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Analysis of Cryptocurrency as a Financial Instrument

Boyang Dong[1]

[1] *Master of Science in Financial Mathematics, University of Chicago, IL, USA*

**Corresponding author E-mail: eliza6723s@gmail.com*

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Abstract

This paper provides a comprehensive analysis of cryptocurrency as a financial instrument, examining its underlying mechanisms, market structure, and risk characteristics. The study begins with an overview of cryptocurrency fundamentals, including blockchain technology and the evolution of the cryptocurrency market. Through quantitative analysis of daily returns for six cryptocurrencies and six traditional assets between January 2018 and December 2021, the research demonstrates cryptocurrency's distinctive risk-return profile. Principal Component Analysis reveals three major risk factors driving cryptocurrency returns, while clustering analysis identifies meaningful groupings among cryptocurrencies. The findings indicate that cryptocurrencies exhibit significantly higher volatility and tail risk compared to traditional assets but provide substantial diversification benefits when incorporated into conventional portfolios. Tangency portfolio analysis shows that adding cryptocurrencies to traditional assets substantially improves risk-adjusted returns, with the combined portfolio achieving a Sharpe ratio of 2.72, compared to 0.39 for traditional assets alone. The study further examines regulatory challenges, tax implications, and emerging frameworks, particularly within the European Union. This research contributes to understanding cryptocurrency's role in modern investment portfolios while highlighting the unique risks and regulatory considerations that accompany this emerging asset class.

1. Background Information

1.1 Definition, history and market structure

Definition：

Cryptocurrency is defined as a digital currency in which transactions are verified and records maintained by a decentralized system using cryptography, rather than by a centralized authority.

Crypto Overview：

Bitcoin, launched in 2008, was the first cryptocurrency introduced to the industry. It also has remained as the biggest and the most influential one. Bitcoin relies on peer-to-peer software and cryptography, in which a public ledger records all transactions and copies held on servers around the world. Anyone with a computer can register on one of these servers known as nodes. Then, transactions are publicly broadcasted to the network and shared from node to node. Simply stated, Bitcoins are stored in a peer-to-peer network of nodes (digital wallets). They can be accessed by owners using their private keys that are designed for ownership authentication.

Cryptocurrencies also have characteristics of high risk. Many of them were introduced to the market and do not exist anymore now. According to data from Coinopsy.com, there are 2398 dead coins, which means that they do not exist anymore, by the time of filing this report.1 There are multiple reasons that coins become dead. For instance, they are used as a scam, their website remains down, they have nodes or wallets issues, they have low liquidity etc.2 Compared with those dead coins, Bitcoin has retained its status in the cryptocurrency market by its well knownness and long-lasting.

Computed by market capitalization, the most popular cryptocurrencies are Bitcoin, Ethereum, Binance Coin and Tether.3 Characteristics：
Transferability. Crypto makes it possible to transfer value online without the need of a middleman - a bank or payment processor.

Decentralized. Normally Cryptocurrencies are not issued or controlled by any government or other central authority, although some governments are trying to release centralized digital currencies.

Security. The underlying technology of cryptocurrency is blockchain, which is similar to a bank's balance sheet or ledger, where any transaction will be recorded. Secured using blockchain, each block contains a set of transactions that have been independently verified by each member of the network, and each new block generated needs to be verified. This logic makes it almost impossible to forge transaction histories.

Transparency. Unlike ledgers, the blockchain of cryptocurrencies is distributed across participants including investors and consumers ofthe currency by the entire network.

Portability. Since cryptocurrencies are decentralized and not tied to any financial institution, they are still available even during financial crises among financial intermediaries.

Irreversibility. Unlike credit or debit payments, payments of cryptocurrencies are not reversible. Major Milestones：

2008 - The concept of cryptocurrency was published by an anonymous name called santoshi nakamoto. This marked the first appearance of bitcoin to the general public.

2009 - The launch of Bitcoin. Mining started this year.

2010 - Rapid growth stage. Being the only cryptocurrency in the market, Bitcoin started to draw public attention as the economy recovered from the great recession

2011 - Rivalry emerges. Competing cryptocurrency started emerging on the market. Examples included Namecoin and Litecoin.

2017 - Bitcoin reached the $10,000 mark for the first time, then it went viral.

2020 - The rally continues. Although the capital market experienced a severe downturn during the pandemic, Bitcoin has stayed strong and rallied upwards.

2021 - China bans Bitcoin mining due to its harm to China's pursuit of carbon neutrality.

Market structure (Exchange information)

There are two types of different exchange platforms for cryptocurrency - centralized exchange platform (CEX) and decentralized exchanges (DEX). CEX functions as intermediaries in trades, and often acts as custodians by storing and predicting users'private keys. 5 Examples of CEX include Coinbase and Binance. A huge advantage ofCEX is its huge trading volumes and high liquidity. Also, CEX typically supports conversions between fiat and crypto, enabling users to buy bitcoins with US dollars. 6 Moreover, CEX usually has a more user-friendly interface, making trades easier for beginners. On the other hand, CEX has strict know-your-customer (KYC) policies, making it difficult for users to maintain privacy and anonymity. In addition, since CEX acts as a custodian, they hold authority over users' assets, posing a major security risk.

DEX can be a good alternative to solve the issues with CEX. A DEX is an exchange that operates using self-executing smart contracts on the blockchain. It is deployed without permission, allowing anyone from anywhere in the world to interact with the liquidity pool from users and protocols hosted on the DEX's smart contract, trading and swapping tokens without the need for a central authority. As a result, they are not custodial and do not implement many of KYC's policies. But due to DEXs relatively complicated process to set up wallets and deposit funds, users may spend more time familiarizing themselves with the platforms.

Currently, due to its ease-of-use and relatively large trading volume (94% of global trades were done through CEXs in October 20209), CEX is still the dominant type of platform. Recently, Automated Market Maker (AMM) is a big innovation within DEXs. AnAMM is one type of DEX protocol that relies on a mathematical formula to price assets. For example, in the case of Uniswap, it uses the formula $x*y = k$ to price assets. X is the amount of one token in the liquidity pool, and y is the amount of the other. In this formula, k is a fixed constant, meaning the pool's total liquidity always has to remain the same. Unlike traditional peer-to-peer (P2P) transactions where there are two counterparties, AMM is peer-to-contract. Trades happen between users and contracts, and the price is determined by the formula. Out of the formula, the liquidity pool is important in order for AMM to work. People are rewarded for adding funds to liquidity pools by earning fees from trades happening in their pools. And those who inject funds into the liquidity pools are called Liquidity providers (LPs). AMMs are not mature yet as they only have limited features. However, more innovative AMMS can bring more growth to DEXs in the future.

1.2 Generation, mining, and underlying technology used along with restrictions (Block chain, Ethereum)

Generation:

Mining

Once new bitcoins are entered into circulation, miners can start to "mine" them by solving an extremely complex computational math problem. It is done through the use of computer processing power.

"Rewards" Bitcoin miners receive Bitcoin as a "reward" for completing "Blocks" of verified transactions. By "reward" here, however, no one is paying for the solutions to the math problems. The problem that mining solves is the problem of providing secure transactions without a central authority. There would be no way to securely exchange bitcoins. Once these coins are mined, they are added to the blockchain afterwards. The probability that a participant will be the one to discover the solution is related to the portion of the total mining on the network, since they need to discover a solution to a complex hashing puzzle first. Therefore, a powerful technology infrastructure is essential in this process.

Underlying technology:

Blockchain

Blockchain is a growing list of records. They are linked together using cryptography. It is basically a digital ledger of transactions that is duplicated and distributed across the entire network of computer systems on the blockchain.

Bitcoin blockchain is a public general ledger that records bitcoin transactions. However, Bitcoin is not the only version of it. Several other cryptocurrencies work with their own blockchain and distributed ledger architectures.

Ethereum

Ethereum was launched in 2015, which is the second-biggest cryptocurrency by market cap after Bitcoin. The initial objective is to set out to build a new kind of global, decentralized computing platform that takes the security and openness of blockchains and extends those attributes to avast range of applications. In addition, it has no limits on its total amount. Unlike the maximum cap on Bitcoin is 21 million, but some of the other types, for instance, Ethereum, do not have such restrictions.

Hardware Infrastructure:

Computing Power:

Miners need to call a hash function repetitively and programmatically. A hash function generates a fixed length character string from data records of any length. This data can be a word, a sentence or even an entire file. It is essentially a mathematical function that illustrates an expression or a relationship involving one or more variables or sets. It derives an output from an input. The output can be a string of bytes with a fixed length and structure. The output or value created is called "checksum" or "hash value". The hashing algorithm is always the same length and one-way when creating data, therefore, they are irreversible. The computing speed is measured by hashrate which represents "hash per second". It shows a mathematical problem that is solved. Here in the cryptocurrency world, the higher the hash rate the higher the hash rate the miner should have to solve the bitcoin mining problem. Computers processors can run these processes in parallel and complete the mining process rapidly. The computing power becomes a key factor of this mining competition.

Parallel Computing by Central Processing Units (CPUs):

Originally a powerful enough home computer could handle crypto mining. As the network grew, however, mathematical problems became more and more complicated. Miners started to look for a more efficient way of mining since they believe the greater the computing power is, the quicker new coins can be potentially claimed.

Graphic Cards:

A programmable Graphics Processing Unit (GPU) has millions of cores as compared to a CPU. Originally it was regarded as a perfect solution to compute intensive hash problems. Indeed, it defeats "CPU miners" to some degree. With more miners realizing and equipping themselves with graphic cards, CPU gradually became useless for bitcoin mining. This has been the case for a few years. Besides the fact that an unbearably high electricity consumption and cost, on a modern GPU, miners would need a couple thousand years to mine 1 BTC[1]. Almost none of them can get close to breaking the financial even point. Therefore, a more powerful and faster performance mining equipment was eagerly required.

ASIC:

ASIC stands for application specific integrated circuits, which can compute hashes (using algorithm SHA-256) exponentially in parallel. Each ASIC miner is constructed to mine a specific digital currency. For instance, S19 antminer is specifically designed to mine bitcoins. However, it makes it profitable, at least when miners are mining alone. The miners, therefore, tend to regroup to stay competitive in which revenues are shared according to the effort spent. Now cloud mining allows miners to lease infrastructure at a dedicated colocation, also known as mining farm, with a contract.

Mining Farm:

It is essentially a data center that emerged with the constant complication of the mining process. The management party is responsible for the construction and management of it. It is jointly invested by miner seat owners who own all the properties of the mining farm. Similar to other platforms, cloud mining allows users to either select a desired amount of hashing power and a period for the contract or to trade their hashing power.

1.3 Primary consumers of crypto-currency for transactions

Global overview:

As of 2021, global crypto ownership rates are estimated at an average of 3.9%, with over 300 million crypto users worldwide (shown in Figure 1). Over 18,000 businesses are already accepting cryptocurrency payments.

Figure 1: Global Cryptocurrency Ownership16

As seen in Figure 2, between 2012 and 2021, the price of Bitcoin has increased by over 540,000% (from 5.27 to 29391.78). Bitcoin reached an annual growth rate of 274% in 2020, which can largely be attributed to market's speculations, and the cryptocurrency market is predicted to grow with a compound annual growth rate of 56.4% from 2019 to 2025[2].

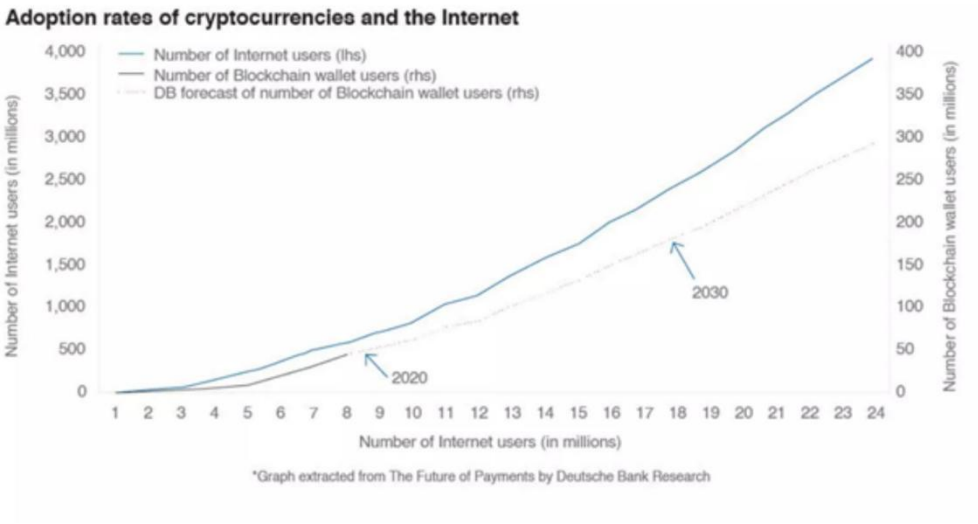


Figure 2: Growth of Cryptocurrency Adoption Rate

Companies who accept or partly accept bitcoin include:

- Wikipedia
- Microsoft
- AT&T
- Burger King
- KFC

- Overstock
- Subway
- Twitch
- Pizza Hut
- Miami Dolphins
- Dallas Mavericks
- Virgin Galactic
- Norwegian Air
- Namecheap
- CheapAir
- Gyft
- NewEgg
- The Internet Archive
- The Pirate Bay
- ExpressVPN
- Benfica
- Quiznos
- AMC

1.4 Primary investors in crypto-currencies (Retail vs Institutional)

In 2017, the price of bitcoin spiked to nearly $20,000 in December of that year after starting the year below $1,000. One year later, however, the price had tumbled to around $3,000, about 75% below its peak. Ever since this cryptocurrency bubble in 2017, cryptocurrency investment has become more mainstream for institutional, corporate, and retail investors.

Institutional Investors:

An April 2021 survey from Fidelity Digital Assets found that 52% of US and European institutional investors were already investing in crypto assets. These institutional investors included financial advisors, family offices, crypto hedge and venture funds, traditional hedge funds, endowments, and foundations.

Banks:

Cryptocurrencies have also gained great popularity across the banks. As of August 2021, 23 of the top 100 banks by assets under management are building custody solutions, or investing in the companies that provide them, according to Blockdata20. Based on the size of the funding rounds, the top 5 banks are Standard Chartered (with $380M funding in 6 rounds), BNY Mellon (with $320.69M funding in 5 rounds), Citigroup (with $279.49M funding in 9 rounds), UBS Group (with $266.2M funding in 5 rounds) and BNP Paribas (with $236.05M funding in 9 rounds).

Public Companies:

Corporate treasuries are also showing more and more interest in crypto investments. As of 28 June 2021, 34 public companies in the U.S. hold 1.14% of the total supply of bitcoins in circulation, according to data from CryptoTreasuries[3]. Among the top 10 public and private companies holding cryptocurrencies on their balance sheet, most are blockchain and bitcoin mining companies like Coinbase and Block.one, but there are also those that consider bitcoins an ideal inflation hedge. The idea of viewing Bitcoin as an inflation hedge is based on the fact that the number of Bitcoin is limited to 21 million, while the number of U.S. dollars typically increases over time, then as the supply of the U.S. dollar increases, the value of Bitcoin in dollars should also increase[4]. Companies having this inflation hedge consideration include the business intelligence software company MicroStrategy and the electric-automobile manufacturer Tesla.

Retail Investors:

Celebrities:

With the increased investment in cryptocurrency among institutional investors, the general public and high net worth individuals also have shown increased interest in the market. Celebrities and CEOs such as Elon Musk, Bill Gates, and Jack Dorsey have openly talked about their interest in surrounding Bitcoin, Ethereum, and Dogecoin. These celebrity investors also contribute to the momentum of cryptocurrencies as the coins' reputation expanded through celebrity-related events.

General Public:

Along with the trend driven by these celebrities and CEOs, the general public also showed great interest in the cryptocurrency market. Overall, about 14% of the U.S. population own cryptocurrency, according to a 2021 U.S. crypto report by Gemini22, a cryptocurrency exchange. With the spreading awareness of cryptocurrencies, Gemini estimated that about 19.3 million U.S. adults will be entering the crypto market very soon.

2. Trading and Transaction Aspects

2.1 Advantages and Limitations/Disadvantages of Cryptocurrency Trading (Table1)

With the industrialization and involvement of technology, Cryptocurrencies are gaining an upper hand over others. Since Bitcoin was first

created in 2009, cryptocurrencies have been attractive to many investors and financial services institutions. Cryptocurrencies do have many unique characteristics and advantages of their trading behaviors, meanwhile they also have some limitations or disadvantages compared to traditional currencies.

Advantages	Limitation/Disadvantages
Protection from inflation The source code specifies the amount of any type of coins. As demand for them increases, the value increases to keep up with the market. In the long run, this demand-supply relationship prevents the impact of inflation.	Data losses can cause financial losses If any user loses the private key to their wallet, there's no getting it back. The wallet will remain locked away along with the number of coins inside it. This will result in the financial loss of the user.
Self-governed and managed The cryptocurrency transactions are stored by developers/miners on their hardware, and they get the transaction fee as a reward for doing so. Since the miners are getting paid for it, they keep transaction records accurate and up-to-date, keeping the integrity of the cryptocurrency and the records decentralized.	Adverse Effects of mining on the environment Mining cryptocurrencies require a lot of computational power and electricity input, making it highly energy-intensive. It cannot be done on ordinary computers. Major Bitcoin miners are in countries like China that use coal to produce electricity. This has increased China's carbon footprint tremendously.
Secure and private The blockchain ledger is based on different mathematical puzzles, which are hard to decode. This makes a cryptocurrency more secure than ordinary electronic transactions. Cryptocurrencies, for better security and privacy, use pseudonyms that are unconnected to any user, account or stored data that could be linked to a profile.	Can be used for illegal transactions Due to high privacy and security of cryptocurrencies, the government is hard to track down the use of them. Bitcoin has been used as a mode of exchanging money in a lot of illegal deals in the past, such as buying drugs on the dark web. Cryptocurrencies are also used by some to convert their illicitly obtained money through a clean intermediary, to hide its source.
Currency exchanges can be done easily Cryptocurrency can be bought using many currencies like the US dollar, European euro, British pound, Indian rupee or Japanese yen. One currency can be converted into the other by trading in cryptocurrency, across different wallets, and with minimal transaction fees.	Some coins not available in other fiat currencies This forces the user to convert these currencies into one of the major currencies, like Bitcoin or Ethereum first and then through other exchanges, to their desired currency. By doing this, the extra transaction fees are added in the process.

Decentralized but still operated by some organization The decentralization helps keep the currency monopoly free and in check so that no one organization can determine the flow and the value of the coin, which, in turn, will keep it stable and secure, unlike fiat currencies which are controlled by the government.	Decentralized but still operated by some organization The flow and amount of some currencies in the market are still controlled by their creators and some organizations. These holders can manipulate the coin for large swings in its price. Even hugely traded coins are susceptible to these manipulations.
Cost-effective mode of transaction One of the major uses of cryptocurrencies is to send money across borders. With the help of cryptocurrency, the transaction fees paid by a user is reduced to a negligible or zero amount. It does so by eliminating the need for third parties.	Susceptible to hacks Although cryptocurrencies are very secure, exchanges are not that secure. Most exchanges store the wallet data of users to operate their user ID properly. This data can be stolen by hackers, giving them access to a lot of accounts. After getting access, these hackers can easily transfer funds from those accounts.
Afast way to transfer funds Due to that the verification of cryptocurrencies transactions requires very little time to process as there are very few barriers to cross, both international and domestic transactions are lightning-fast.	No refund or cancellation policy If there is a dispute between concerned parties, or if someone mistakenly sends funds to a wrong wallet address, the coin cannot be retrieved by the sender. This can be used by many people to cheat others out of their money.

Table 1. Pros and Cons for Cryptocurrency Trading

2.2 Different types of crypto-currencies and products on crypto traded available in various markets

Classification:

Crypto generally fall into one of two categories below,

- Tokens: programmable assets live within blockchain of given platforms
- Coins: Bitcoin and altcoins (non-Bitcoin cryptocurrencies) Difference between Tokens and Crypto Coin:

Crypto currency/coin: individual make payments using their digital currency

Tokens: individuals use them for trading, as a form of currency, and hold as a store of value.

Tokens:

Virtual currency token or denomination of a cryptocurrency that allows the holder to use it for economic purposes and investment, like legal tender. It's a tradable asset or utility that resides on its own blockchain.

ERC-20 Standard:

Cryptocurrency and blockchain system Ethereum are based on the use of tokens. One of the most significant standards is called ERC-20.

It emerged as the technical standard that provides a list of rules that all Ethereum based tokens must follow. It is used for all smart contracts on the Ethereum blockchain for token implementation. Rules include but not limited to,

- How tokens can be transferred
- How transactions are approved
- How users can access data about a token
- Total supply of tokens

Digital currencies with this standard: including Binance Coin, Maker(MKR), Basic Attention Token (BAT), Augur (REP), and OmiseGO (OMG). They are all issued on the Ethereum network, unlike other tokens that run on their own blockchain. Advantage and limitation are discussed as below,

Advantage:

- Simplify tasks set forth for developers

○ Empower developers to accurately predict how new tokens will function

○ Proceed work with no need ofredone every time a new token is released

○ Avoid incompatibility issues between the many different tokens issued on Ethereum

- Compliance

○ Token developers have fallen in line with ERC-20 rules. Most tokens released through Ethereum initial coin offering are ERC-20 compliant

- Massive increase in ICO campaigns in crypto market Limitation:

- Ethereum Ecosystem Improvement

○ The ERC-20 standard remains relatively nascent, bugs and glitches need to be ironed out.

○ Introduction is a time-consuming process, involving different parties:

exchanges, wallets, DApps, etc.

Other than ERC-20, a most widely used Ethereum token standard, Ethereum token community members are constantly starving to improve upon existing standards by implementing useful new features and designing functionalities for new use cases, for instance, ERC-223, ERC-777 standard.

Initial Coin Offering (ICO):

It is essentially the cryptocurrency industry's equivalent to an IPO. An enterprise level action to raise funds. Due to its simplicity, it draws a lot of attention from investors, who pay in a popular existing token and receive a commensurate number of new tokens in exchange. However, on the other hand, unlike shares, a token does not have any no intrinsic value or value guarantees.

Cryptocurrencies:

Bitcoin:

Introduction to Bitcoin:

Bitcoin was created by Satoshi Nakamoto, a pseudonymous person or team, who brought up the idea of"A Peer-to-Peer Electronic Cash System" in a white paper published in 2008. Thousands of new cryptocurrencies have been introduced ever since then, but bitcoin remains the largest by market capitalization and trading volume. The value of bitcoin has risen dramatically since its public release in 2009[5]. While it once sold for less than $150 per coin, as of November 16, 2021, a bitcoin now sells for more than $60,000. With its supply limited to 21 million pieces, many expect its price will only continue to rise over time, especially as more and more large institutional investors begin to use it as a kind of digital gold to hedge against market volatility and inflation, as well as the various platforms that provide uses for bitcoin: wallets, exchanges, payment services, online games, and more[6].

Bitcoin Products:

One way to gain exposure to the price of bitcoin is through owning derivatives, or synthetic products. These derivatives change their price based on the price of bitcoin. The most popular bitcoin derivatives are futures, options, perpetual contracts, and ETFs.

- Bitcoin Futures

Similar to traditional futures contracts, Bitcoin futures are simply contracts or agreements between two parties to buy and sell BTC at a specific price on a specific date in the future. Neither party is required to actually hold bitcoin, just settle the contract in USD or any other agreed upon currency. The difference between futures contracts and other cryptocurrency derivatives is the specific settlement date.

- Bitcoin Options

Bitcoin options are also cryptocurrency derivative contracts that follow the price of bitcoin, except that these do not necessarily settle on the expiration date, giving the trader the option or right to buy or sell at a predetermined price at a specific date in the future.

- Bitcoin Perpetual Contracts

Bitcoin perpetual contracts are cryptocurrency derivatives that, unlike futures or options, do not have an expiration or settlement date. Traders are able to maintain their positions under certain conditions, but their accounts must contain a minimum amount of BTC (margin). Another obvious factor to consider is the funding rate. This is a unique mechanism that helps tether the price of a perpetual contract to the price of Bitcoin. Due to its time constraints, the price of a futures contract always converges with the price of the underlying asset at expiration. Since perpetual contracts don't expire, their prices may start to deviate significantly from the price of bitcoin.

- Bitcoin ETFs

Bitcoin ETFs provide both the convenience of investing in an ETF and the exposure to bitcoin. Investing in bitcoin itself can be complicated, but investing in a bitcoin ETF will give investors easy access to the world of cryptocurrencies. The operation of these products is similar to other ETFs. However, a bitcoin ETF will track the price of bitcoin, not a market exchange like the S&P 500 or the Dow Jones Industrials. On October 19, 2021, ProShares launched its first bitcoin-linked ETF. This ETF (ticker: BITO) does not invest directly in bitcoin. Instead, it will be based on futures contracts linked to the cryptocurrency. Nevertheless, it is a milestone for cryptocurrency trading since with this ETF, any investor can have exposure to this volatile asset without fussing over online exchanges or bitcoin wallets.

Volatility of Bitcoin:

In the early days of bitcoin, prices were highly volatile, often deviating by more than 10% from its daily returns. After the rally and subsequent pullback in late 2017, bitcoin's volatility decreased, and since then, the coin has only exceeded this 10% deviation barrier once during the outbreak of the pandemic in early 2020 (Figure 3). The impact of this gradual calm is largely attributable to more institutional investors entering the cryptocurrency market. As more money comes into the market, bitcoin price will become more stable.

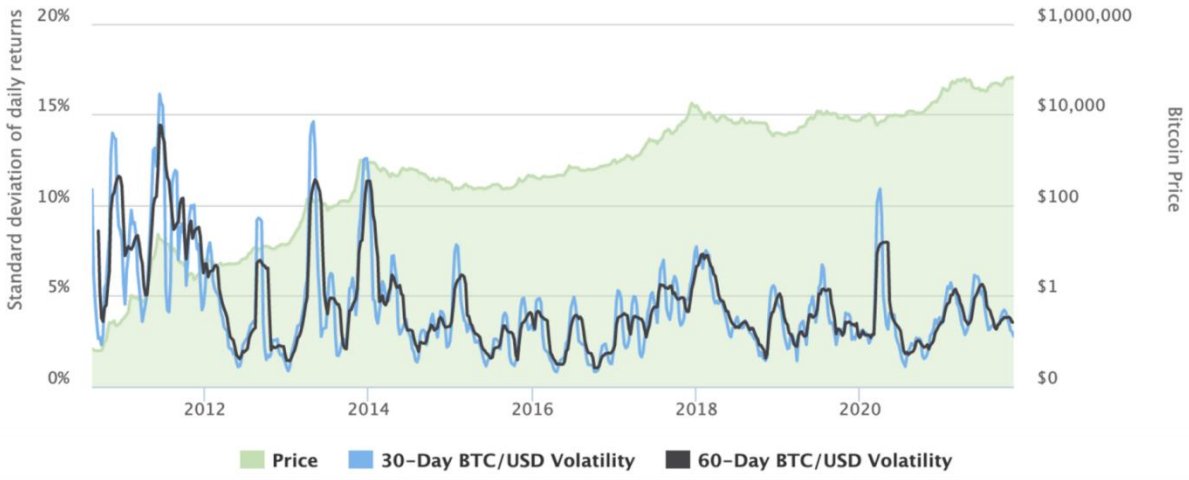


Figure 3. Bitcoin Price and Volatility25

What causes the volatility of Bitcoin?

- A market driven by sentiment

Unlike traditional currencies, bitcoin has no intrinsic value. While there is a growing number of use cases for bitcoin, there is still no clear value to attach to the price of bitcoin. As a result, the currency's movement is more susceptible to sentiment. However, sentiment can also work both ways. While bitcoin prices can rise on a whim, they can also plummet for seemingly no reason at all. Because they are not tied to a tangible value like gold is, these changes in sentiment can affect bitcoin in a more extreme way than the traditional stock market.

- Lack of Regulation

Because blockchains are distributed on many different machines around the world, this means that cryptocurrencies do not have a centralized location. As a result, established regulatory frameworks make it difficult to control them. Recent restrictions imposed by China have led to severe volatility in the price of bitcoin. In the short term, this lack of regulation may cut back the cryptocurrency growth, but this will not be a longstanding issue. In August 2021, Gary Gensler, the chairman of the U.S. Securities and Exchange Commission, mentioned at the Aspen Security Forum that the SEC "has taken and will continue to take our authorities as far as they go[7]."

Trade on Bitcoin *'s* volatility?

Regardless of the decrease in volatility, bitcoin is still capable of delivering massive price swings and risk diversifications. As of November 15, 2021, the volatility of bitcoin is 2.79%. For comparison, the volatility of gold averages around 1.2%, while other major currencies average between 0.5% and 1.0% (Figure 4). In this case, investors can use traditional portfolio allocation methods to resize their positions by inverse weighting volatility, so bitcoins will receive a lower portfolio allocation given its high volatility.

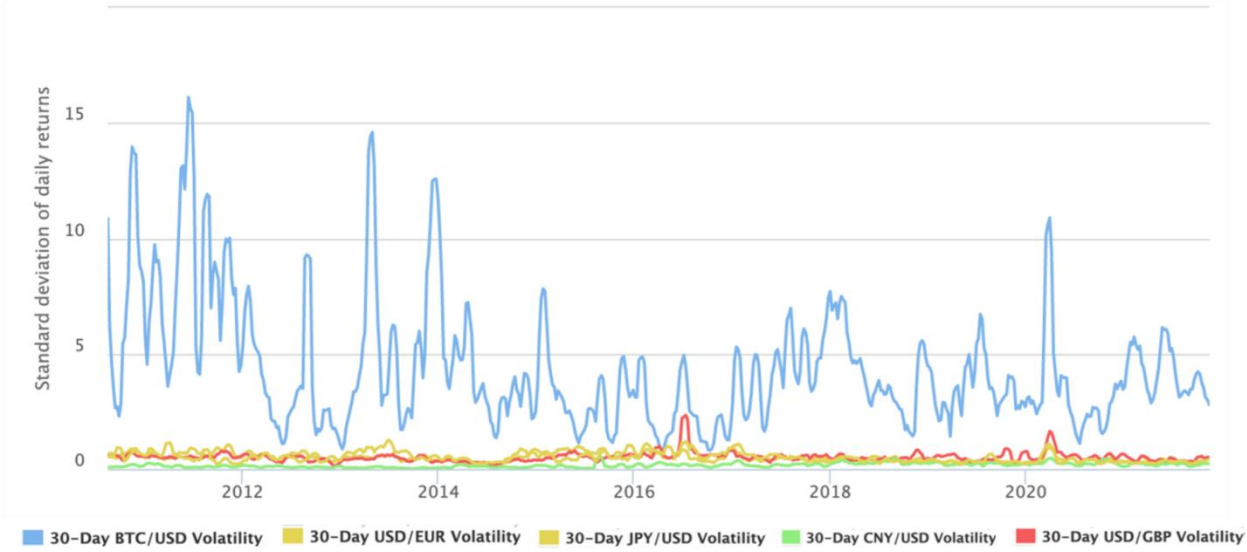


Figure 4. 30-Day Volatility for Bitcoin and other traditional currencies28

Altcoins:

Alternative digital currency to Bitcoin that operates under its own rules but also shares some characteristics with Bitcoin. 5000 of these alternative currencies have been created worldwide. Basic functions are essentially the same as Bitcoins. The majority of the Altcoins are based on Bitcoin. Certain Altcoins are serving more purposes than exchanging the coin for something of value. They can be classified as "Utility Tokens" or "Security Tokens". Based on market capital, most well-known Altcoins are Ethereum, Cardano, Binance, etc[8].

Here are the advantages and limitations of Altcoins.

Advantages:

- Alternative to Bitcoin

Should Bitcoin's value plummet, altcoins are generally good as a fallback option.

- Offer improvement to Bitcoin problems with
  - Higher transaction speed
  - Lower cost of mining Limitation:
- Irregulation

Since altcoins are newer, they lack public acceptance and exposure. Their value can change dramatically. It's not for the faint-hearted or risk averse investor.

- Scams

With pump and dump schemes, altcoins are often used in scams to fleece unsuspecting victims

- Conversion issue

Unlike bitcoin, altcoin are not really convertible to fiat currency. Since only a selected free token can be exchanged for fiat currencies. Additionally, only several cryptocurrency exchanges can make this trade for you.

Stablecoins:

It's a type of Altcoin. The name comes from the price stability. Stablecoins are cryptocurrencies that attempt to peg their market value to some external reference. They combined properties of both cryptocurrency and fiat currency. Examples include Tether (USDT) and MakerDAO.

Unlike altcoins and bitcoins, which are highly volatile, they can be chosen by investors that are looking to book large profits, even though that will make it risker.

Overview:

In short, stablecoins are cryptocurrencies designed to have values backed by a fiat currency or other reference assets. Proponents of stablecoins predict stablecoins to become widely used by households and businesses as a means of payment in the coming decades as stablecoins can provide faster and more efficient payment methods.

Up to 2021, stablecoins in the US are predominantly used to facilitate trading, lending, and borrowing ofother digital assets. By using stablecoins in speculative digital asset trading and asset movements between digital asset platforms and applications, the need for fiat currencies and traditional financial institutions can largely be reduced. In addition, stablecoins provides the convenience for users to engage in digital asset trading, lending, and borrowing within the distributed ledger environment. More is detailed in Table 2

	Altcoins	Stablecoins
Classification	Type of Cryptocurrency	Type of Altcoins
Subtypes	Ethereum, Binance Coin, Tether, Uniswap, etc.	Commodity collateralized stablecoins, crypto-collateralized stablecoins, fiat-collateralized
Advantages	Serve as an option to Bitcoin, with less transactional fee and quicker processing speed.	New features can be added accordingly. Borderless. Borderless. Offer complete translucency.
Limitations	Less exposure with high volatility.	Less ROI. Require external audits.

Table 2. Comparison Between Altcoins and Stablecoins

Market Capitalization:

The market capitalization of stablecoins exceeded $127 billion as of October 2021, a nearly 500 percent increase over the preceding twelve months. In specific, stablecoin supply grew from $21.5 billion on October 19, 2020 to $127.9 billion as of October 18, 2021.

Top ten stablecoins by market capitalization by November 202130:

- Tether
- USD Coin
- Binance USD
- Dai
- TerraUSD
- TrueUSD
- Pax Dollar
- Neutrino USD
- Reserve Rights

Main Advantage: Stability:

Stablecoins are generally created in exchange for fiat currency that an issuer receives from a user or third-party. To maintain a value pegged to fiat currency or other reference assets, stablecoins often offer a promise or expectation that the coin can be exchanged for the reserve assets.

Consequently, stablecoins have values that are designed to be stable.

As a result, stablecoins have the potential of leveraging the benefits of cryptocurrencies, such as transparency, security, immutability, digital, fast transactions, low fees, and privacy, without losing the guarantees of trust and the stability that come with using fiat currency.

Limitation One: Lack of Standard in Reserve Asset:

There are no universal standards regarding the composition of stablecoin reserve assets. Infact, stablecoins differ significantly in the riskiness of their reserve assets. In addition, the information made publicly available regarding the issuer's reserve assets is not consistent across stablecoin arrangements as to either its content or the frequency of its release. Some stablecoin claim to hold virtually all reserve assets in deposits at insured depository institutions or in U.S. Treasury bills, while others reportedly hold riskier reserve assets such as commercial paper or other digital assets.

Limitation Two: Lack of Standard in Redemption Rights:

Stablecoin redemption rights vary considerably. There is a large variety of redemptions policies among stablecoins regarding both who may present a stablecoin to an issuer for redemption and whether there are limits on the quantity of coins redeemed. Some issuers are permitted under the terms of the arrangement to suspend redemptions at any time, which thus give rise to considerable uncertainty about the timing of redemptions. Moreover, stablecoins differ in the nature of the claim provided to the user, with some providing a claim on the issuer and others providing no direct redemption rights to users.

Limitation Three: Lack of Systematic Regulation:

There is no legal federal framework for how to regulate stablecoins in itselfup to now.

Stablecoin providers often find themselves to be violating existing rules. For example, the Commodity Futures Trading Commission asserted that for nearly four years Tether did not fully back its stablecoin with US dollars. Historically, Tether was ordered to pay more than $40 million in penalties to settle charges from the CFTC and a case brought by the state of New York[8].

Section 3 - Trading Platforms and Associated Costs:

There are mainly two types of trading platforms - centralized exchange platform (CEX) and decentralized exchanges (DEX). A detailed description of pros and cons of each type of exchange can be found in the previous deliverable. The Table 3 shown below lists some of the most important pros and cons.

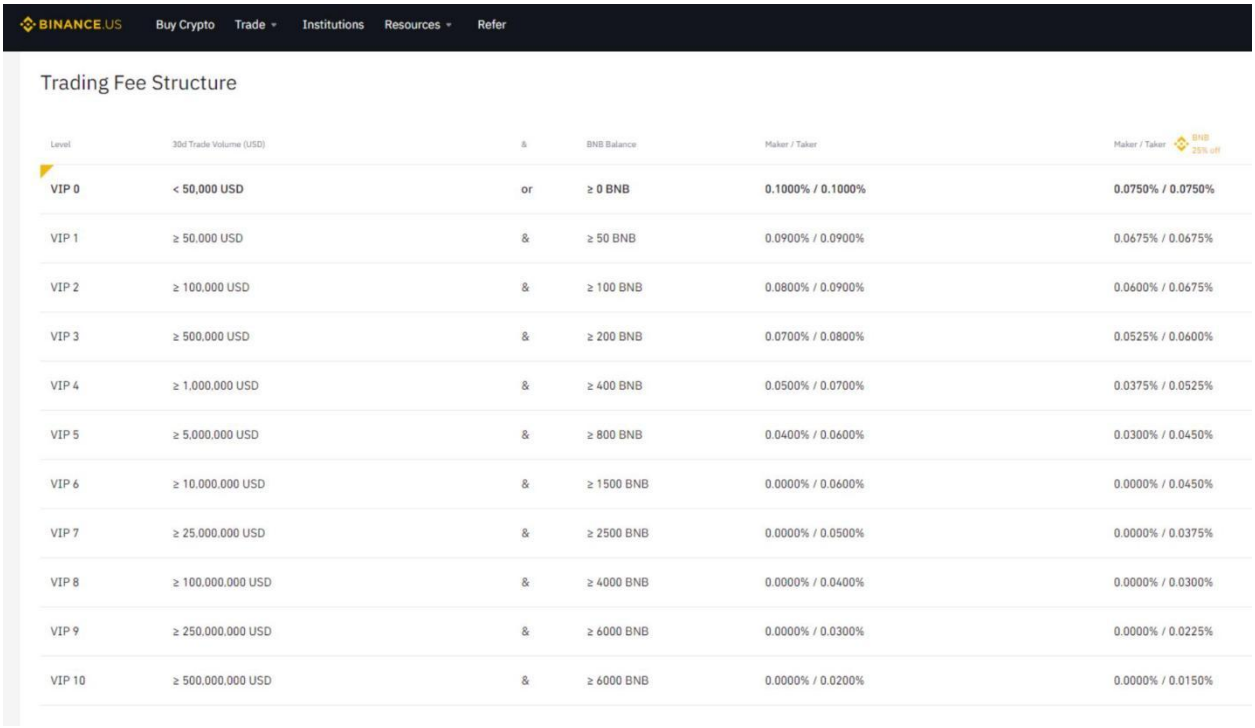
	CEX	DEX
Pros	- User friendly	- Best Privacy
	- High Liquidity - Easy conversion between Fiat and crypto currency	- Less security risk - More control over your e-wallet
Cons	- KYC policy - Hard to maintain anonymity - Security risk	- More complicated to use

Table 3. Comparison between CEX and DEX

We also listed three examples ofCEX and their pros & cons in Table 4:

CEX exchanges	Binance/Binance.US	Coinbase	Kraken
Transaction Fees	0.015% to 0.1% (Figure 5)	0.04% to 0.50% (taker orders); 0% to 0.50% (makers orders)(Figure 6)	0% to 0.26%
Pros	Lower fees; Advanced charting	Variety of altcoin choices; Easy user interface Great liquidity	Lower fees
Cons	US version has fewer trading pairs than the international version	No control over wallet keys	Not Beginner friendly

Table 4. CEX Examples



Level	30d Trade Volume (USD)	&	BNB Balance	Maker / Taker	Maker / Taker BNB 25% off
VIP 0	< 50,000 USD	or	≥ 0 BNB	0.1000% / 0.1000%	0.0750% / 0.0750%
VIP 1	≥ 50,000 USD	&	≥ 50 BNB	0.0900% / 0.0900%	0.0675% / 0.0675%
VIP 2	≥ 100,000 USD	&	≥ 100 BNB	0.0800% / 0.0900%	0.0600% / 0.0675%
VIP 3	≥ 500,000 USD	&	≥ 200 BNB	0.0700% / 0.0800%	0.0525% / 0.0600%
VIP 4	≥ 1,000,000 USD	&	≥ 400 BNB	0.0500% / 0.0700%	0.0375% / 0.0525%
VIP 5	≥ 5,000,000 USD	&	≥ 800 BNB	0.0400% / 0.0600%	0.0300% / 0.0450%
VIP 6	≥ 10,000,000 USD	&	≥ 1500 BNB	0.0000% / 0.0600%	0.0000% / 0.0450%
VIP 7	≥ 25,000,000 USD	&	≥ 2500 BNB	0.0000% / 0.0500%	0.0000% / 0.0375%
VIP 8	≥ 100,000,000 USD	&	≥ 4000 BNB	0.0000% / 0.0400%	0.0000% / 0.0300%
VIP 9	≥ 250,000,000 USD	&	≥ 6000 BNB	0.0000% / 0.0300%	0.0000% / 0.0225%
VIP 10	≥ 500,000,000 USD	&	≥ 6000 BNB	0.0000% / 0.0200%	0.0000% / 0.0150%

Figure 5. Binance Transaction Fee Tiers 35

Pricing Tier	Taker Fee	Maker Fee
Under $10K	0.50%	0.50%
$10K - $50K	0.35%	0.35%
$50K - $100K	0.25%	0.15%
$100K - $1M	0.20%	0.10%
$1M - $20M	0.18%	0.08%
$20M - $100M	0.15%	0.08%
$100M - $500M	0.10%	0.02%
$500M - $1B	0.06%	0.00%
$1B - $2B	0.05%	0.00%
$2B+	0.04%	0.00%

Figure 6. Coinbase Transaction Fee Tiers36

Table 5 lists some examples for DEX:

DEX Exchange	**Uniswap(V2)**	**Uniswap (V3)**	**dYdX**
Transaction Fee	0.3% swapping fee + gas fee	Three tiers - 0.05%, 0.3% and 1%	0% - 0.05% (Maker); 0.06% - 0.1% (Taker)

Pros	Relatively good liquidity; Usage of Automated Market Maker (AMM) in place of an order book37	Usage of Automated Market Maker (AMM) in place of an order book	Layer 2 protocol; No Gas Fee; Easy Access to leverage
Cons	Gas fee	Gas Fee	Limited assets for swaps

Table 5. DEX Examples

Note: Gas fee is the fee required to successfully conduct a transaction or execute a contract on the Ethereum blockchain platform. They are payments made by users to compensate for the computing energy required to process and validate transactions on the Ethereum blockchain.

Traditional DEX like Uniswap allows users to trade ERC-20 Tokens via Ethereum smart contracts. This gives traders the ability to trade on margin while also benefiting from the security provided by Ethereum. However, this brings gas fees to the transactions. dYdX partnered with StarkWare to build a layer 2 protocol for the exchange. This allows traders to deposit funds and trade instantly without paying gas fees for every transaction.39 This gives dYdX a huge advantage over competing DEXs and fueled dYdX to quickly become one of the largest platforms.

3. Risk Quantification and Modeling

3.1 Sample and Data

We examine daily returns for six crypto assets and six non-crypto assets from January 1st 2018 to December 1st 2021, using the adjusted close prices. The assets are used to form three types of portfolios: crypto portfolio, non-crypto portfolio, and combined portfolio. The six crypto assets include Litecoin (LTC-USD), Ethereum (ETH-USD), Bitcoin (BTC-USD), Dogecoin (DOGE-USD), XRP (XRP-USD), and Stellar (XLM-USD)[9]. They are chosen from the set of crypto assets that have historical data available during the chosen time window with the largest market capitalization. The six non-crypto assets can be further categorized into 4 different categories, which are market indices, commodities, interest rates, and sector ETFs. For market indices, we choose the S&P 500 ETF Trust (SPY), which will be a good measure of investors' sentiment of the stock market. For commodities, we choose Gold (GC=F) due to its high trading volumes and less proxy on future interest rate moves. Eurodollar Futures (GE=F) with settlement time June-2022 is used as the proxy of future interest rate moves. We use Financial Select Sector SPDR Fund (XLF), Energy Select Sector SPDR Fund (XLE), and Technology Select Sector SPDR Fund (XLK) as the sector ETFs[10]. The data are extracted from finance.yahoo.com.

Since certain assets are not traded 24/7, there will be "N/A" values displayed in our extracted datasets. We performed missing data analysis by forward filling and backfilling all the "N/A" for any of the fields, leaving us with a total of 1431 observations. The final data frame after data preprocessing is shown in Table 6.

Date	LTC-USD	ETH-USD	BTC-USD	DOGE-USD	XRP-USD	XLM-USD	SPY	GE=F	GC=F	XLK	XLF	XLE	^FVX
2018-01-01	0.116363	0.144702	0.097011	0.026490	0.037586	0.176576	0.006325	0.000000	0.001903	0.008341	0.005373	0.014976	-0.001333
2018-01-02	0.116363	0.144702	0.097011	0.026490	0.037586	0.176576	0.006325	0.000000	0.001903	0.008341	0.005373	0.014976	-0.001333
2018-01-03	-0.040347	0.088503	0.014611	0.019136	0.251711	0.586900	0.006325	0.000000	0.001903	0.008341	0.005373	0.014976	-0.001333
2018-01-04	-0.016294	0.018907	0.026196	0.034764	0.029388	-0.192113	0.004215	-0.000178	0.002431	0.005055	0.009263	0.006036	0.009346
2018-01-05	0.032734	0.017125	0.117333	0.261613	-0.046274	-0.084715	0.006664	0.000000	0.000682	0.010517	0.002824	-0.000400	0.007496
...	...	...	...	...	...	...	...	...	...	...	...	...	...
2021-11-27	0.001538	0.016374	0.023247	0.022202	0.011543	-0.004150	0.012267	0.000050	-0.001680	0.025001	0.003095	0.005757	0.013687
2021-11-28	0.021416	0.048217	0.044393	0.010348	0.022798	-0.008969	0.012267	0.000050	-0.001680	0.025001	0.003095	0.005757	0.013687
2021-11-29	0.032685	0.035080	0.009749	0.037128	0.023959	0.015088	0.012267	0.000050	-0.001680	0.025001	0.003095	0.005757	0.013687
2021-11-30	0.010416	0.041928	-0.013859	-0.002138	0.006848	0.023259	-0.019458	0.000050	-0.004881	-0.008346	-0.023914	-0.023435	-0.029536
2021-12-01	0.004599	-0.009606	0.003937	-0.024349	-0.007834	-0.024643	0.000000	0.000000	0.004511	0.000000	0.000000	0.000000	0.004348

1431 rows × 13 columns

Table 6. Final Data Frame after Data-preprocessing with the First and Last 5 Rows Displayed Only

3.2 Annualized Statistics of Asset's Daily Returns

Crypto Assets:

By calculating the mean return, standard deviation, and Sharpe ratio for each of the six crypto assets (Table 7.), we first examine the risk-adjusted returns of crypto assets. The Sharpe ratio is one of the industry-leading tools for looking at risk-adjusted returns. The results show that DOGE-USD is the crypto asset with the highest mean return and volatility, but it also has the largest Sharpe ratio. XRP-USD is the least appealing crypto asset among the six in terms of both mean return and Sharpe ratio. Overall, all six crypto assets have mean returns greater than 42% and volatility greater than 1.2, which represent crypto assets' high risks and high returns features.

Non-crypto Assets:

All non-crypto assets have Sharpe Ratios less than one. The Technology sector ETF (XLK) has the highest Sharpe ratio of 0.27 with highest mean return of 25.62%, which makes it the most appealing asset in the non-crypto portfolio. The Eurodollar futures (GE=F) has the lowest Sharpe ratio of-0.08 due to its negative mean return. Meanwhile, GE=F (GE=F) also have fairly high volatility, which makes it the least appealing asset in the non-crypto portfolio. Overall, the volatilities among the six non-crypto assets are fairly similar, ranging from 0.87 to 1.07.

Combined Assets:

The twelve assets vary widely in their returns and volatilities. Overall, DOGE-USD has the highest mean return and sharpe ratio while exhibiting the largest volatility. The worst-performing asset is the GE=F (GE=F), which has a negative return of-9.54% and a negative sharpe ratio of 0.10. In general, the six cryptocurrencies stand out among the twelve assets by having the highest returns accompanied by the highest volatilities. Returns ofthe cryptocurrencies are all above 1.0 while no traditional assets have a return over 0.3. Similarly, all six cryptocurrencies have volatilities over 1.2 while no traditional assets have volatility above 1.0. As such, the results provide solid statistical evidence for the high riskiness and high reward of the cryptocurrencies.

	Mean	Vol	Sharpe
LTC-USD	0.4662	1.4295	0.3261
ETH-USD	0.8947	1.3880	0.6446
BTC-USD	0.5949	1.2464	0.4773
DOGE-USD	2.2167	2.5211	0.8793
XRP-USD	0.4202	1.5680	0.2680
XLM-USD	0.5624	1.5561	0.3614
SPY	0.0870	0.9321	0.0934
GE=F	-0.0832	1.0108	-0.0823
GC=F	0.0903	1.0738	0.0841
XLK	0.2562	0.9562	0.2679
XLF	0.0584	0.8720	0.0670
XLE	0.0575	0.8975	0.0641

Table 7. Annualized Statistics ofAssets, Daily Returns

3.3 Tail Risk Analysis

Crypto Assets:

In order to explore the risk features of crypto assets, we examine the tail risk measures by computing each crypto asset's skewness, excess kurtosis, 95% value at risk (VaR), expected shortfall, and their maximum drawdown (Max Drawdown) with the start (MDD Start) and end dates (MDD End). The result in Table 8 shows that DOGE-USD has a large positive skewness of 13.60, and also the largest excess kurtosis of 346.90, which indicates a much heavier tail and a largely right-skewed distribution than a normal distribution, as shown in the distribution graph for DOGE-USD in Figure 7. Investors note skewness and kurtosis when judging a return

distribution because they reveal the extremes ofthe data set rather than focusing solely on the average. Short- and medium-term investors in particular would like to look at extremes because they are less likely to hold a position long enough to be confident that the average will work itself out. The large positive skewness of DOGE-USD's distribution could possibly indicate that an investor may expect frequent small losses and a few large gains from the investment, and therefore are generally more desirable by investors since there is some probability to gain huge profits that may cover all the frequent small losses. Going back to what happened in the real world in the market, this skewness risk and volatility occurred with notable events that happened to DOGE-USD especially as it has been attracting huge attention in social media. For example, one of the biggest Booster is Tesla's CEO Elon Musk, and he has become one of the most prominent and vocal champions of dogecoin in 2021, and last month, DOGE-USD's price has surged again following his announcement that Tesla will soon accept Dogecoin for its merchandise payments.

Besides DOGE-USD, we notice that XRP-USD has the largest maximum drawdown, which lasted from January 7th, 2018 to June 22nd, 2021, and it also has large values for other tail risk measures. In this case, XRP-USD seems to be more likely to experience greater loss than other crypto assets, and it is also less predictable using a normal distribution. On the other hand, among the six assets, LTC-USD, ETH-USD, and BTC-USD appear to be more "stable" and predictable given that they have smaller skewness and excess kurtosis in magnitude, and also

relatively less value at risk, expected shortfall, and maximum drawdown. In addition, these three crypto assets have negative skewness, compared with the positive values of the other three crypto assets, which indicates that the tail of the left side of the distribution is longer or fatter than the tail on the right side. The mean and median will be less than the mode. In contrast, DOGE-USD, XRP-USD, and XLM-USD have positive skewness so the tail of the right side of the distribution is longer or fatter than the tail on the left side, as shown in the distribution graph in Figure 7. We notice that LTC-USD, BTC-USD have their maximum drawdown at a very close level that both started on April 3rd, 2020 and ended on June 25th, 2021. In this case, we could expect a certain risk driver to become significant during this time and it is related to both LTC-USD and BTC-USD. In terms of risks of loss, all of the six crypto assets have 95% 1-day value at risk are close to -0.10 and their expected shortfall values are smaller than -0.158, which imply relatively higher risks of loss than non-crypto assets.

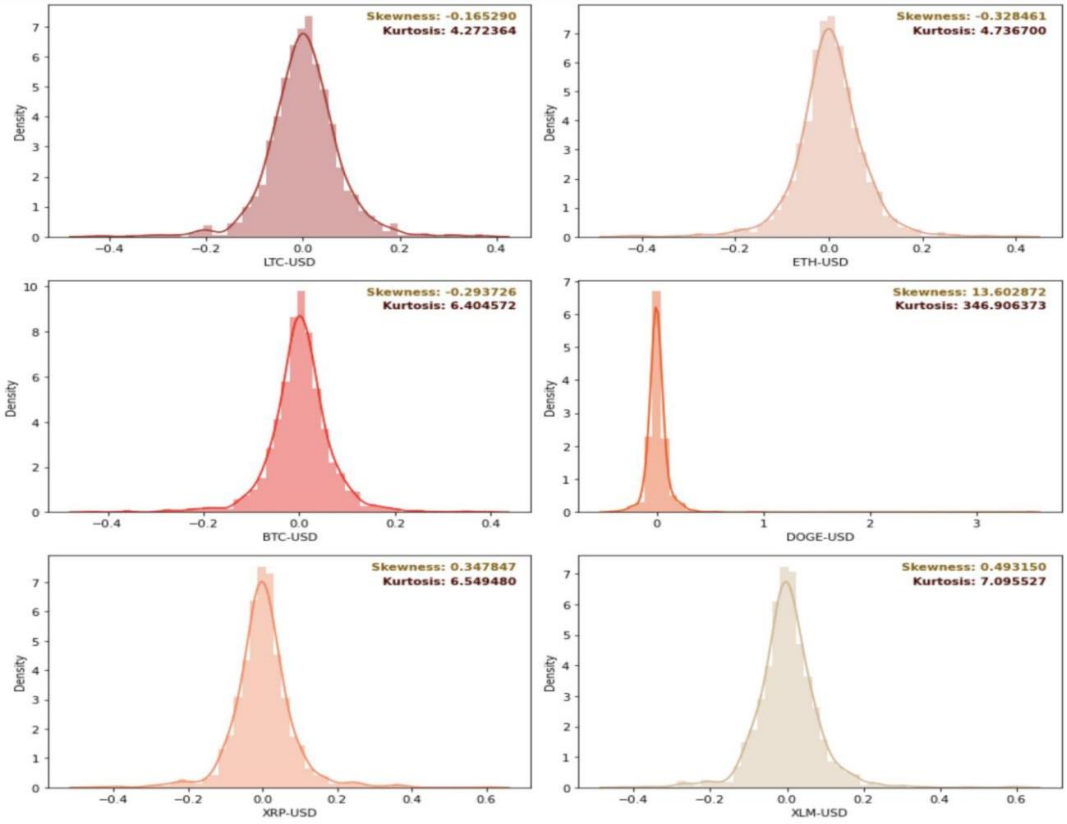


Figure 7. Distribution for Crypto Assets with Tail Risk Measures

Non-crypto Assets:

Overall, the six non-crypto assets have tail risks if compared to crypto assets (Figure 8). All six assets have slightly negative skewness. Compared to the numbers for crypto assets, these non-crypto assets have a less heavy tail, which shows that non-crypto assets have less tail risk than crypto assets. Also, the negative skewness implies that those assets regularly make smaller gains and occasionally make larger losses. Non-crypto assets also have comparatively smaller excess kurtosis, which demonstrates a lighter tail if compared to crypto assets. The 95% VaR and expected shortfall for non-crypto assets are respectively around -5% and -11%.

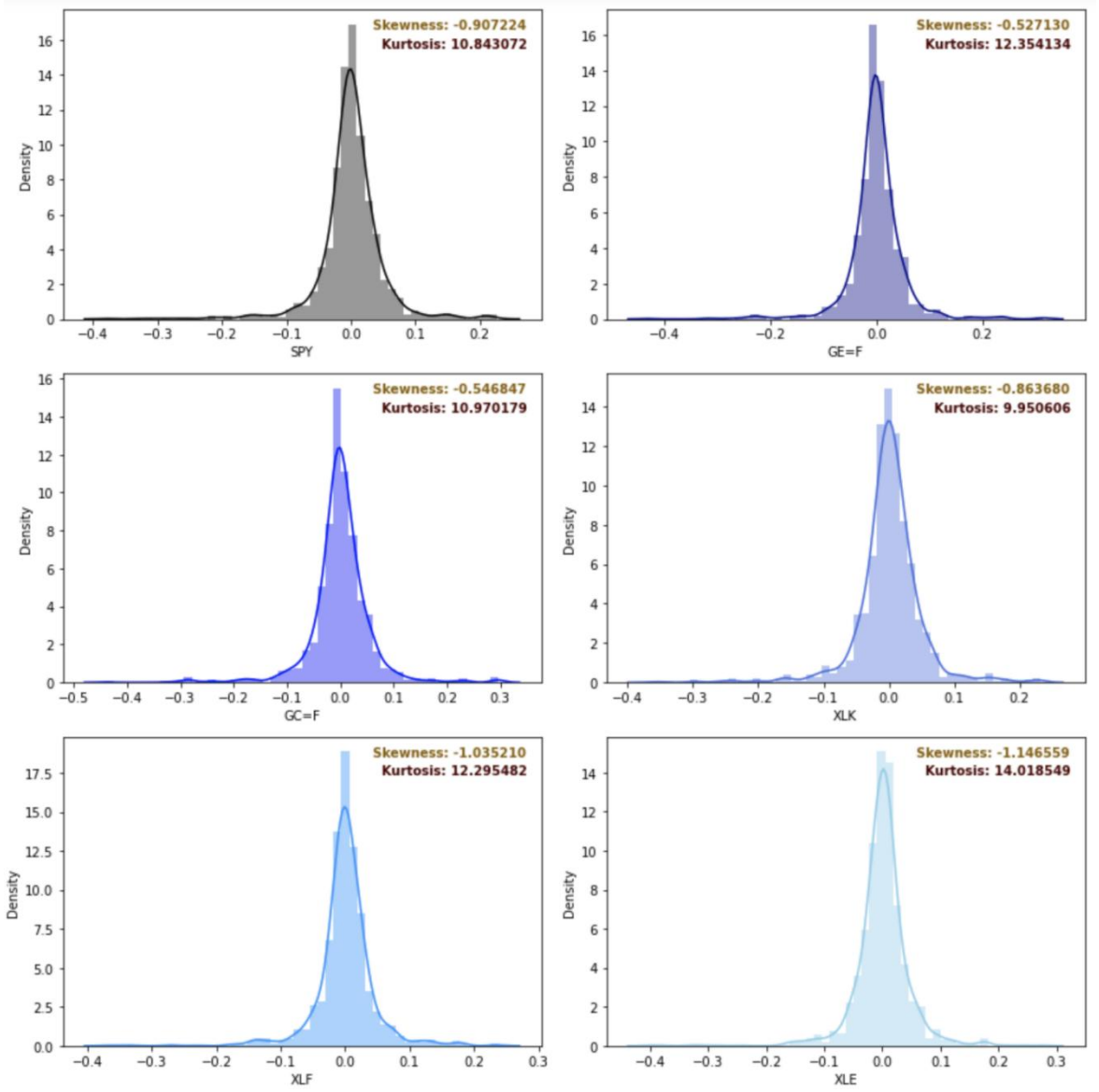


Figure 8. Distribution for Non-crypto Assets with Tail Risk Measures

Combined Assets:

Overall, our six cryptocurrencies exhibit much higher tail risk when compared with traditional assets (Table 8). Specifically, the 95% value at risk of the six cryptocurrencies have values ranging from -9% to -12% while the corresponding value in traditional assets are no more than -7%. Similarly, the expected shortfall of cryptocurrencies is significantly larger as of magnitude, with values ranging from -14% to -19%. In terms of maximum drawdown, cryptocurrencies and traditional assets show fairly similar statistics with around -90%.

	LTC-USD	ETH-USD	BTC-USD	DOGE-USD	XRP-USD	XLM-USD	SPY	GE=F	GC=F	XLK	XLF	XLE
Skewness	-0.165290	-0.328461	-0.293726	13.602872	0.347847	0.493150	-0.907224	-0.527130	-0.546847	-0.863680	-1.035210	-1.146559
Excess Kurtosis	4.272364	4.736700	6.404572	346.906373	6.549480	7.095527	10.843072	12.354134	10.970179	9.950606	12.295482	14.018549
VaR	-0.109706	-0.108367	-0.095635	-0.118442	-0.110241	-0.111842	-0.062608	-0.067270	-0.076283	-0.067698	-0.061133	-0.061338
Expected Shortfall	-0.174194	-0.172989	-0.158524	-0.196685	-0.187284	-0.182006	-0.127862	-0.135950	-0.144736	-0.130985	-0.119489	-0.121022
Max Drawdown	-0.981704	-0.951552	-0.972117	-0.948651	-0.982520	-0.971200	-0.984468	-0.995566	-0.995247	-0.981464	-0.976401	-0.954708
MDD Start	2020-04-03	2018-01-13	2020-04-03	2020-04-01	2018-01-07	2018-01-03	2020-03-30	2020-04-03	2020-04-03	2020-03-30	2020-03-30	2020-04-03
MDD End	2021-06-25	2018-12-14	2021-06-25	2020-11-09	2021-06-22	2021-11-24	2021-11-24	2021-11-24	2021-11-24	2021-11-24	2021-11-24	2021-11-22

Table 8. Tail Risk Measures

3.4 Tangency Portfolio & Diversification Effects

As a proxy for well-diversified portfolios of crypto assets, we construct a tangency portfolio with the six crypto assets and use the 5 Years Treasury Yield as the risk-free rate to find the mean excess returns of each asset. Since a tangency portfolio is the portfolio with the highest Sharpe ratio on the efficient frontier formed by the six crypto assets, we can use the weight of each asset in the tangency portfolio to further explore the risk-adjusted return.

Crypto Assets Tangency Portfolio:

The weights ofthe tangency portfolio are shown in Figure 9. We see that the tangency portfolio has the most weights in ETH-USD, BTC-USD, and DOGE-USD, then it allocates less weights in Stella, LTC-USD, and XRP-USD. By comparing with the correlation matrix of the crypto assets shown in Figure 10, we notice that the tangency portfolio maximizes the portfolio Sharpe ratio by allocating most weights in the two highly correlated and high-Sharpe ratio assets, ETH-USD and BTC-USD, and then also allocating relatively larger weight in the DOGE-USD, which is the asset that with the highest Sharpe ratio, and also is the most diversified asset given its small correlations with all other assets. The annualized portfolio performance in Table 9 has shown a significantly large Sharpe ratio of 1.313 (Sharpe ratio greater than 1.0 is considered acceptable to good by investors.) and a high mean excess return of 94.41% per year.

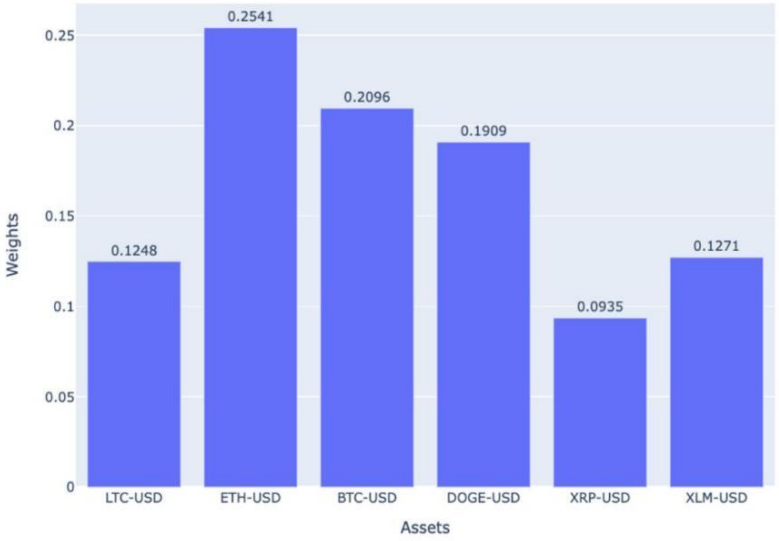


Figure 9. Tangency weight crypto portfolio

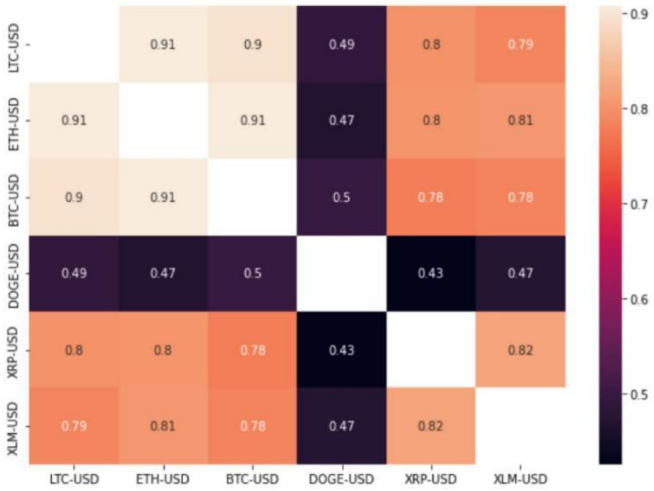


Figure 10. Correlation Matrix of Crypto Assets

	Tangency Portfolio Stats
Mean	0.9441
Volatility	0.7188
Sharpe	1.3134

Table 9. Tangency Portfolio Performance ofCrypto Assets

Non-crypto Assets Tangency Portfolio:

As shown in Figure 11, the tangency portfolio is heavy on the long position of XLK (technology ETF) and short position of GE=F to maximize Sharpe ratio (SR). This makes sense as all the non-crypto assets are highly correlated and XLK has the highest Sharpe ratio and GE=F has the lowest Sharpe ratio(Figure 12). Compared to the tangency portfolio of crypto assets, the non-crypto portfolio has smaller Sharpe ratio and smaller volatility (Table 10). This aligns with the conclusion drawn above that crypto assets have higher volatility and thus are compensated with higher returns.

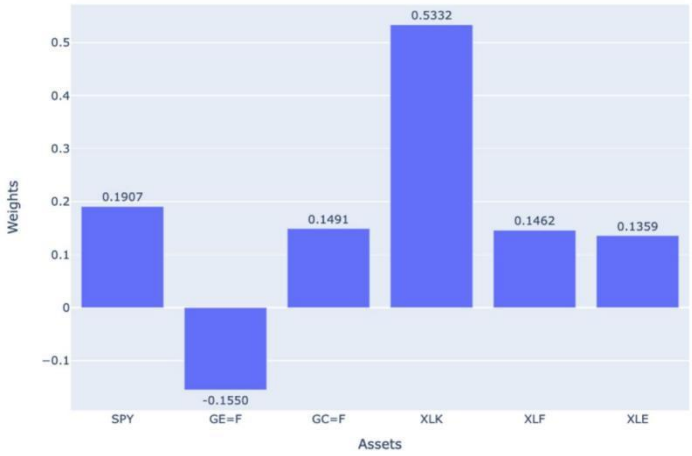


Figure 11. Tangency weight non-crypto portfolio

Figure 12. Correlation Matrix of Non-crypto Assets

	Tangency Portfolio Stats
Mean	0.1959
Volatility	0.6106
Sharpe	0.3209

Table 10. Tangency Portfolio Performance of Non-crypto Assets

Combined Assets Tangency Portfolio:

The weights of our combined tangency portfolio for the twelve assets are shown in Figure 13.

Our mean-variance optimization gave the largest weights to the six cryptocurrencies while putting less weights on traditional assets. In specific, our six cryptocurrencies had weights above 10% while the majority of the weights given to traditional assets were less than 5%. It is noticeable that a negative weight was given to the GE=F (GE=F), which had a negative mean return of-9.54%. Our tangency portfolio maximizes the overall Sharpe ratio by allocating the most weights in the cryptocurrencies, which have relatively lower correlations to the overall portfolio when compared with the traditional assets. This is exemplified in the correlation matrix where the charts reveal that while the traditional assets exhibit heavy correlation with one another ranging from 0.88 to 0.98, cryptocurrencies are generally correlated with other assets in the range of 0.4 to 0.8 (Figure 14). The annualized portfolio performance in Table 11 shows a Sharpe ratio of 2.7202 and a mean excess return of approximately 156% per year, which can largely be attributed to the high return of cryptocurrencies in the past four years.

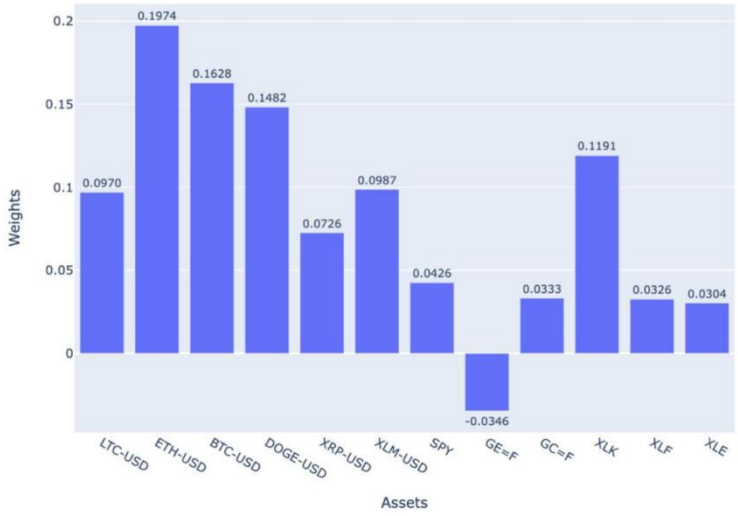


Figure 13. Tangency weights-combined portfolio

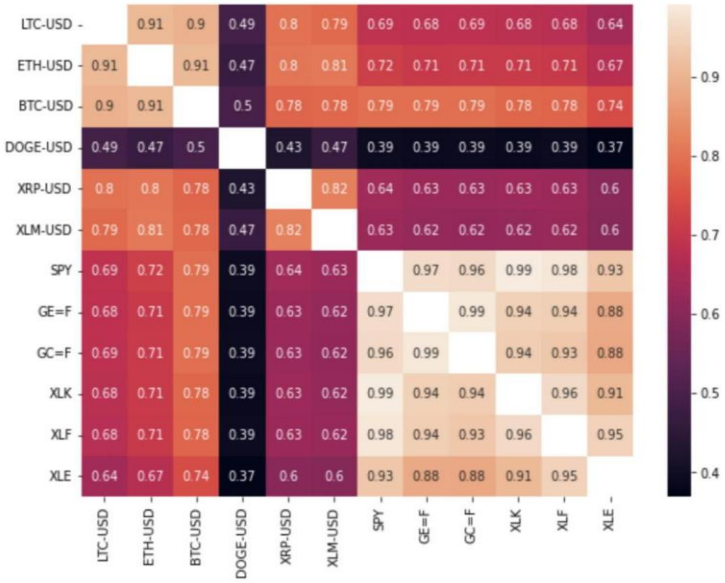


Figure 14. Correlation Matrix of Combined Assets

Tangency Portfolio Stats	
Mean	0.7770
Volatility	0.5747
Sharpe	1.3521

Table 11. Tangency Portfolio Performance ofthe Combined Assets

Diversification Effects:

The diversification effect of cryptocurrencies in the combined portfolio is enormous. As shown in figure 8, correlations among traditional assets generally lie in the range of eighty to ninety percent while cryptocurrencies seldomly show correlations higher than 0.7. In specific, DOGE-USD and XRP-USD particularly stand out by correlating with other assets no higher than 0.6. As such, by adding cryptocurrencies to our portfolio of traditional assets, we expect to boost the overall return as well as the Sharpe ratio significantly.

This is exemplified in comparing performances ofthe combined asset portfolio with the non-crypto asset portfolio in our previous analysis. Excluding cryptocurrencies, the best portfolio with regards to mean-variance optimization achieved an annualized mean return of 0.2174, a volatility of 0.5513 and a Sharpe ratio of 0.3943. In contrast, by adding the six cryptocurrencies, our optimized portfolio obtained an enhanced annualized mean return of 1.5593, a slightly increased volatility of 0.5732 and a significantly improved Sharpe ratio of 2.7202. As can be seen from the statistics, by incorporating cryptocurrencies, our portfolio's mean return improved dramatically while the increase in volatility is fairly moderate. As such, we believe cryptocurrencies are able to enhance portfolio performances in traditional assets considerably.

3.5 Crypto Risk Modeling

Principal Component Analysis:

Principal Components Analysis (PCA) extracts uncorrelated principal components from the six crypto assets' covariance matrix. We can interpret the principal components as risk factors associated with the assets. By applying this PCA, we are able to reduce the dimensionality of the 6 by 6 covariance matrix to a set of components that help reveal common risk drivers across the assets. Although the components are generated as statistical risk factors and the underlying risks are

less clearly identifiable, we use this analysis to explore whether there are common risks across this crypto portfolio and relate the quantity and effects of the risk drivers to the risk features of the crypto assets.

We start with trying to identify 6 principal components. The explained variance ratios ofthe 6 components shown in Figure 15 indicates that the first three components can explain more than 95% of the variance of the crypto assets.

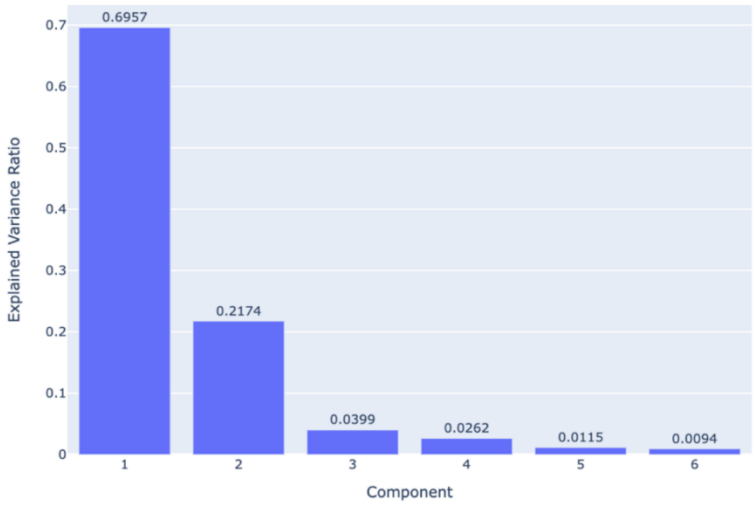


Figure 15. PCA Explained Variance Ratio

Then, we check the weights on each crypto asset for the three most significant components from the result above. These weights reveal that there were three major risk drivers across these coins over the past four years. As seen in Figure 16, the first component has positive weights almost evenly allocated to each of the six crypto assets, so we expect that the first risk is about overall market risk, which takes long positions in all the cryptos. The second component allocates a large positive weight in the most diversifying crypto asset, DOGE-USD, and it also has short positions in all other crypto assets. This may imply a unique risk associated with Memecoins like DOGE-USD. The third component shows a risk that short BTC-USD, ETH-USD, and LTC-USD while long DOGE-USD, XRP-USD, and XLM-USD. According to a study by Skynova40, BTC-USD, ETH-USD, and LTC-USD are the top three accepted cryptocurrencies as a form of payment by companies in the U.S. The percentages of businesses that accepted Bitcoin, Bitcoin Cash, Ethereum, and Litecoin are 58%, 36%, 35%, and 28%, respectively41. In this case, the third risk driver might be some factor associated with the established coins and emerging coins as different types of cryptos are gradually adopted in the industry, but since the third component only explains about 3.99% variance, its effects may not be significant compared with the other two factors.

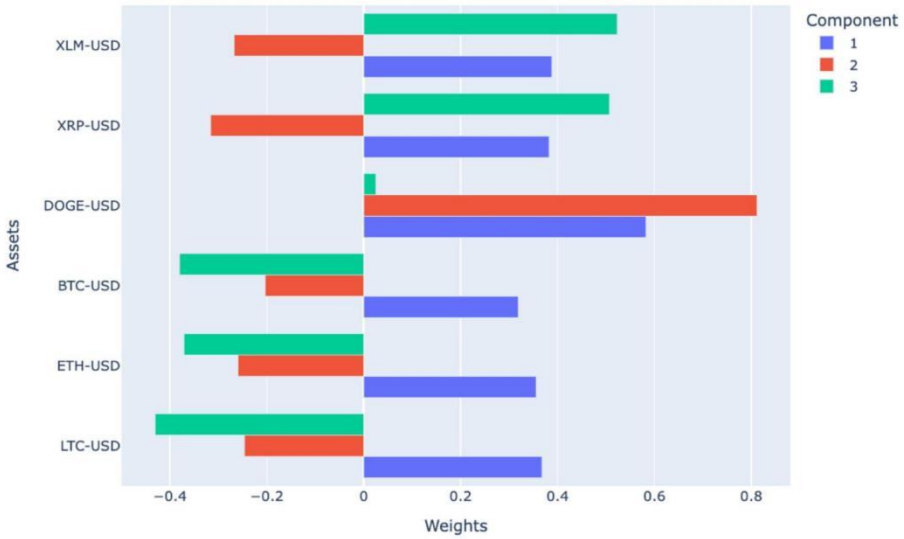


Figure 16. PCA-Crypto Weights for the 3 Most Significant Components

Clustering Analysis:

Next, we conducted a clustering analysis in order to try to organize the six crypto assets into clusters, on the basis of how closely associated they are. In this case, we used the correlation matrix to measure the closeness of the cryptos and as we can see from Figure 17, the six coins are separated into three groups, the first group is the cross-border payment coins shown on the left, which includes XRP-USD and XLM-USD, as cross-border payment coins, they replace the process of the international wire and currency conversion in a single pathway, making transactions fast and efficient. The second group has ETH-USD, BTC-USD, and LTC-USD, they are the high-usage coins that include the top three coins accepted as a form of payment. The only coin remaining is DOGE-USD by itself, which originates as a meme coin, and has not been widely used as payment coins. Meme coins like DOGE-USD are cryptocurrencies inspired by memes and internet jokes. These cryptocurrencies often aren't meant to be taken seriously but can still gain momentum when members of the community buy into the newest one in order to be in on the joke.

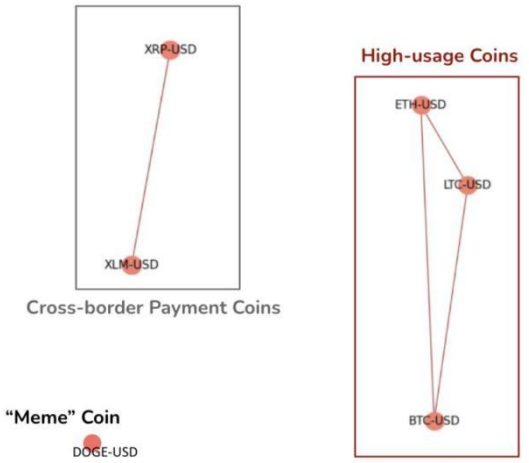


Figure 17. Clustering Graph of the Six Crypto Assets

Inspired from the six crypto assets, we would like to check whether this type of clustering exists in a broader sense for more crypto assets. We added more crypto assets and checked their relationship from January 1st, 2020 to December 1st, 2021, and the new clustering graph shown in Figure 18 now includes another cluster that has Tether (USDT-USD), Binance (BUSD-USD), and USD Coin (USDC-USD). These coins can be identified as Stablecoins, which are cryptocurrencies with prices designed to be pegged to a cryptocurrency, fiat money, or to exchange-traded commodities. In this case, USDT-USD, BUSD-USD, and USDC-USD's prices are closely associated with fiat money, as they are all 1:1 backed by U.S. dollars.

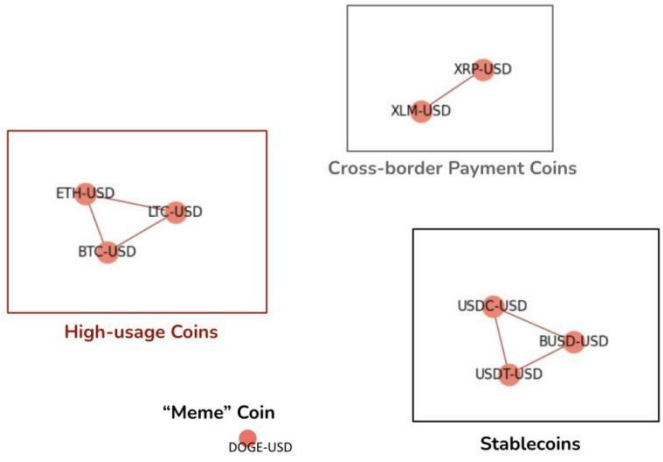


Figure 18. Clustering Graph of More Crypto Assets

4. Other Risks

4.1 Money Laundering

Definition:

Money laundering is defined as a method where illegally obtained money is altered to make the translation look legitimate. They occur when source, ownership, location or control of funds are falsified.

Background:

In the crypto currency field, indeed, it allows transactions to be processed faster, and has stronger security, since they lack third parties or intermediaries. Bitcoin transactions are stored on the blockchain, which however, makes money laundering easier for criminals since with "every" transaction transferred, conducted on a decentralized platform, cybercriminals can move their funds or coins instantly across borders. With this, cryptocurrencies become an attractive option for laundering.

Another feature that is worth mentioning is pseudonymous, which means names of individuals are not used to register transactions, rather, a certain degree of anonymity is associated with Bitcoin transactions. It also becomes challenging to link a particular transaction back to any individual for agencies. Only the individuals that make transactions can have access to the digital wallet. This allows criminals to cash out without fear of ever being identified, due to the anonymous action. The inconsistent and loose regulation, compared with traditional financial institutions and banking, make the criminal occur more frequently. This has become a serious problem for law enforcement agencies.

4.2 Regulation Risk

Institutions:

With an increasing utilization of cryptocurrency, it reflects on the risk to the financial services industry too. Not just the company fraud losses, the risk can also be detrimental to regulatory compliance. Fraud practices and poor anti money laundry make risk widespread and adopted.

Consumers:

Crypto is highly intangible, volatile, being traded and available on a non-regulated stock market. It is uninsured by any authority.

4.3 Macroeconomics Impacts

Inflation:

Cryptocurrency may generate currency competition in practice. Residents from inflation and in- stable fiat currency countries, for instance, Argentina, opted to have complex work arounds to get their hands on US dollars to save their savings. Cryptocurrency provides a way to avoid the inflationary official currency and engage in transfers outside the banking system that is based on such a currency, and to protect one's savings. It is very necessary to look at the inflationary tendencies of crypto currencies since it is pointless in exchanging one type of bad money for one that might be worse. However, arguably speaking, with a mixed system of official and private currencies emerging, it may be possible to get the best of both, which means the existence of a decentralized crypto currency can also maintain price stability. This would mean a regulation of the issuers of crypto currency in the same way that banks are regulated.

Stability:

Continuing analysis from above, related to inflationary stability is also the wider issue of stability of an asset that is subject to speculative transactions. From what we have seen in the past few years, the demand for cryptocurrencies changed dramatically and fast. If people suddenly get rid of them by flooding the market and drowning prices. Not only just from people buying crypto currencies, speculative purposes due to their potential benefits also drives the demand for cryptocurrencies. One biggest concern is the price manipulation behind the scenes, that is hard to investigate due to a lack of transparency. Therefore, cryptocurrencies lack the stability of office fiat currencies, like US dollar, European Euro.

4.4 EU Regulations in Cryptocurrency

On September 24th, 2020, the EU Commission published a proposal42 for the regulation of crypto assets: the "Markets in Crypto-Assets Regulation" (MiCA). The document is a part of a comprehensive "Digital Finance Package," which also includes other documents such as a "Digital Finance Strategy," a "Retail Payment Strategy," and legislative proposals for a "DLT Pilot Regime". The MiCA includes all types of crypto assets that are not yet covered by EU financial law. This also means that MiCA does not govern "security tokens" that are already regulated as shares, bonds, or investment funds. For all other forms of crypto-assets, various regulation categories are created:

- Crypto-assets generally, as a "catch-all" category (e.g., bitcoins, ether, litecoins, etc.)
- Utility Token (e.g., Filecoin token, Basic Attention Token, etc.)

- ART – Asset-Referenced Token (e.g., Libra Basket Coin, etc.)

- EMT – E-Money Token (e.g., USDC, Libra Euro, etc.).

In November 2021, the European Council published a significantly expanded proposed MiCA document. Results from the expanded document include stablecoins such as the DAI being heavily restricted. In short, MiCA has 4 broad objectives:

- To provide legal certainty for crypto assets not covered by existing EU financial services legislation, for which there is currently a clear need.

- To establish uniform rules for crypto-asset service providers and issuers at EU level

- To replace existing national frameworks applicable to crypto assets not covered by existing EU financial services legislation

- To establish specific rules for so-called 'stablecoins', including when these are e-money.

Openness/transparency Risk:

Compared to traditional fiat currency (USD for example), crypto currency provides openness to all users and frictionless transactions due to its lack of centralized control. This openness, however, has its own pros and cons. On the one hand, this openness provides everyone access to crypto assets without censorship, preserving privacy. On the other side, this openness is also a vulnerability, one that opens the door to asymmetric threats and small-time malicious actors43.

For example, images can be embedded into the bitcoin block chain, and everyone can put in any content without restriction. This leads to an issue if malicious contents are posted. Also, this easy access makes it a platform to perform illegal transactions. For example, in 2015, the creator of The Bitcoin market called the 'Silk Road' was sentenced to life in prison for facilitating the sale of $1 billion in illegal drugs44.

Fortunately, crypto-currency transactions are traceable. All transactions of bitcoin are recorded on the blockchain and are visible to every participant. But that does not mean it's completely transparent. The anonymity of crypto currency comes from the fact that some decentralized exchanges do not require know your customer (KYC) requirements and do not record user's personal information, making it hard to track from crypto wallets to its owners. Therefore, compared to traditional transactions, crypto-currency transactions can remain relatively anonymous. This lower level of transparency makes crypto-currency one of the best platforms to make transactions for the privacy savvy, but also increases the difficulty to crack down criminal transactions.

Investor Protection:

In a crypto market regulation proposal made by the European Commission in 2019, it is mentioned that "the EBA and ESMA underlined that – beyond EU legislation aimed at combating money laundering and terrorism financing – most crypto-assets fall outside the scope of EU financial services legislation and therefore are not subject to provisions on consumer and investor protection and market integrity, among others, although they give rise to these risks"45 Similarly, in the U.S., a gap in the regulation of crypto assets needs to be addressed. This gap has led to fraud and inadequate protection for investors in the distribution and trading of crypto assets. Better regulation would benefit crypto assets investors, facilitate the development of new technologies, curb crypto assets used for illicit payments, and reduce the risk of cyberattacks, which can result in collateral damage elsewhere in the financial system. Crypto assets cut across current jurisdictions and therefore fall into a gap between regulators. While both the U.S.

Securities and Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC) have some regulations regarding crypto assets. The Exchange Commission (CFTC) has some authority over crypto assets, but neither has sufficient jurisdiction. They also do not have concurrent jurisdiction.

According to Securities and Exchange Commission Chair Gary Gensler's response to the House Financial Services Committee on October 5th, 2021, with the help of the Commodity Futures Trading Commission and other financial regulators, the SEC could give cryptocurrency assets greater investor protection and stronger oversight. The SEC has been working with the Federal Reserve, the Treasury Department, the CFTC, the OCC, and other members of the President's Working Group on Financial Markets to achieve this goal, including on anti-money laundering and tax compliance issues.

Traceability for Money Laundering:

Recently, there have been some efforts made by the authorities in Europe to enhance the traceability for money laundering. Under new rules proposed by the European Commission46, cryptocurrency exchanges such as Binance, Coinbase and Kraken could be forced to collect details of how people send and receive cryptocurrencies. This requires that the service provider exchanging cryptocurrency on behalf of the customer must

record the customer's name, address, date ofbirth and account number, as well as the name of the intended recipient of the transfer.

Some crypto asset service providers are already covered by the EU's anti-money laundering and terrorist financing rules. The new proposed rules will be applied to the entire cryptocurrency sector, forcing service providers such as cryptocurrency exchanges to conduct due diligence on their users.

The EU executive announced this potential change on August 24th, 2021, and the purpose of this package is to improve the detection of suspicious transactions and activities and to close loopholes through which criminals launder illicit proceeds or finance terrorist activities through the financial system. In particular, the requirements will capture the risks associated with the technical characteristics of crypto-assets and crypto-asset transfers, such as traceability requirements that take into account the specific characteristics of the technology underlying those transfers. In addition, to effectively mitigate AML/CFT risks, transactions between both custodial and non-custodial wallets should be included, so the same information must be collected and stored as for other crypto-asset transfers. Additionally, money laundering activities involving crypto-assets without the use of service providers or in decentralized peer-to-peer transactions should also be monitored closely. Finally, given the rapid pace of technological development in the crypto-asset market, it is essential to follow the implementation of the framework in cooperation with the relevant authorities and the private sector.

4.5 Efficient Tax Collection

Based on the newest released rules in the U.S. related to tax collection of crypto currencies investment, the government is trying hard to do it efficiently. There are several facts that have significance to bring attention to47.

“The IRS treats crypto currencies like bitcoins as property, meaning that they are taxed in a manner similar to stock or real properties. ”

There are several taxable events related to crypto currencies investment or mining. First, realized capital gains are taxable. For example, if you buy one bitcoin for $10,000 and sell it for $40,000, the $30,000 gain is taxable. Second, purchasing or consuming by using crypto currencies is taxable since it is an alternative way to liquidate crypto currencies. Third, mining crypto currencies is defined as self-employment income, which is also taxable. According to the IRS, tax rates of mining crypto currencies are between 10% to 37%.

“The agency recently ramped up efforts to subpoena centralized crypto exchanges for information about noncompliant U.S. taxpayers. ”

In spring of 2021, courts authorized the IRS to issue John Doe summonses to crypto exchange operators Kraken and Circle to find individuals who have experienced at least $20,000 of transactions in crypto currencies from 2016 to 2020. Similar actions have been done in 2016 to monitor crypto currencies tax collection from 2013 to 2015. “Letter 6173” gave individuals 30 days to respond and report their crypto currencies tax profile to the IRS.

“President Joe Biden *’s* 2022 budget proposal could lead to a raft of new crypto reporting requirements. ”

The U.S. Treasury Department’s new “Greenbook”, released in May 2021, defined more comprehensive reporting requirements for crypto currencies. From this date, it is hard to spend crypto currencies without fully reporting. For example, businesses are required to report all transactions valued at more than $10,000, crypto exchanges are required to report user account data which conduct at least $600 worth of gross inflows or outflows in a calendar year. Another significant blow to crypto currencies holders is Biden's proposal to raise the top tax rate on long-term capital gains from 23.8% to 43.4%. This proposal is trying to eliminate the difference between the tax rate of long-term capital gains and the ordinary rates.

4.6 Fostering Continued Innovation

In May 2021, the Washington State Department of Financial Institutions (DFI) announced the creation and launch of the Center for FinTech Information (CFI) to facilitate communication between the DFI and entrepreneurs, investors, and fintech companies. While Washington aspires to be a global hub for blockchain innovation, the lack of transparency and regulatory clarity has long created challenges for innovative crypto and digital asset startups, funds, and investors in the state. The creation of this center is a welcome, positive step forward for the sector, and if effectively staffed and resourced, can help transform the experiences of crypto companies in Washington48.

Based on the CFI official website, there are several public information sections available for individuals and businesses to refer to related to crypto currencies. 1. FinTech Licensing Decision Tree: Decision tree to help FinTech companies determine what license they need and what regulations apply; 2. FinTech Licensing and Regulation Guidance: Licensing and regulation information for

virtual currencies, cryptocurrencies, and digital assets; 3. Timeline: History of FinTech Regulation: A brief history of financial regulation to fintech regulation; 4. FinTech Glossary of Terms: Definitions of common FinTech terminology; 5. FinTech Guide for Consumers and Investors: A guide to virtual currency, cryptocurrency, and digital assets for consumers and investors; 6. File A Complaint: If you are having trouble with a financial company operating in Washington, you can file a complaint with DFI49.

All the resources are dedicated to educating individuals and businesses on crypto currencies investment and regulation, which will further foster continuing innovation on the uses of crypto currencies both nationally and internationally.

Conclusion

In conclusion, this analysis of crypto currency as a financial instrument starts with a review of the crypto currencies in terms of some general background information. Then we investigated the consumers, investors, and trading aspects of crypto currencies. Next, we conducted some quantitative analysis and modeling of crypto-related risks. We first created tangency portfolios to explore the diversification effects of crypto currencies. From there, we dived deeper into more crypto related risks by checking the tail risk distributions, conducting a principal component analysis, and ended with a clustering analysis on the crypto currencies. We conclude that there could be risks specific to certain groups of crypto currencies, and each crypto currency's risk feature may also increase diversification effects or loss/profit probability when including crypto currencies into a portfolio.

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Appendix

Mini mining station

Shot by Boyang D. in February 2018

Mining Farm under construction at Sichuan Province, China

Shot by Boyang D. in April 2021

(now serve as a digital datacenter)

Mining Farm Colocation

Screenshot by Boyang D. from an onsite visit video