0.002%	-0.037%	0.016%	0.48
36	-0.002%	0.000%	0.177%	0.015%	0.058%	0.048%	0.35
37	-0.002%	0.000%	-0.162%	-0.001%	-0.087%	-0.052%	0.25
38	-0.002%	0.000%	0.056%	-0.003%	-0.046%	0.000%	0.37
39	-0.125%	0.000%	-0.045%	-0.002%	-0.039%	-0.043%	0.12
40	-0.031%	0.000%	-0.005%	-0.002%	0.123%	0.016%	0.34
41	-0.002%	-0.080%	-0.045%	-0.024%	0.026%	-0.026%	0.20
42	0.156%	0.056%	-0.180%	-0.002%	0.106%	0.026%	0.25
43	-0.002%	0.000%	0.001%	-0.002%	0.045%	0.007%	0.53
44	-0.002%	0.000%	0.023%	-0.001%	-0.044%	-0.006%	0.27
45	-0.087%	0.000%	0.001%	-0.002%	-0.048%	-0.028%	0.20

The null hypothesis of no abnormal performance is tested for every single minute in the event window. The null hypothesis is rejected at a 10% significance level in three single minute test, minute -6 and -4 before the announcement and minute 18 after the announcement. In all the other single-minute tests the null hypothesis of no abnormal performance could not be rejected at a 1%, 5%, and 10% level of significance

<u>T-test and Wilcoxon test – 1-day estimation window</u>

	CAR							
	7/31/2019	**9/18/2019**	**10/30/2019**	**3/3/2020**	**3/15/2020**	**CAAR**	**T test p-value**	**Wilcoxon test p-value**
-10,45	-0.22%	0.14%	-1.52%	-0.07%	0.95%	-0.15%	0.730	0.392
-10,40	-0.28%	0.16%	-1.32%	-0.04%	0.86%	-0.12%	0.741	0.431
-10,30	-0.07%	0.17%	-1.24%	-0.16%	0.36%	-0.19%	0.528	0.297
-10,20	-0.09%	0.17%	-0.77%	-0.19%	0.30%	-0.12%	0.555	0.378
-10,10	-0.12%	0.21%	-0.48%	-0.25%	0.40%	-0.05%	0.775	0.848
-5,20	0.00%	0.17%	-0.74%	-0.19%	0.64%	-0.02%	0.919	0.603
-5,15	0.18%	0.15%	-0.88%	-0.21%	0.50%	-0.05%	0.833	0.794
-5,10	-0.02%	0.22%	-0.46%	-0.26%	0.74%	0.04%	0.839	0.717
-5,5	0.02%	0.22%	-0.48%	-0.16%	0.68%	0.06%	0.787	0.700

The null hypothesis of no event effect cannot be rejected for all intervals analyzed in the event window at a 1%, 5%, and 10% level of significance. This result is found in both the traditional t-test and the Wilcoxon t-test.