Groupe ICHEC-ECAM-ISFSC

ICHEC

et

UNIVERSITE CATHOLIQUE DE LOUVAIN

LOUVAIN SCHOOL OF MANAGEMENT

Is the marginal addition of digital assets a useful strategy to diversify the risk-return profile of a standard portfolio?

Mémoire présenté par :

Vincent KOPPMAIR

Pour l'obtention des diplômes de :

Master en Gestion de l'Entreprise (ICHEC)

Master en Sciences de Gestion (LSM)

Année académique 2021-2022

Promoteur : **Bruno DU BUS**

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ABSTRACT

Over the past ten years, the euphoria linked to digital assets has pushed them to new highs. The asset class has become an inevitable topic in the financial community. Often dismissed due to the immense volatility, digital assets are supposed to offer a good risk-adjusted performance while also offering diversification capabilities. This begs the question of whether the marginal addition of digital assets would improve a standard portfolio.

In this thesis, we based our analysis on the Modern Portfolio Theory (MPT) to construct a standard optimal portfolio based on seven assets acting as proxies for five key asset classes (equity, fixed income, commodity, currency, and real estate). Afterwards, utilizing six performance indicators (Sharpe ratio, Sortino ratio, Treynor ratio, Jensen's Alpha, Maximum Drawdown, and Calmar ratio), we analyzed the effect on the marginal implementation (0% to 5%) of digital assets to the portfolio in increments of 0.5%.

The results show that the marginal implementation of digital assets greatly improves the performance of a standard portfolio. However, some controversial aspects might halt the general adoption of the asset class in the near future.

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General Introduction

In the past decade, a new type of tradeable investment has emerged – digital assets. Based on blockchain technology, which provides, among other things, a decentralized, distributed, public ledger. This means that neither a person nor an entity owns it or controls it. “Digital asset” is an umbrella term for the spectrum of technologies based on this concept. First created in 2008, digital assets were to provide individuals with an alternative to the traditional markets. (Miller, 2021) A transnational informatic network in which individuals could transact without knowing each other, bypassing the traditional banking system. Blockchain technology, while still in its infancy, leads enthusiasts to foresee its potential to become a global economic game changer similar in impact to the internet.

No other investment opportunity in the last couple of years has captured the world's attention as much as they have. Due to the recent euphoria, the asset class skyrocketed from an under USD 20 billion market capitalization in January 2017 to USD 2.9 trillion in November 2021. (CoinMarketCap, n.d.) This is comparable to the capitalization of the largest corporation in the world, Apple.

Famous for its return potential and notorious for its risk, the asset class is not short of controversies. The prominent financial figure, Warren Buffett, has regularly warned investors against digital assets, naming them “rat poison squared”. (Kendall, 2021) Scandals plague the asset class as the feature that defines it, decentralization, also implies no protection. For traditional investors, the volatility, risk of theft, and scams linked to the underlying complexity of the technology might simply be too much to bear. Furthermore, as investors are striving towards carbon neutrality and sustainable investing, digital assets proved to be rather carbon intensive. (Hamilton, 2021)

However, academic research has shown that, despite their flaws, when considering digital assets as investment opportunities, they might offer investors an interesting alternative. Papers have shown that digital assets are uncorrelated to the traditional financial market. Additionally, they have shown that while the asset class shows highly speculative aspects, the risk-adjusted return is outperforming traditional assets. (Brière et al., 2015 & Baur et al., 2018)

The selection of this subject was made for fairly straightforward reasons. The first reason is that an investor's role is to optimize and maximize the return given a certain level of risk (or minimize the risk for a certain level of return). The aim of an optimal portfolio is to diversify as much risk as possible by combining different assets that ideally have a low correlation. As such, if digital assets have a low correlation while also offering a good risk-adjusted return, if allowed to, should all investors consider implementing digital assets into their portfolios? Since the asset class is highly risky, it would only make sense to consider the marginal implementation to minimize the volatility and not dramatically increase the portfolio’s risk profile. The second reason is that digital assets are currently the most promising financial technology. Thus, it seemed fitting to complete my educational program by striving to satiate my curiosity on such a contemporary subject.

This thesis will tackle these initial ideas with the following research question: **“Is the marginal addition of digital assets a useful strategy to diversify the risk-return profile of a standard portfolio?”**

In an effort to address this research question, this thesis will be divided into two main parts. In the first part, the theoretical research, we will start off by defining digital assets in a financial context, and we

will examine key historical events. Then we will determine their classification and assess the environment in which they exist. This implies understanding the key drivers of the asset class. Afterwards, we will explore the potential financial benefits digital assets might provide to a portfolio. Lastly, we will investigate the controversial aspects of digital assets which might hinder their adoption. We will analyze legal, criminal, environmental and pricing risks associated with them.

In the second part, the empirical analysis, we will assess whether the marginal inclusion of digital assets improves the risk-return profile of a standard portfolio. To evaluate this, we will first create an optimal portfolio following the Modern Portfolio Theory framework, based on a long-only global asset class diversification. We will empirically examine the impact of marginal inclusions of digital assets to this optimal portfolio. To assess the impact, we will be using a multitude of performance metrics to have more in-depth results. The thesis is concluded with a summary of the findings and recommendations.

The methodology utilized throughout the thesis is mostly based on scientific publications. Some topics, however, lack scholarly consideration, and as such professional reports or public data were cautiously used to complete the research. As digital assets are still a new and broad concept, it is crucial to keep in mind that not every aspect of them is yet rigorously examined on top of sometimes conflicting results of similar investigations.

The implication of this thesis is to determine, assuming that it is lawful, whether investors should consider digital assets as investable assets. The first goal is to clarify some fundamental ideas and risks about digital assets for investors. Secondly, it is to determine if digital assets do, in fact, offer diversification opportunities while producing a favorable risk-adjusted return for investors.

Part 1: Literary review

1. Digital assets

1.1. Definition and history

1.1.1. Definition of digital assets

In this thesis, we will use the term "digital asset" as an umbrella term for most Cryptocurrencies and similar assets, such as non-fungible tokens (NFTs) that use blockchain technology in their products. According to Frankenfield, J. (2022), cryptocurrencies are a form of a digital asset. While the term "digital asset" exists outside of the realm of the ones based on blockchain technologies, Gartner (n.d) defined it as "anything that is stored digitally and is uniquely identifiable that organizations can use to realize value (e.g: documents, audio, websites...)". While Schlaffer, W., et al. (2022) define digital assets as "digital representations of values that are not issued or guaranteed by a central bank or public authority and do not have the legal status of currency of money."

The popularity of digital assets has also reached financial institutions. Recently, the European Central Bank (ECB) (2019) defined digital assets as a "new type of asset recorded in digital form and enabled by the use of cryptography that is not and does not represent a financial claim on, or a liability of, any identifiable entity". According to the Financial Action Task Force (FATF) (2014), a digital asset represents a virtual value that can be traded digitally with similar characteristics to currencies. The main difference between historic currencies and digital asset is that they are not backed by any jurisdiction and therefore has no legal tender status in most countries.

For the purpose of our research, we will use "digital assets" while referring to blockchain-based technologies which are more similar to the definition from FATF. We will analyze whether these assets have the merit of being a new financial asset class or if they are just alternative assets.

In the next parts, we will look at the history of digital assets so that afterwards we will investigate the most common types of digital assets. The goal is not to analyze their underlying technologies more than necessary to ensure their understanding, but to, in fact, better under the ecosystem in which they exist and operate.

1.1.2. History of digital assets

In this part, we will see a brief history of digital assets until 2008, the goal of this thesis is not to analyze the fundamentals and the technology of these assets, but to understand the philosophy behind them might help us gain a better understanding of the assets in a financial context. The technology of digital assets has already been analyzed in detail by academics. (Wu et al., 2021) As such, we believe that analyzing the asset class in a financial context would provide a new point of view.

Digital asset as a phenomenon is still quite a new one, with its first mainstream media appearance in 2017 with the first Bitcoin wave hitting nearly 20 000$ in December 2017. (Edwards, 2022) Since then, the popularity of these assets has been ever-growing like a modern-era virtual gold rush, a hope for fortune. Yet, the idea of a digital currency or cryptocurrency is not a new one. According to Chaum, D. (1983), in 1983 the first invention of cryptographed cash was developed by the author himself. Cash would work as a promise of payment with an unforgeable signature. He stipulated that, as long as people trust in his product, it would act similarly to a banknote. The inventor later went to commercialize his idea and developed "DigiCash" in 1989. (Narayanan et al., 2016) DigiCash ultimately

failed as banks and merchants were wary of the product which ultimately affected its adoption. (Narayanan et al., 2016)

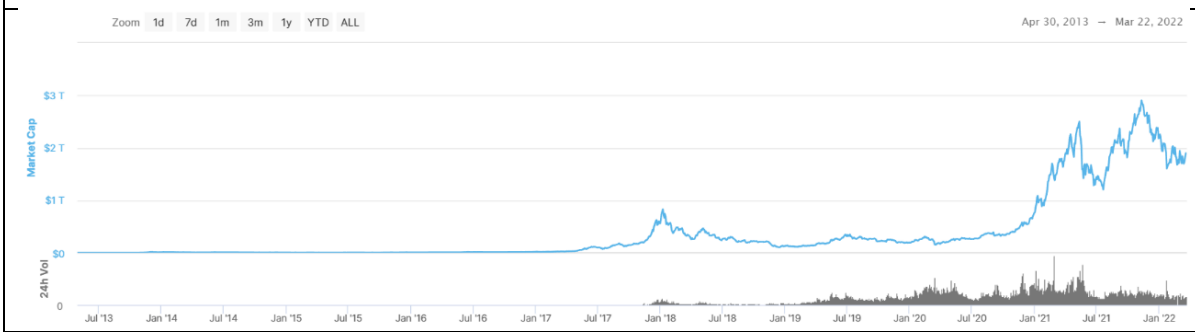
In the meantime, there were many products trying to fix DigiCash's issues and developed their own innovations that would pave the way for Bitcoin's technology. NetCash for example developed the idea for minting digital money, which later became the idea of "mining", the process of deciphering a computational problem to receive the "money". Haber, S., & Stornetta, W.S. (1991) developed the first ledger based on linking documents together to ensure the timestamping of digital documents. This allowed them to make documents tamperproof by ensuring their integrity. This same technology will later become the basis for the blockchain technology used in Bitcoin. (Narayanan et al., 2016)

In 2008, Satoshi Nakamoto, the pseudonym of the Bitcoin creator, published the white paper of Bitcoin protocols. The inventor's objective was to create the most transparent payment network. (Nakamoto, 2008) It seems that Bitcoin was able to achieve what its predecessors were unable to do by promising to solve the inefficiencies of traditional currencies and also by appearing during a period when the traditional system was going through the subprime crisis. (Miller, 2021)

1.1.3. Important moments

In this part, we look at important moments that have shaped the history of digital assets. These moments may derive from digital assets achieving a certain milestone and from external factors that have shaped the industry since the release of the Bitcoin white papers in 2008. (Nakamoto, 2008) Since Bitcoin represented over 90% of the digital assets' total market capitalization until 2016 (and still represents over 40% of the market capitalization (CoinMarketCap, n.d.)) the historical events are more skewed towards Bitcoin's history. (Kendall, 2021)

Figure 1 – Evolution of market capitalization of all digital assets from 2013 to 2022



Source: CoinMarketCap. (n.d.). *Global Cryptocurrency Market Charts*. Retrieved June 5, 2022, from https://coinmarketcap.com/charts/

2009

The first major event, after the release of the white papers, happened in 2009 when the first Bitcoin transaction occurred from Bitcoin creator Satoshi Nakamoto toward revered cryptographer Hal Finney. (Kaaru, 2022) This event marked the start of a trillion-dollar industry 13 years later.

2010

According to Miller, M. (2014), 2010 marked the year where the first official Bitcoin exchange was established, at the time one Bitcoin was still very cheap and traded for less than USD 0.003. That same year on May 22, Laszlo Hanyecz, an early Bitcoin enthusiast, purchased 2 pizzas for 10 000 Bitcoins, which equated to approximately USD 40. (DeCambre, 2021) This event was the first economic transaction in Bitcoin's history. By the end of 2010, the Bitcoin industry was worth more than USD 1m. (Miller, 2014)

2011

Sergeenkov, A. (2021) mentions that 2011 marked the launch of *Silk Road*, a dark web marketplace for illicit activities with a unique payment system: Bitcoin. The usage of Bitcoin was preferred for the dark web due to the anonymity of the digital asset. In the same year, TIME magazine published a few articles on Bitcoin, which then saw its price grow up to USD 30, but then crash back down a few days later. (Miller, 2014)

2012

According to Wolfson (2015), 2012 was a quieter year than the previous years for Bitcoin. The assets market capitalization steadily grew from nearly USD 80m in 2011 to USD 150m in 2012, with a bigger increase in the volume of daily transactions going from USD 0.7m to USD 3.3m.

A major event impacting the Bitcoin network was that 2012 was the first halving of the digital asset's rewards (or emission). (Meynkhard, 2019) To simplify what Meynkhard, A. (2019) explained in this paper, individuals (or miners) participate in the blockchain network by validating (or mining) the legitimacy of a transaction, which they then would add to the blockchain. As compensation, these individuals receive a reward (a sum of Bitcoins). Originally, the reward for mining a block was 50 Bitcoins, after "the halving", the rewards were 25 Bitcoins. The halving is an embedded occurrence in which after every 210 000 blocks mined the miners' rewards get cut in half, which happens around every 4 years.

2013

2013 was a big year for Bitcoin as it was the year that it breached the USD 1bn market capitalization. (Wolfson, 2015) The digital assets gained a lot of public attention, some praise, and some criticism, during public appearances from celebrities such as Bill Gates, Ashton Kutcher, Warren Buffet, and many others. (Kendall, 2021)

Not only were celebrities mentioning Bitcoin, but governments did it as well, with the US Senate Banking Committee holding hearings on the subject and the Chinese government seemingly being content to let the market develop. (Kendall, 2021) During 2013, the price of 1 Bitcoin also grew from below USD 100 to approximately USD 600 at the end of the year. (Kendall, 2021)

2014

According to S. N. Wolfson (2015), 2014 started on a bad foot with Bitcoin price steadily declining from USD 1044 to USD 448 at the beginning of the year. The year started with "Mt. Gox", the biggest Bitcoin exchange in the world, filing for bankruptcy. The company had lost almost half a billion dollars of its customers' money during a cyberattack.

A few weeks later, Newsweek magazine reported having found the creator of Bitcoin, Satoshi Nakamoto. (Kendall, 2021) In the end, it seems as if the report was wrong, but it prompted a worldwide manhunt to find the real Satoshi. (Kendall, 2021)

On top of that, the U.S. Inland Revenue Service (IRS), responsible for income tax laws and the oversight of federal income taxes, issued a statement that Bitcoin and digital assets would be recognized as assets and not as currencies. (Kendall, 2021)

In the end of 2014, another major event occurred. According to Corbet, S., et al. (2018), the US government shut down one of the world's biggest black markets, a new Silk Road. The bust reportedly downloaded multiple million US dollars, linking yet again Bitcoin to illicit activities. Even though the number of Bitcoins found was small compared to the overall market, the article mentioned that it was believed that the news would be the last straw. The author goes on to mention that, in the end, the price "only" fell 20% which thereby strengthened the market's sentiment around the digital asset.

2015

In July 2015, the Bitcoin network survived a cyber-attack, as a result, the network strengthened its security from future potential attacks, therefore increasing confidence that future attacks would be less likely to impact the network. (Corbet et al., 2018) Additionally, in August 2015 Bitcoin suffered a flash crash of around –30% due to leveraged positions closing simultaneously. (Corbet et al., 2018)

In the same year, the European Court of Justice declared that Bitcoin and its alternatives should be considered as currencies and traded as such. (Clinch, 2015) As a result, this meant that European citizens could trade on digital assets without paying any taxes. (Kendall, 2021)

At the end of the year 2015, the market capitalization of digital assets reached USD 6.9 billion, a good level but still below the level of 2013. (CoinMarketCap, n.d.)

2016

The surge in Bitcoin's price continued in 2016, as the price surged by 80% during the year. (Bovaird, 2016) Multiple political factors might have impacted the increase. 2016 is said to be a tumultuous year, full of political shocks affecting the world. (Gray, 2016) The war in Syria, terrorist attacks in Europe, the Brexit referendum, and the election of Donald Trump were some of the major political events impacting the world in 2016. (Gray, 2016)

Another major event in 2016 was the hacking of Bitfinex. According to McCorry, P., et al. (2018), Bitfinex, which at the time was among the biggest exchange platforms, got hacked which resulted in the loss of around 120 000 Bitcoins (valued at around USD 72m at the time). This hack caused the Bitcoin price to drop by around 20%. (Bovaird, 2016)

2016 was also the year in which the second halving occurred, slashing mining rewards from 25 Bitcoins to 12.5. (Meynkhard, 2019)

2017

2017 is a major year for digital assets as it is the year in which it truly entered mainstream consciousness through a huge euphoria rallying the asset's price. (DeMatteo, 2022) This is also the year in which Bitcoin's dominance over the asset class started to decrease from around 80% to around

50% of total digital assets market capitalization. (CoinMarketCap, n.d.) This shows that altcoins were starting to establish themselves.

During that year, Bitcoin started the year by crossing the USD 2 000 value for the first time in May 2017. Then, the first Bitcoin frenzy started as the digital assets gained new media attention to reach past the USD 19 700 mark at the end of December. (Kendall, 2021) Bitcoin started the year with a market capitalization of around USD 20 billion and in December arrived at a value of over USD 300 billion. (CoinMarketCap, n.d.) Yet, shortly after, the price completely plummeted by over 40% to around USD 11 000. This convinced the media that the assets should be disregarded as they might be ill-intentioned. (Chohan, 2022) But governments economists and scientists started to pay attention to the curiosity of digital assets. (Edwards, 2022)

2018

Heading into the new year, digital assets continued their downward trend. This was due to negative comments from well-established investment individuals such as Warren Buffet calling digital assets "rat poison squared" and the UBS chairmen, Axel Weber, mentioning that he does not recommend Bitcoin during the World Economic Forum, which further pushed the narrative of the illegitimacy of digital assets. (Kendall, 2021)

But rumblings from Asia also played a key role in the further drop in the valuation of digital assets. The year started with rumors from South Korea about a potential ban on trading in digital assets. (Chohan, 2022) Similar ideas came from China on banning exchange platforms. (Kendall, 2021) On top of that, Japan's biggest Over the Counter (OTC) digital asset exchange, "Coincheck", stated that it had lost USD 530 million worth of digital assets in a hack. (Chohan, 2022)

Due to all of these incidents, digital assets declined overall in 2018, with Bitcoin's price even falling below USD 4 000 in December 2018. (Kendall, 2021)

2019

2019 was plagued by many of the issues from the previous years while having mostly sideways movements. (Edwards, 2022) At the same time, regulators are still trying to grapple with digital assets and what to do with them. In the end, the US authorities mostly decided to continue to allow the trading of digital assets (to not stifle innovation) while keeping an eye on it. (Chohan, 2022)

The year ended on a surprising note, as China openly being supportive of blockchain technology, in a turnaround for the country that previously had banned the assets on multiple occasions. (Kendall, 2021) The year ended with Bitcoin's price near the USD 8 000 range.

2020

According to Chohan, U. W. (2022), while the global pandemic affected the globe, and individuals were under lockdown, governments decided to inject the economies with some stimuli checks. As individuals had more free time to explore new interests, they also had additional disposable income. As such, more and more individuals started investing in digital assets which meant that the prices started to soar. As 2020 ended with Bitcoin's price reaching USD 29 000, a new all-time high. (Edwards, 2022)

During that year, companies also started disclosing their crypto plans. PayPal announced its own crypto service allowing users to access digital assets. (Kendall, 2021) Mastercard also stated the addition of digital assets to its services. (Dhamodharan, 2021) Both companies are therefore pushing for mainstream adoption of digital assets.

2021

The year 2021 started where 2020 left off, with Bitcoin reaching USD 40 000 by January 7. The market rallied as Bitcoin's market capitalization surpassed USD 1 trillion in February, which caused a further peak at USD 63 000 on April 12. (Kendall, 2021)

This price rally occurred for a multitude of external reasons that made this bull-run possible. One of the reasons is that Tesla announced having acquired USD 1.5 billion Bitcoin. (de Vries et al., 2021) Tesla later backtracked due to environmental concerns, but at the time it still fueled the euphoria. (Kendall, 2021) A second reason was that more general adoption seemed to be getting more pull. Morgan Stanley allowed clients to be exposed to Bitcoin in their portfolios and German financial institutions were allowed to hold up to 20% of their balance sheet in digital assets. (Kendall, 2021)

Then the price fluctuated again after the backtracking of Tesla and an announcement by the Chinese government to ban crypto mining in China. (Kendall, 2021) At the time, most of the crypto mining came from China, therefore the news created an uproar in the mining community. (Sergeenkov, 2021)

But in the end, the year still ended on a high note. This is due to news such as the SEC (Securities and Exchange Commission) approving a Bitcoin future ETF (BITO) and El Salvadore announcing that they allow Bitcoin as legal tender. (Kendall, 2021) Consequently, Bitcoin reached a new all-time high of nearly USD 69 000 on November 10th. (Edwards, 2022) Nonetheless, the year ended amid increasing inflation fears and a new covid variant which created fluctuations in the market that would see Bitcoin's price drop below USD 40 000. (Edwards, 2022)

1.2. Understanding Digital Assets

1.2.1. Digital assets

According to Nian, L. & Chuen, D. (2015, p.4) the definition of a digital asset is a "peer-to-peer version of electronic cash. It allows online payments to be sent directly from one party to another without going through a financial institution." The paper explains that these transactions will then be time stamped by using cryptography and added to the record which cannot be altered. In this research, there are a few keywords necessary to broadly understand digital assets:

- Cryptography
- Blockchain
- Peer to peer
- Decentralized
- Transparency
- Accessibility

More colloquially known as "cryptocurrency", as indicated by the term, we can clearly understand the importance of cryptography in these assets. According to Narayanan, A. et al. (2016), cryptography is the mechanism that enforces the security of a system. It is used to prevent tampering and equivocation

by transforming data into an enciphered string of letters and numbers. The mechanism is based on mathematical protocols (or algorithms) to securely encode and cipher the text into an unreadable form. Narayanan, A. et al. (2016) explain that for Bitcoin the cryptographic algorithm is the "SHA-256" that converts any text into a 256-bit string that is very secure.

Contrary to centralized currencies where supply is controlled by a governing body such as a government or a central bank (Vigna & Casey, 2016), decentralized currencies do not have a third party (institution or bank) controlling the currency and operating on completely public and transparent ledgers. (Brito et al., 2015) The innovation behind decentralized currencies is also the reason that enables peer-to-peer transactions with no involvement from third parties (and therefore, lower transaction fees). (Nakamoto, 2008) According to Sakar, A. (2022), in 2021 the average Bitcoin transaction fee was around USD 2. The blockchain technology enables the decentralization of the network by ensuring a temper-proof public ledger system (which is not analyzed in detail in this paper) where one can trust the code, meaning to have trust in the technology and not in a third-party institution. (Bratspies, 2018) To ensure this trust, the technology is mainly open source and allows developers to control the code and keep an eye out for potential issues. Additionally, since the technology is supranational, the currencies are global and allow access to everyone around the world by only needing an internet connection. (Gomzin, 2016)

1.2.2. Bitcoin

We are talking about the world's first, and most famous, decentralized, peer-to-peer, and open-source digital currency. This means that no third party can interfere or change the supply. According to **Figure 2** (CoinMarketCap, n.d), it has a market capitalization of more than USD 800 billion in February 2022 (Bitcoin was at its all-time high on November 8th, 2021, at a market capitalization of ~USD 1,27 trillion at a price of ~USD 67 000 per Bitcoin) and one Bitcoin is worth ~USD 43 000. **Figure 3** (CoinMarketCap, n.d) shows that this represents ~42% of the total digital asset market capitalization, which is valued at ~USD 1,9 trillion (CoinMarketCap, n.d.). Evidently, Bitcoin is still the biggest asset in this class.

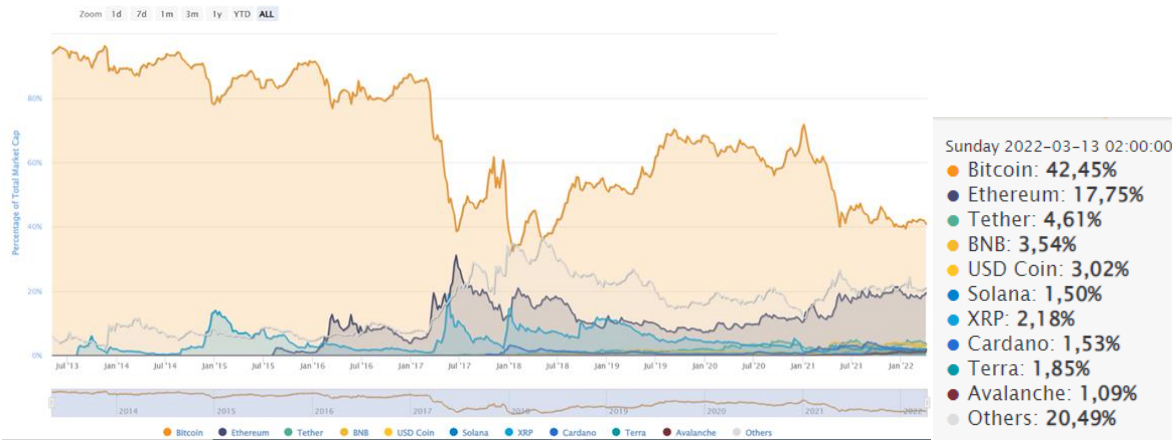
Figure 2 - Ranking of the top 7 digital assets by market capitalization on April 8th, 2022

#	Nom	Prix	24h %	7d %	Cap. Marché
1	Bitcoin BTC Acheter	$42,699.28	▼1.75%	▼7.86%	$812,942,439,540
2	Ethereum ETH Acheter	$3,227.72	▲0.21%	▼6.56%	$389,600,225,100
3	Tether USDT	$1.00	▲0.02%	▲0.01%	$82,519,161,962
4	BNB BNB Acheter	$426.36	▼2.12%	▼4.26%	$70,566,199,847
5	USD Coin USDC	$0.9998	▼0.01%	▲0.01%	$50,946,937,175
6	Solana SOL Acheter	$112.51	▼4.48%	▼17.52%	$36,935,928,630
7	XRP XRP	$0.7615	▼2.52%	▼8.57%	$36,720,749,253

Source: CoinMarketCap. (n.d.). *Cryptocurrency Prices, Charts And Market Capitalizations*. Retrieved April, 2022, from https://coinmarketcap.com/

Developed in 2008 by an unknown entity called Satoshi Nakamoto, Bitcoin is often compared to gold, even dubbed “digital gold”. (Selmi et al., 2022) It is labeled as having the potential of storing value when markets lose their trust in other currencies, something we will investigate in the next chapter. Despite being intangible, Bitcoin and gold share some similarities such as a limited supply, there cannot be more than 21 million Bitcoins. (Rawal & Peter, 2022) This supply cap is deeply rooted in Bitcoin’s protocol. According to Rawal, B. & Peter, A. (2022), in 2022 ~90% (~19 million) of Bitcoin have been mined with the remaining 10% being expected to be mined by 2140, as marginal efficiency from mining goes down with each new Bitcoin in circulation. But this doesn’t mean that 90% of Bitcoins are in circulation since many have been removed from the market as they have been lost by their owners. It is expected that 20% of Bitcoins are permanently lost. (Voas & Kshetri, 2021)

Figure 3 - Evolution of market capitalization of digital assets from 2013 until 2022



Source: CoinMarketCap. (n.d.). *Global Cryptocurrency Market Charts*. Retrieved June 5, 2022, from https://coinmarketcap.com/charts/

1.2.3. Altcoins

Steinert, L. & Herff, C. (2018), define the term "Altcoin" as any cryptocurrency that is not Bitcoin. So basically, the other 59% of the digital asset's market share. This would also include Ethereum. **Figure 3** (Coinmarketcap, n.d.) shows that Ethereum is the 2nd biggest cryptocurrency in terms of market capitalization, behind Bitcoin, with ~18% of the market share. In February 2022, it is reported that there currently are over ~17 000 Altcoins in circulation. (Coinmarketcap, n.d.) The reason why there are so many Altcoins is that individuals believe they can create a "better" project than Bitcoin. (Redman, 2020) According to Shah, A. & Moss, A. (2021), some coins were created to improve the current protocol and add something new. This is made possible due to the fact that Bitcoin was created as an open-source technology thus enabling other informaticians to base themselves on Bitcoin and created a new cryptocurrency. (Halaburda, 2016)

On the other hand, some Altcoins have no other purpose other than simply being "for fun" with the rise in popularity of some "meme coins" such as Dogecoin (DOGE). For example, DOGE's invention was intended to satirize the hype regarding cryptocurrencies, and not to be taken seriously. (Frankenfield, 2022) Yet, according to CoinMarketCap (n.d.), in February 2022 it is the 11th biggest coin with a market capitalization of USD 18 billion.

As time passed, Altcoins have increased their market shares. According to **Figure 3** (Coinmarketcap, n.d.), in 2017 Bitcoin had 85% of the market share to the 41% today that we have seen previously. This shows the increasing opportunity in the entire asset class and not just in Bitcoin (even though it is still the biggest by far). But the problem with the high number of altcoins is the fact that investors must be more diligent because not every altcoin is a good investment or has a fundamental project that will not fail. (Gailey, 2022)

1.2.4. Stable coins

Shah, A., & Moss, A. (2021, p.32), define stable coins as "digital assets pegged to another asset class such as fiat currency (like the US dollar), a commodity (like gold), other digital assets or a combination of assets with the goal of maintaining a stable value." According to Chohan, U. W. (2019), the main usage of stable coins was to resolve the high volatility of digital assets by pegging their value to a "traditional" asset. This begs the question, what is the use case for such coins? As stated by Lyons, R., & Viswanath-Natraj, G. (2020), the value of Stable coins is multiple. First is the fact that on some exchanges, it takes more time to process, and they have bigger fees when exchanging digital assets for fiat currency. Secondly, stable coins are usable across different exchange platforms, which allows users a simpler transfer of funds. According to Shah, A., & Moss, A. (2021), some exchange platforms don't have relationships with banks, which means that they don't accept fiat currency. But it is possible to access their platform thanks to stable coins.

For example, Tether (USDT), the "most liquid and heavily traded of the stable coins" (Lyons & Viswanath-Natraj, 2020, p. 3), is according to CoinMarketCap (n.d.) the 3rd biggest digital asset with a market capitalization of USD 78bn (4% market share) in February 2022. USDT has a daily trading volume of USD 49bn, more than twice the volume of Bitcoin which has the second biggest in terms of daily trading volume at USD 21bn. According to Tether (n.d.), their USDT is pegged at 1-to-1 to a matching fiat currency such as the US dollar, which means that each Tether token is nearly at all times 100% backed by their reserves and therefore preserves its worth of USD 1.

Therefore, it is quite understandable that the usage of stable coins could be a potential digital safe haven for investors who want to keep their money in digital assets, during potential downturn periods. (Shah & Moss, 2021)

1.2.5. Non-Fungible Token (NFT)

According to Kugler, L. (2021), Non-Fungible Tokens (NFTs) are cryptographic tokens built on blockchain technology. Being non-fungible means that each token is unique, and that token is proof of ownership of the asset. This asset can be digital or physical. Therefore, technically, an NFT is proof of ownership, and this proof is stored on blockchain technology which, as we have seen previously, protects it from tampering.

With the recent rise in the popularity of digital assets, so has the popularity of NFTs. (Silver, 2021) According to Wang, Q., et al. (2021), NFTs allow for potential opportunities in the field such as, for example, boosting the gaming industry by allowing players to have personal in-game exclusives while the developers earn royalties on them. The paper also explores the idea of "NFT-based tickets" to reduce the potential of fraudulent third parties trying to scam individuals with counterfeit tickets. But NFTs are mostly well known for their "digital art" where digital images, trading cards, or similar are sold for millions. (Silver, 2021) As we can see, one of the main draws of NFTs is that it ensures authenticity, and trust, thanks to blockchain technology.

2. A currency or an asset class?

As we have seen in the previous part, digital assets are still mainly known as cryptocurrencies. Yet is this appellation justified, and are they currencies since they are mostly based on a peer-to-peer payment system? Or are they just highly speculative assets? This begs the question of what does it need to be a currency? In this section, we will attempt to answer all these questions.

2.1. Are digital assets a currency?

According to Baur, D. G., et al. (2018), a currency needs to have three main characteristics to be considered as one:

- A medium of exchange
- Store of value
- Unit of account

If we analyze these criteria with Bitcoin as an example (since it was the first "cryptocurrency"), we can see that the first criterion as a medium of exchange is met as Bitcoin was created as a peer-to-peer payment system. (Nakamoto, 2008) While technically, a Bitcoin does not have an underlying value, its price is determined by supply and demand. Since Bitcoin is limited to a maximum amount of 21 million, supply is capped, while demand has been growing in recent years. Bitcoin has value as long as people believe in it.

Secondly, there is the criteria of value storage. The storage of value is defined as the possibility for a currency to pay for goods or services for a considerable time after acquiring said currency. This criterion is one of the fundamental issues cryptocurrencies faces to be considered a currency. The inherent volatility of digital assets makes it so that it is risky to hold this digital currency for a certain period and therefore makes it a poor fit as a store of value.

Thirdly, a unit of account is a unit by which something can be accounted for or compared to. When considering most digital assets, they have such value. One could acquire goods with these assets. For example, Tesla allowed its US customers to buy their cars in Bitcoin for a while (Shead, 2021). Nevertheless, digital currencies are often held back by their volatility. If the currency's value is increasing daily, consumers might push back their consumption to a later time, and at the same time, merchants might find it challenging to know which price to establish. (Chuen, 2015)

These criteria ring true for Bitcoin and most Altcoins, but if we consider stable coins, which were described in the previous part, these criteria might be respected. These coins heavily rely on the value of a pegged asset (e.g., gold). (Reiff, 2021) This linkage between values is similar to how the dollar was pegged to gold during most of the 20th century. (International Monetary Fund, nd.) So, this specific subcategory of digital assets might be considered as a currency due to their ability to act as a store of value and as a unit of account.

As we can see, the current state of digital assets would suggest not to consider them as a currency even though some might show some characteristics of a currency. (Shah & Moss, 2021) Alternatively, maybe, our definition of a currency might be outdated, and these assets might philosophically work as a new form of currency. However, on the other hand, Glaser, F. et al. (2014) have pointed out that most investors in these digital assets are primarily interested in these assets for speculative purposes rather than using an alternative transaction system.

2.2. Are digital assets a new asset class?

2.2.1. What is an asset class?

According to Greer, R. J. (1995), strategic asset allocation is a crucial decision on the proportion of a portfolio to understand risk exposition. This exposure is essential because it also allows for diversification and thus decreases the portfolio's volatility. The author defines an *asset class* as "a set of assets that bear some fundamental economic similarities to each other, and that have characteristics that make them distinct from other assets". (Greer, 1995, p. 1) Furthermore, he adds that it is not enough for this group of assets to have a low correlation to other groups of assets.

Research indicates that Bitcoin has historically had a low correlation to most traditional asset classes (Baur et al., 2018; Akhtaruzzaman et al., 2020). But Greer, R. J. (1995) has mentioned that this is not a sufficient condition to be considered a new asset class.

During his research, Greer, R. J. (1995) came up with three main categories of asset classes:

- Capital assets (C assets)
- Consumable / Transformable assets (CT assets)
- Store of value assets (SV assets)

C assets are assets that bring in cashflows which can be valued through their Net Present Value of their expected return. This asset class includes equities, bonds, and real estate. CT assets are assets that have value but that do not yield any ongoing stream of value. Therefore, they cannot be valued through a Net Present Value approach. These assets are valued by supply and demand. This asset class includes commodities such as grains, energy products or metals. And lastly, there are SV assets that neither provide revenue nor can be consumed. They do, however, have value. SV assets include currencies, or fine arts.

If we try to fit digital assets in one of these three classes, we can eliminate them from C assets since digital assets most often do not have ongoing cash flows. If we look at CT assets, it could be argued that some digital assets might fit this description, so it might be understandable that some financial market agencies have classified them as commodities. (Commodity Future Trading Commission, n.d.) And lastly, as we have seen in the previous part, digital assets could be considered by some as an SV asset, even though this is one of the main arguments against digital assets as a form of currency.

Therefore, either digital assets have to be considered as consumable assets, or there is not a clearly defined asset class in which digital assets fit into, and therefore requires the creation of a new asset class. However, according to White, R. et al. (2020), digital assets do not resemble any of the principal commodities. The authors state that from 2010 to 2016, Bitcoin was inversely correlated to gold, silver, and oil. In this case, we must now try to understand if it is possible to define the "asset class" for digital assets.

2.2.2. Can Digital assets be considered a new asset class?

In the previous part, we saw that according to Greer, R. J. (1995), to be considered as a new asset class, there must be at least three conditions:

- Low correlation with other asset classes
- Strong internal correlation in the asset class
- The asset class must offer distinct features to allow for distinguishment from other classes

According to numerous research works (Baur et al., 2018; Akhtaruzzaman et al., 2020), it has been strongly suggested that digital assets offer a low correlation to almost every other asset class. While Krückeberg, S., & Scholz, P. (2019) have also shown that digital assets have a robust internal correlation. The external correlation is something we will test further in the second part of this thesis. Generally speaking, this means that two of the three conditions would already be met. It remains to be seen if the asset class offers distinct features. Previously, we have defined digital assets; therefore, we can understand that to be considered a digital asset, the assets must be based on blockchain technology, use cryptography, and are mainly decentralized. The fact that they are peer-to-peer and allow every person with an internet connection to have access to these assets is a compelling argument in favor of this asset class.

Therefore, we can conclude that digital assets can be considered a completely new asset class that should be considered by portfolio managers. The impact of this new asset class on portfolio management is something we will focus on in the second part of this paper.

3. A favorable macro-economic environment

In this section of the paper, the emphasis is put on trying to understand the current macro-economic environment of digital assets as well as to ascertain why these assets have risen in popularity in general but exceedingly so for portfolio managers. To do this, we will look at the different stakeholders driving the interest in these assets, and afterwards we will try to understand why these assets are appealing in the current market.

3.1. Growth drivers

3.1.1. Retail investors

The growth of digital assets was mainly due to the ever-more-growing interest by retail investors in these assets, and only later private institutions became aware of them. As we have seen previously, this asset class was created after the subprime crisis. This was a philosophical shift in the perception of banking and finance and presented an alternative to these institutions. According to a Goldman Sachs poll (Bloomberg News, 2015), less than 20% of millennials trust the stock market as the route to invest for the future. This erosion of trust and generational change is one of the main driving forces of the adoption of digital assets. Younger generations have become increasingly technology native and expect these trends to continue in financial services. (Shah & Moss, 2021)

According to Gemini Trust Company, LLC. (2021) report, the majority (77%) of people holding digital assets in the United States of America are below the age of 45. The Gemini report estimates that in 2021 14% are holding digital assets in their portfolio, while a further 63% of the American population is fairly interested in holding some in the future (they call these individuals “crypto curious”. The report also suggests that currently, this phenomenon is mostly skewed toward young Caucasian males having a 74% probability of owning digital assets. Furthermore, the paper acknowledges that at this moment, the majority of holders are male, but 53% of “crypto-curious” individuals are female. While this report is based on American data, it allows us to understand that the shift and interest is mainly a generational one.

If we suppose that the Gemini report reflects mainly “western” countries, the use of digital assets is also widely growing in so-called emerging countries. (Wilson, 2021) According to Wilson, T. (2021), emerging countries generally use digital asset due to distrust in their national central banks and domestic banking systems. Nevertheless, this adoption of another “currency” is not something historically new. The report compares the adoption of digital assets to the “dollarization”. Dollarization is the process of a country additionally accepting the US Dollar as a national currency because of the low credibility of the domestic currency. The low credibility of the domestic currency can be due to high inflation rates or the instability of the said currency. The article argues that this phenomenon has historically impeded the financial stability of these countries since they became more dependent on US monetary policies rather than their corresponding national policies.

This is a reasonable conjecture why the digital asset market has been spiking in emerging regions, allowing them to have access to a sort of global banking system, which they would not have been able to access without digital assets. (Cuen, 2021). According to Krause, M. (2016), the strong adoption rate in emerging countries is therefore strongly correlated to the stability of the domestic financial stability. In developed countries, payment by credit card is instant and convenient. For digital assets to become more widespread, they would have to challenge this convenience. This convenience, at least to a certain degree, is still often missing in developing countries (at the moment). The paper suggests that this is a strong reason for the high adoption rate of digital assets in those countries concerned, in addition to the high inflation rates and the distrust in the domestic currency.

Over and above, adoption rates are increasing but so is the holding period. According to Coinbase Global, Inc. (2022), their yearly retail users have increased by 107% from 2020 to 2021, from 34 million verified users to 89 million verified users in 2021. This shows the increasing interest in digital assets and is also one of the key growth drivers of these assets. Furthermore, the Gemini Trust Company, LLC. (2021) report mentioned that - concerning the average investor, 69% of them hold these assets for their long-term potential. This demonstrates that there are real demand drivers from retail investors, which is favorable for the future of these assets.

3.1.2. Businesses

Not only are retail investors becoming increasingly interested in digital assets, but so are companies. Tesla has been in the news for openly accepting digital assets as a payment method. (Shead, 2021) However, Tesla is not the only one; according to Lisa, A. (2021), a multitude of S&P500 companies are accepting these payment methods. Not only are these companies becoming gradually more accepting of this payment method, but companies are also replacing their cash positions in their treasury with digital assets. (Shah & Moss, 2021) The aim of this paper is not to analyze treasury decisions made by global firms but to simplify the main reason for this. According to Shah, A., & Moss, A. (2021), cash and cash equivalents yield on average 0,5% yearly. While if this money had been placed in stable coins, which are often pegged to the US Dollar, one could amass a passive income of 2%. Obviously, there are risks associated with this, but the report shows that putting 10% of one’s cash and cash equivalents into digital assets would increase the yearly yield by 30%.

Another reason companies are interested in using digital assets as a payment method has to do with the fees associated with money transfers. As published by Woock, K (2021), the standard fee for the processing of a payment by credit card companies is around 3% (this value varies depending on the processor). However, for digital assets, this rate is between 0% to 1% depending on the payment tool.

Thus, it is understandable that multi-billion companies are interested in digital assets due to their lower fees, which would enable them to save millions of dollars yearly.

Considering these two reasons, we can understand why companies are also looking into digital assets to improve their balance sheet and enable corporate financial decisions that would permit the company to a higher yield. More demand from companies spells, therefore also a sturdy growth driver in this market.

3.1.3. Investment firms

Subsequently, there are also investment banks and hedge funds that have gained an interest in digital assets. (PricewaterhouseCoopers, 2021) As mentioned by PricewaterhouseCoopers (2021) report, more than 20% of hedge funds around the globe have invested in digital assets. The report mentions that these hedge funds had around USD 3.8 billion of digital assets under management in 2020, nearly double the previous year's value. The paper states that on average digital assets represent 3% of their portfolio, but with the intent of increasing this percentage in the future. Furthermore, 26% of hedge fund managers who have not yet invested in digital assets confirmed that they plan to invest soon. (PricewaterhouseCoopers, 2021)

At the same time, some traditional asset management firms have started to develop their digital assets services. For example, Fidelity, a world-renowned asset management firm, has launched its digital assets division, where they offer custody, execution, and research services linked to this asset class. (Fidelity Digital Assets, n.d.)

While these investment firms have many assets under management, when considering the market capitalization of this class, they currently own less than 1%. We have previously seen, in Figure 3 (CoinMarketCap, n.d.), that the market capitalization in April 2022 is around USD 800 billion. Therefore the USD 4 billion owned by hedge funds is currently 0,5% of the market capitalization. Nevertheless, this still shows that there is interest from financial institutions that would lead to growth in the market.

3.1.4. Governments and central banks

The latest actors exploring digital assets are governments and central banks. (Atlantic Council, 2022) Logically, governments have initial distrust in an asset class they cannot control but in which a lot of money is invested. As we have seen previously in the section mentioning retail investors, one side effect of the wide adoption of digital assets is that domestic monetary policies may develop less impactful. Furthermore, fiscal authorities are also wary of potential tax evaders using these assets. But in the end, central banks are acknowledging the potential and important of this new technology and are trying to control it.

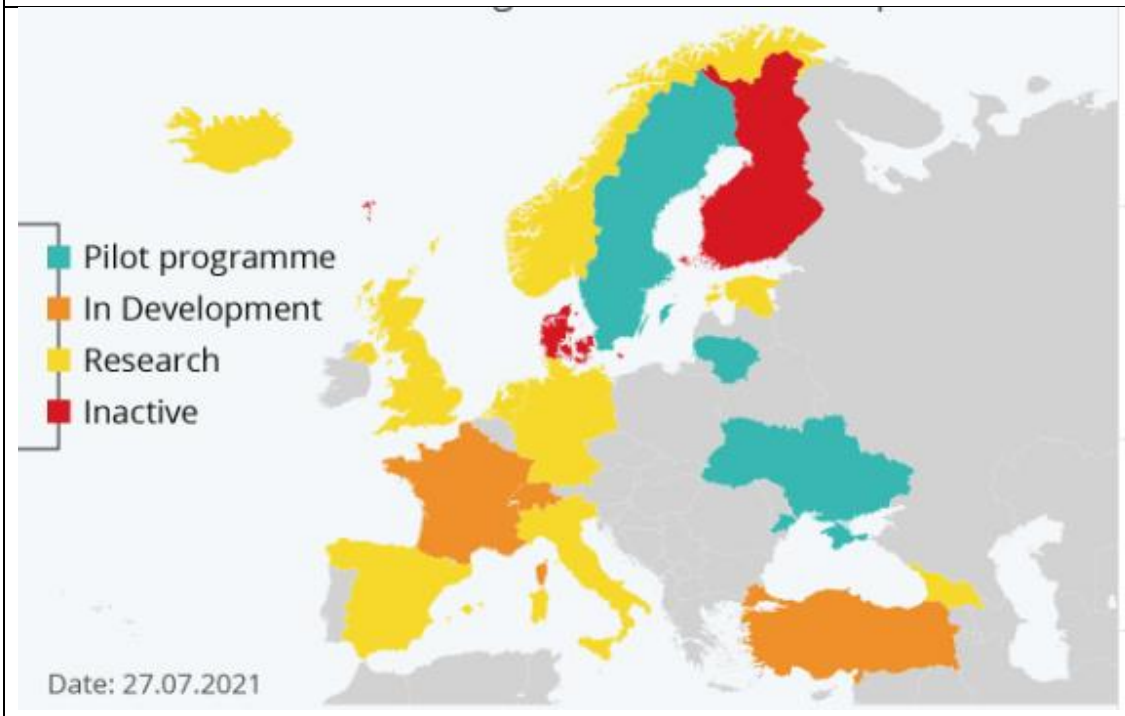
The majority of public entities around the globe are starting to investigate the potential of governmental digital assets. (Coeuré,2018) This new monetary asset is called "Central Bank Digital Currencies" (CBDC) and works similarly to stable coins. The goal is to replace physical cash completely, which would potentially become a more effective payment system. (Shah & Moss, 2021) These CBDC as a replacement for cash seems like a logical progression for the digitization of the monetary systems. Currently, we use credit card companies as third parties to transfer money for a fee. However, with CBDC, we could potentially directly send electronic money in a peer-to-peer system without traditional intermediaries. (Shah & Moss,2021). As stated by Bech, M., & Garratt, R. (2017), this would mean that central banks must digitize their liabilities and therefore need consumers to have "central bank

accounts" to use this digital cash. This digital cash system already exists. While it is only available for financial institutions, CBDC could make it accessible to the public. (Catalini & Massari, 2021)

Last but not least, McKinsey & Company (2020) stated in their report that the usage of cash between 2010 and 2020 has dropped by 62% on average in western countries, with an average of only 19% of transactions being in cash in 2020, down from an average of 53% in 2010. This is mainly true in mature markets and explains why more than 80% of governments are looking into CBDC. (McKinsey & Company, 2021).

In the end, as mentioned by Catalini, C., & Massari, J. (2021), CBDC could be interesting as an efficient solution to the decrease in demand for physical cash. The paper mentions that, while it is still debated whether governments should create those CBDCs and what form they should take, the disruptive potential to the current financial system is interesting but also potentially risky.

Figure 4 - Central Bank Digital Currency projects advancement in Europe



Source: Zandt, F. (2021, July 27). *Central Bank Digital Currency still in its Infancy*. Statista Infographics. Retrieved July 23, 2022, from https://www.statista.com/chart/25408/status-of-central-bank-digital-currencies-in-europe/

3.2. A complex financial market after the pandemic

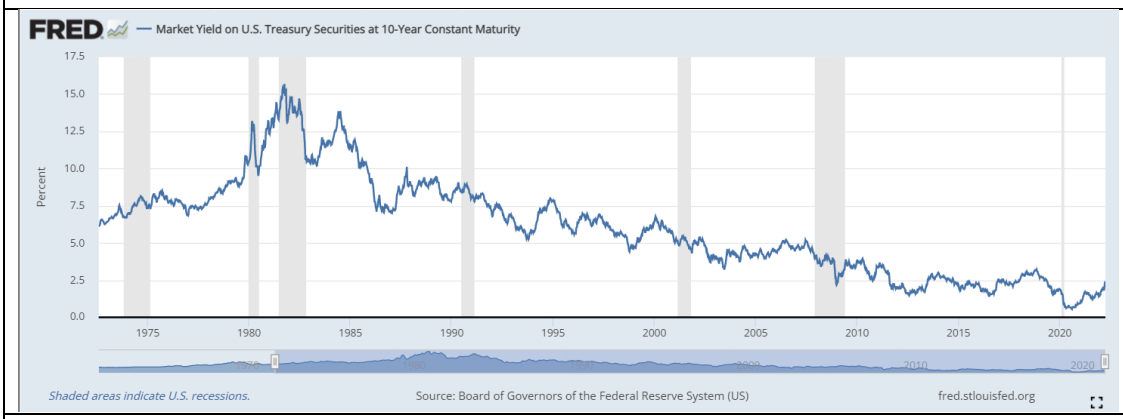
3.2.1. Fixed income

At the beginning of 2022, interest rates from the European Central Bank were near 0% (depending on the time horizon, this varies by 0,5%). (European Central Bank, 2022) However, this is not something unusual because for the past decade, interest rates have been at similar levels or even lower. According to David-Pur, L. et al. (2020), global interest rates have been relatively low and have even gone negative

for the first time in the last decade. The paper states that one of the first financial institution to have negative interest rates was the Danish National Bank in 2012. The author suggests that the bank supposedly had been a pioneer in this matter because other central banks have followed their steps since then. The author stated that countries like Switzerland, Sweden, and Japan followed and adopted negative interest rates in the following years.

But historically speaking, this has not always been the case. As stated by Blanchard, O. (2019), if we were to look at **Figure 5** (FRED, 2022), the historical graph of US 10-year treasury rates over the last 40 years, we can see that there has been a gradual decline since the 1980s where United States Government Bonds interest rates were at 15% to today near 0% levels (for real returns rates). This level can also be observed in other developed countries.

Figure 5 – United States 10-year treasury yield evolution from 1975 to 2022



Source: Federal Reserve Bank of Saint-Louis Economic Data (FRED). (2022, July 18). *Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity, Quoted on an Investment Basis (WGS10YR)*. Retrieved July 23, 2022, from https://fred.stlouisfed.org/series/WGS10YR

Since interest rates are so intertwined with the economy, this begs the question of why central banks would reduce these rates. One of the reasons why banks have historically reduced rates was to stimulate the economy. (David-Pur et al., 2020) Interest rates imply the supposed "risk-free" rate of financial products. (Schmidt, 2021) So, a financial product that is expected to have virtually no risk since a government would back this asset. (Hayes, 2022) When trying to stimulate the economy, one of the aims would be to reduce the reward of some so-called "sleeping" money and therefore push investors and consumers to invest more actively in different products, or for consumers to buy more goods instead of waiting for the purchase. (Hirshleifer, 1987)

Interest rates also affect money stockpiling (and all investment decisions), previously, not investing and keeping your money in the bank was an interesting alternative for people with a small risk appetite. (Hirshleifer, 1987) With current near-zero interest rates, many investors would be tempted to make more risky investment decisions since they would not gain anything from their "sleeping" cash. (David-Pur et al., 2020) More people have therefore invested in capital or alternative and more risky products, as we can observe from the growth in the stock market. (Yahoo! Finance, 2022) Yet the goal of central banks is to ensure the economic stability of a country and reduce economic fluctuations. (International

Monetary Fund, 2016) Therefore, having lower interest rates that push investors to make riskier decisions seems counterintuitive as it would promote more risk-taking from investors.

On the other hand, simultaneously, there has been an increase in public debt, especially since the Covid Crisis. (Gaspar et al., 2021) If we take the example of public debt in the United States of America, the debt level has drastically increased to 134% of the country's GDP in 2020, up from 107% in 2017. (Statista, 2022) As we have seen previously, one of the goals of central banks is to ensure monetary stability. However, recent actions seem to undermine the actual risk to the financial system these decisions have.

As we have seen in this part, interest rates are useful leverage to keep the economy (and inflation) in check. A rate hike should help slow down inflation, while a rate drop should reaccelerate the economy. (Engemann, 2021) However, the global pandemic has put economies in a conundrum. Economies are facing a situation of stagflation that could put countries in a downturn market for the coming years. (World Bank Group, 2022) *Stagflation* is defined as an economic situation with persistently high price inflation and relatively low economic growth. (Cambridge Dictionary, 2022) The conundrum lies in the fact that if the central banks want to tackle inflation, they risk an economic recession, and if they want to accelerate the economy, they will drastically increase inflation. (Bogage & Whalen, 2022) Overall, the outlook for the macroeconomic landscape is looking rather grim.

3.2.2. Equity

In the financial market, equities are the shares of a company that is publicly traded. (Cambridge Dictionary, 2022) What this means is that these are companies that made the decision to open themselves up to external investors. Shareholders are interested in owning these shares because they expect a return on their investment. This can be achieved by receiving some dividends from the company or by the value of the shares increasing due to a good performance from the company. (Hayes, 2022) Equities, compared to fixed income (and bonds), are considered riskier investments, which implies that due to the increased risk, investors are expecting higher returns. (Morah, 2021)

Let us look at the Standard and Poor's 500 (S&P 500), which is an index that tracks the 500 most prominent companies in the United States of America. (S&P Global, n.d.) If we consider the S&P 500 as a proxy for the stock market, we can observe that the stock market is at historically high levels. (**Figure 6**) We can observe that in the 1980s, the S&P 500 was valued at approximately USD 115, while in 2022, it is valued at around USD 4500. This represents a 3813% increase in 4 decades or, on average, a 9% compound annual growth rate.

Figure 6 - S&P 500 evolution from 1980 to 2022 (in USD)

Source : Google Finance. (2022). *S&P 500: Cours, cotation en temps réel et actualités - Google Finance*. Retrieved July 23, 2022, from https://www.google.com/finance/quote/.INX:INDEXSP?hl=fr&window=MAX

Since all financial markets are linked, the decline in interest rates has positively affected the stock market twofold:

1) As we have seen previously, reducing interest rate make stocks become a more attractive alternative for investors since they directly affect the investment decision process. (Hirshleifer, 1987 & David-Pur et al., 2020)

2) As interest rates decline, this positively affects the valuation of stocks. Stocks are often valued using the Discounted Cash-Flow methodology. This methodology aims to estimate the company's future cash flows and then discount them using a discount rate. This discount rate is somewhat based on interest rates; a higher interest implies a higher discount rate (all things remaining equal). The fact that discount rates have dropped implies the discount rate has decreased; therefore, future cash flows have become more valuable today. This, in turn, means that the valuation of companies has increased. (Fernando, 2022)

Interest rates have a negative correlation with the stock market. (Markowicz, 2022) For this reason, one could imply that stock price valuation over the past four decades have been inflated due to decreasing interest rates. On top of that, as we have seen previously, declining interest rates push investors to find other sources of revenue besides fixed income, which might have driven some investors to take on more equities in their portfolios. (Hirshleifer, 1987 & David-Pur et al., 2020)

The fact that equities and the stock market, in general, are high is not necessarily an issue. The issue with the current valuation is that overall, the stock market is overpriced compared to historical values. (Estimite, 2022) This is something we can see when analyzing the valuation multiple of the S&P 500.

Figure 7 - S&P 500 spot Price to Earnings ratio evolution from 1880 to 2022

Source: Multpl. (2022). *S&P 500 PE Ratio*. Retrieved July 23, 2022, from https://www.multpl.com/s-p-500-pe-ratio

In **Figure 7** (Multpl, 2022), we can observe the historical evolution of the Price-to-Earnings multiple (P/E) of the S&P 500. The price to earnings ratio compares one share's price (or stock price) to the earning per share (EPS) of that company (for the EPS, one divides the net profit of the company by the number of shares). (Fernando, 2022) The multiple is used to see how many years of profits at the current rate would be necessary to recoup an investment in the stock. (Fernando, 2022) The historical average for the P/E between 1980 and 2020 comes in at 21. (FINASKO, 2022) Therefore, on average, it would take an investor 21 years to recoup their investment. As we can see in the graph, in 2020, we were at a P/E level of nearly 26, which is 24% higher than the mean.

So, we can confidently say that compared to historical values, the stock market is currently overvalued. According to Neureuter, J. (2021), this leads to two schools of thought. Either, the market is overvalued, implying that in the foreseeable future, we will have a "back to mean" market crash. Alternatively, we are currently in an unprecedented period in the financial market in which current valuation will become the "new normal" where high multiples (compared to historical average) for stocks would become the norm.

In case higher multiples become justified going forward, analysts and investors assume that higher multiples will become the norm because companies today in the 2020s are not the same companies as before the 2000s. (Neureuter, 2021) The assumption is that globalization, digital services, and assets light business models (such as Uber and Airbnb) mainly use intangibles rather than tangible assets to incur their business. (Smith, 2016) This enables firms to have stronger competitive advantages. These companies benefit from assets they do not own. As such, these companies require less investment for a higher growth potential than traditional business models. (Smith, 2016)

According to Neureuter, J. (2021), this would therefore mean that companies could also expect higher growth rates going forward. This is setting a high bar for companies to beat in the future, which might be unsustainable in the long term. Potentially, this is something that is already accounted for by analysts, which would explain the current levels. Therefore, the current high valuation reflects the low

interest rates mixed with the outlook by investors of stronger growth by these global companies that, with the help of new technologies, are expected to outperform historical return rates.

The other scenario implies that the current high multiples are not justified; if this is the case, we could expect equities to decline towards their historic levels. (Estimite, 2022) This outcome is something already expected by some hedge funds that foresee the stock market to decline annually by –8% during this decade if we would see a "back to mean scenario". (Neureuter, 2021) With this scenario, we would expect to face at some point slower underlying growth than investors expected and then would cause a decline, or slower than expected growth, in the market

The first scenario seems less likely given the expected increasing returns after the last decades already above-average returns. (Divine, 2019) All in all, it seems that the decrease in interest rates has pushed valuations up, which we can expect to not happen anymore in the following decades. Therefore, it is more likely that in the following decade, equities will face a drawback to historical levels.

3.2.3. Implications for the future

The fact that these two major asset classes are becoming less appealing, as seen previously, has substantial implications for the following years. Because the fixed income market, which relies on interest rates set by central banks, is, as we have seen, historically low. This is shifting the way portfolio managers have to think about asset allocation since low interest rates impact investing decisions. (Hirshleifer, 1987 & David-Pur et al., 2020) And on top of that, equities are potentially facing a decline in the following decade on top of the stagflation fears. (Estimite, 2022)

The fixed income market is expected to be valued at around USD 100 trillion in 2021. (International Capital Market Association, 2020) At the same time, the stock market, or the sum of all publicly traded companies, was valued at around USD 90 trillion in 2020. (World Bank, n.d.) So, these two asset classes together are valued at nearly USD 200 trillion. This implies that if just 10% of portfolio managers believe that there needs to be a shift in asset allocation because these two classes losing their attractivity due to the economic outlook. Then there is potentially USD 20 trillion to be reallocated in alternative asset classes to diversify their portfolio. One of these recipients could be digital assets since the cost of opportunity currently being lower. (Neureuter, 2021)

4. A new asset class to consider for portfolio management

In the last chapter, we have mentioned the potential shift in asset allocation and the need to diversify a portfolio to optimize it to face potential macroeconomic trends. In this section, we will dive into more detail about what portfolio optimization means while trying to understand what the role of digital assets in a portfolio is. To understand this, we will therefore start by reviewing the theory of portfolio management to then move on to the potential added value of digital assets from a financial point of view.

4.1. Modern Portfolio Theory

Before seeing what impact digital assets could have on a portfolio, it is important to understand what portfolio management is. The origin of modern portfolio management comes from Harry Markowitz, who wrote in 1952 a paper called "Portfolio Selection". (Rubinstein, 2002) This serves as the

conceptual basis for of what is today known as Modern Portfolio Theory (MPT). In his research, Markowitz mathematically laid out the importance of diversification by the amount of assets in a portfolio and the covariance relationship between the assets. (Markowitz, 1952) But MPT is not only based on Markowitz's discoveries but also on some discoveries made by William Sharpe in 1964 and John Litner in 1965. More precisely, their model of pricing financial assets which is known as the Capital Asset Pricing Model (CAPM). (Fama & French, 2004)

4.1.1. Diversification at the core

The model became famous as it was the first of its kind to not only focus on return diversification but also put an emphasis on the risk. (Chen et al., 2010) According to Markowitz, H. (1952), this diversification effect is possible because each asset reflects two types of risk: a systematic risk (also known as market risk) and an idiosyncratic risk (also known as the diversifiable risk). The systematic risk is believed to not be diversifiable as it reflects external macroeconomic factors which affect the entire market. (Mangram, 2013) Inversely, the idiosyncratic risk reflects a specific risk that is unique to the asset, which, therefore, can be reduced through diversification. (Mangram, 2013) At the core of asset allocation is the idea that diversification will improve the risk-reward profile of the portfolio better than any individual asset could offer. (Mangram, 2013)

4.1.2. MPT theoretical assumptions

To simplify, the MPT is an asset allocation framework based on statistical and mathematical modeling reliant on a few vital theoretical assumptions. (Mangram, 2013) According to Omisore, I., et al. (2012), MPT is based on key assumptions made by Markowitz:

- Investors are rational and risk-averse
- Returns follow a normal distribution
- Correlations between assets are fixed and constant in time
- Investors aim to maximize economic utility
- Investors have access to perfect information.
- Investors are permitted to borrow or lend a limitless amount of capital at the risk-free rate.
- The financial market is perfectly efficient.
- The financial market operates without friction (no taxes or transaction fees).

These assumptions have faced numerous criticisms over the years. Some of the main criticisms claim that Markowitz's key assumptions are out of step with reality; some even argue that none of them might be valid to varying degrees which would undermine the entire theory. For example, the fact that investors are supposed to be rational goes against years of analysis in behavioral finance, which has observed over years that investors show many irrational biases. (Omisore et al., 2012)

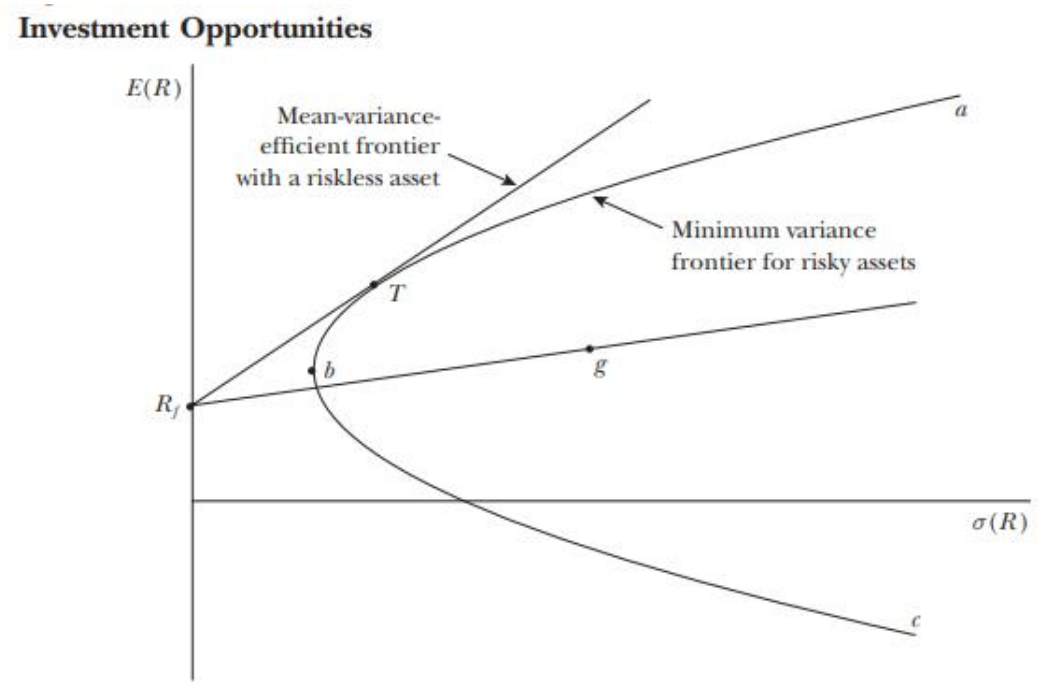
Notwithstanding some flaws, MPT still remains a standard for contemporary portfolio theories. The underlying point of MPT is that it is difficult to outperform the market, and those that do so achieve it, do it by successfully diversifying their portfolio and assume a greater risk than average. (Mangram, 2013)

4.1.3. Efficient frontier

According to Fama, E. F. & French, K. R. (2004), the MPT is a theoretical framework in the financial field with which one can select assets to construct a portfolio to optimize the risk–return of the portfolio. Usually, the risk-return is optimized by maximizing the expected return and, at the same time,

minimizing the risk of the investment. At the core of the concept lies the idea that the optimized portfolio will provide investors with a better risk – return profile than any single asset could have provided the investor individually. Achieving such an optimal portfolio is called an "efficient portfolio" in MPT. There exists a plethora of efficient portfolios for all types of investors depending on their risk-reward appetite. All these portfolios exist on a line called the "Efficient Frontier".

Figure 8 - Capital Asset Pricing Model theory: Efficient Frontier



Source: Fama, E. F., & French, K. R. (2004). The Capital Asset Pricing Model: Theory and Evidence. *Journal of Economic Perspectives*, *18*(3), p. 27. https://doi.org/10.1257/0895330042162430

For the following parts, readers will be expected to be familiar with the concepts from the MPT and how these are calculated because going into detail on this theory is not the point of this part. Some points will be brought up in the second part of this thesis, where we will be looking at the methodology of the analytical part.

4.2. Digital assets in a portfolio

When considering the MPT, digital assets have an interesting profile as financial securities. In this section, we will further investigate the investment case for digital assets, and in this case, we will often look at research papers analyzing the impact of Bitcoin in a portfolio as a proxy for all digital assets. Even though some conclusions are based around Bitcoin especially, we will assume that since Bitcoin represents over 40% of the digital assets market capitalization (**Figure 3** (CoinMarketCap, n.d.)) and additionally, digital assets are supposed to have a strong internal correlation (Krückeberg & Scholz, 2019) that these results match digital assets as an asset class.

In order to analyze the effects of digital assets in a portfolio, we will look at the assets correlation and diversification potential will be examined in line with MPT. Then we will look at two popular arguments favoring digital assets as hedge potential against inflation, similar to how gold is perceived.

4.2.1. Correlation and diversification

According to Baur, D. et al. (2018) & Brière, M. et al. (2015), digital assets as an alternative asset class show that they have nearly no correlation with equities from any sector or fixed income. While it is mentioned that digital assets offer very high expected returns, they do also have higher volatility. But since the asset offers a low correlation, this volatility can be offset and offer a better risk-reward inside a portfolio.

According to Platanakis, E., & Urquhart, A. (2020), the data is clear that adding digital assets to a portfolio improves the portfolio at all levels of risk aversion. The analysis showed this by comparing data from 2011 until 2018 and found that portfolio performance metrics improved drastically. Whether it be by looking at the Sharpe Ratio, Omega Ratio, or Sortino Ratio, the portfolio's performance constantly improved. This improved risk-adjusted performance on itself should be a persuasive argument for all portfolio managers to consider this asset class in their allocation strategy.

As stated by Baur, D. et al. (2018) and Akhtaruzzaman, M. et al. (2020), digital assets offer a very low correlation to most industries and would therefore improve portfolio diversification. The authors mention that the best utilization of digital assets in a portfolio is to hedge them by shorting the "utilities" sector. This strategy would allow minimizing the risk without compromising the expected return. According to Neureuter, J. (2021), Bitcoin had a correlation of around 0.2 with most market indices (American or international) from 2015 to 2021. What is interesting is that Bitcoin had a near 0 correlation with both gold (0.04) and U.S. bonds (0.07). This is something portfolio managers are looking for, assets with positive returns that offer a low correlation to the rest of their portfolio, which begs to be highly advantageous for investors' returns.

4.2.2. Inflation hedge & digital gold

When considering digital assets such as Bitcoin, it is often dupped "digital gold" due to its similarities with real gold. (Selmi et al., 2022) As we have seen previously, Bitcoin has a hard supply cap of 21 million, which offers similar scarcity features as gold. (Dyhrberg, 2016) Gold has historically been considered a safe haven for investors with some hedging capabilities. (Dyhrberg, 2016) This implies that in a situation of distress and uncertainty, investors store their investments in gold during market downturns and general economic uncertainty. As we have seen previously, digital assets don't convincingly offer this same feature. (Klein et al., 2018) However, gold is not only considered a hedge against uncertainty, but it is also considered a hedge against inflation.

According to Neureuter, J. (2021), digital assets offer a good hedge against inflation. Inflation can be analyzed by two factors: monetary financial asset price inflation or through real economic inflation with a consumer-based index like the Consumer Price Index (CPI). When considering the first inflation metric linked to monetary policy, we can see that in 2020 during the pandemic, the balance sheet for the American Federal Reserve grew by 76% to keep the economy afloat. In the same year, the stock market (or S&P 500) grew 18% over the same time. Even though the performance was good, it still means that investors lost value due to the stronger increase in monetary policies. On the other hand, digital assets grew by over 200% in the same period and therefore outperformed inflation risks. To compare digital assets to the CPI is still quite early to say that it is indeed an inflation hedge, but it currently seems that an asset class that is sought after and offers some scarcity-like features would develop to become a hedge against inflation.

In a research paper by Qin, M. et al. (2021), Bitcoin (and subsequently digital assets) might have a useful potential to hedge against policy uncertainty. The assets have a good potential in a portfolio, but the assets' weight must be carefully monitored to be adjusted to the global economic situation.

4.3. Attributes not everybody agrees with

One big financial drawback of digital assets and their diversification purposes is that the asset is unable to provide this diversification and correlation benefits during significant market downturns. It is true that digital assets mainly offer adequate diversification purposes when the market is doing well, but the correlation is stronger during periods of market uncertainty. (Nguyen, 2022) This shows that, indeed, digital assets do not offer safe haven-like qualities compared to what gold offers during crises.

To conclude, the research suggests that given the current economic outlook, it would be more than interesting for investors to take another look at digital assets. The higher level of return might be worth the volatility, given portfolio managers are able to diversify their portfolios. Yet, the analysis warns that historical data might be a poor indicator for the future performance of this asset class, but the same goes for all asset classes. The results may also be impacted by the methodology used, and different models might find different results. On top of that, the analysis by Platanakis, E., & Urquhart, A. (2020) expects to take a high percentage of digital assets in the portfolio (from around 15% to over 70%) which seems unreasonable for a portfolio manager to take on, even if it would be the "optimal" amount according to the theory.

5. A controversial asset class

In the previous section, we analyzed the financial aspects of digital assets linked to portfolio management. This means that we have looked at the theoretical framework and have discussed the potential financial added value of this new asset class in a portfolio and why it seems like every investor should add digital assets to their portfolio. In this part, we will take a look at all the non-financial aspects of this asset class that might affect investors' decision-making outside of financial factors.

We will first analyze the legislative implications of a new asset class that make it potentially illegal for investors to propose these assets to their customers. Then we will go through the claims linking digital assets to criminality and potentially money laundering. Afterwards, we will look at the potential ESG (Environmental, Social and corporate Governance) of the assets that are notorious for being heavy polluters. Lastly, one of the biggest questions for portfolio managers is the question of the fundamental value of the asset and whether it is a financial bubble that is too risky for portfolio managers to take on.

5.1. Legal framework

As we have seen previously, digital assets offer a unique added value for investors to add to their portfolios. But, similarly to any financial security, to be allowed to be exchanged on the market, the security needs to adhere to some regulatory framework. Yet, as we have seen at the beginning of this paper, digital assets fundamentally do not adhere to a centralized system. Therefore, this begs the question of how a decentralized financial security that rejects any form of centralization can adhere to a centralized market. A centralized market adds value by providing a framework and overseeing the market to reduce the potential of abuse.

In this part, we will analyze current market trends and the difficulty of adapting legislation (such as anti-money laundering (AML) or Know Your Customer (KYC) regulations) to this new asset class. Then we will see how the European MiFID regulation on investor protection makes adoption in Europe more difficult.

5.1.1. AML Legislation

In the traditional financial sector, a trend of increasing numbers of compliance focus is preventing illicit activities and money laundering (AML). According to Samy, H. & Rustagi, D. (2018), one of the main reasons of the increase in the need for compliance leaders is the complexity of the current economic environment. With technology, there is an ever-increasing innovation leading to the higher complexity and risks of the product. The rise of the need for compliance is because governments were ill-equipped to handle this added complexity. As a result, governments have flipped the onus of proof. Previously, companies were innocent until proven guilty. However, due to the high level of workload (and taxpayers' money) often necessary to prove a company's guilt (without accounting for the fact that companies would then also try to hide their actions), companies now are presumed guilty until proven otherwise.

Adapting the rules of traditional securities to digital assets is challenging. For example, as we have already seen previously, it is already complex to classify the asset class, and it is even more complex to classify each underlying asset inside the class due to their specificities. We have previously mentioned that new AML regulations have become stricter for traditional assets whose regulations need to be transposed upon digital assets.

According to Kenton, W. (2022), "AML refers to the web of laws, regulations, and procedures aimed at uncovering efforts to disguise illicit funds as legitimate income". In the case of AML, illicit activities mean everything from tax evasion to drug trafficking and everything in between. (Financial Crimes Enforcement Network, n.d.) To combat potential crime, different countries and law enforcement authorities need to cooperate for it to be successful.

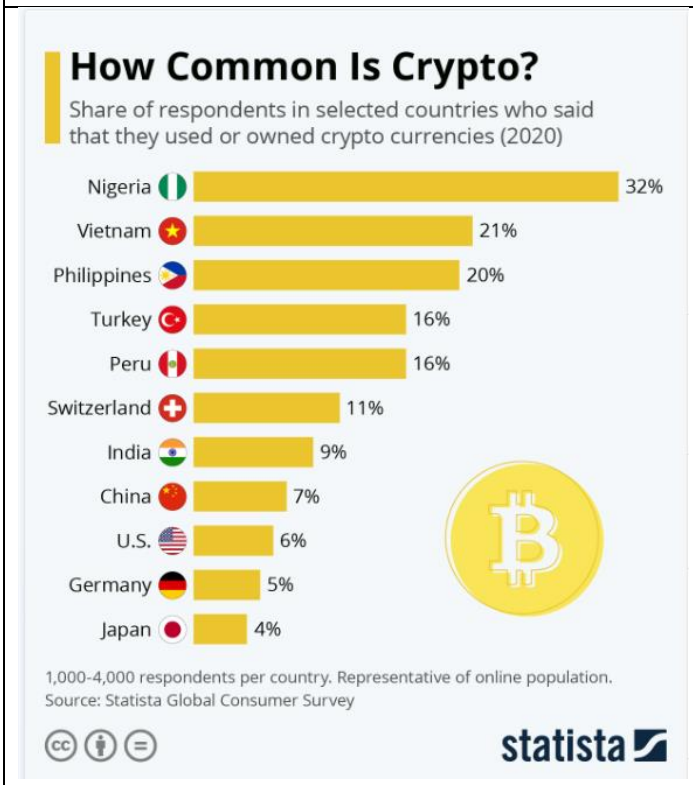
But this is one of the main drawbacks. The lack of international alignment about digital assets is another issue that the new asset class faces. Some governing bodies were already having trouble seeing eye to eye with each other about traditional assets. As stated by the Business Standard (n.d.), the G7 countries established the Financial Action Task Force (FATF) in 1989, an international entity to develop policies against money laundering. The goal of the FATF is to set, promote and implement the standard to combat money laundering and audit countries to identify potential vulnerabilities. All in all, the FATF goal is pivotal to protect the international financial system from misuse while harmonizing legislation around the globe.

According to the Financial Action Task Force (FATF) (n.d.), not all countries adhere to its authority and refuse to participate in FATF's regulations. Therefore, the FATF has developed a so-called "tier list" of countries depending on the country's AML or terror funding practices. This means that countries adhering to FATF regulations cannot simply work with these countries. The two-tier lists are the "Blacklist" and the "Grey List" that regularly get revised. Countries on the Blacklist are countries actively supporting terror funding and money laundering (currently only North Korea and Iran). While on the Grey List are countries that are considered safe havens for supporting terror funding and money laundering.

The issue with digital assets, as we have also seen previously, is that their adoption currently often is the highest in developing countries. According to **Figure 9** (Buchholz, 2021), in 2020, five countries with a high adoption rate were Nigeria (32%), Vietnam (21%), the Philippines (20%), Turkey (16%), and Peru (16%). According to the FATF (2022), from the five countries mentioned, two are currently on the Grey List (Turkey and the Philippines), with two more being regularly on and off the list (Nigeria and Vietnam).

Therefore, adopting digital assets might also mean giving financial access to countries where there exists a potential money laundering or terror financing risk. This is something that puts western institutions at unease and therefore requires further investigation to ensure that it would not compromise the current financial stability.

Figure 9 - Share of respondents per country that used or owned digital assets



Source: Buchholz, K. (2021). *How Common is Crypto?* Statista Infographics. Retrieved June 5, 2022, from https://www.statista.com/chart/18345/crypto-currency-adoption/

5.1.2. Case study of the 3 main markets

5.1.2.1. China

In the report by Shin, F. (2022) from the World Economic Forum, China has a strong stance against digital assets. In September 2021, the People's Bank of China (PBOC) reiterated its ban on all transactions linked to digital assets. This ban is not something new since original bans were already implemented years prior, in 2013 and 2017. (Sergeenkov, 2021) The WEF mentions that the PBOC defends its stance by arguing that the ban is to protect the country's economic stability. The PBOC

argues that digital assets were facilitating financial crime and putting at risk the financial system due to the high volatility of the assets. But the article suggests that another reason was that digital assets were facilitating capital flight from its market, something that the Chinese government vehemently opposes. As maintained by the author, it is expected that in 2020, over USD 50bn worth of digital assets left accounts from the East Asian regions (to outer regions). It is believed that this could represent potential flights to safety out of China, bypassing governmental restrictions.

According to Sergeenkov, A. (2021), this ban was stricter than previous bans and intensely involved Chinese police and supreme court authorities, leaving no room for interpretation for Chinese citizens. Similar legislation had previously been passed on digital asset mining in 2019; at that time, the country had 50% of all miners in the world. The mining process was deemed too polluting by the Chinese government, which then sparked panic within Chinese miners. Their choice was made simple; if they wanted to continue to operate, they had to leave the country.

All in all, one thing is clear, China dislikes digital assets. Whether this is to protect the stability of the economy or because it allows citizens to bypass governmental restriction is another matter. However, one thing is sure, the biggest market in the world is not authorized to have access to digital assets.

5.1.2.2. United States of America

In the United States of America, it is believed that currently, 8% of Americans (or 27 million people) own digital assets. (TripleA, 2021) Yet, according to Comply Advantage (2022), regulations around digital assets are still unclear in the country. Different governmental institutions have mentioned the importance of digital assets for the future of the country, but there is no harmonized legal framework in the country. The article shows that different key institutions are involved in developing a framework, but nothing concrete has been established yet. The Financial Crimes Enforcement Network (FinCEN) is a body from the Treasury Department, and they consider digital assets not to be legal tender but rather an exchange to be "money transmitters". Simultaneously, the Securities and Exchange Commission (SEC), which oversees the stock and bonds market, mentioned that it considers digital assets as securities, therefore falling under its jurisdiction. (Barton et al., 2022) On the other hand, the Commodities Futures Trading Commission (CFTC), which oversees the US derivatives market, has recognized digital assets as a commodity and allows them to be publicly traded under the CFTC's regulations. (CFTC, 2022)

As we can see, it still seems unclear in the United States what regulation to follow as all institutions want a share of the pie. One thing is clear; the country is interested in developing the technology to become a hub for digital assets in the future. (Global Legal Group, n.d.) This is something we can observe as the US accepted the first Bitcoin-linked ETF: "BITO" in October 2021, which quickly became one of the most heavily traded ETFs in history. (Todorov, 2021)

5.1.2.3. European Union

In the European Union (EU), all member states must follow the Commission's directive. (European Commission, n.d.) But currently, there are no directives implemented around digital assets. This leads to every country adopting a national view of the matter. To counter this, in 2020, the Commission published a proposal for the Market in Crypto Assets Regulation (MiCa). The goal is to harmonize

regulation on the subject within the EU. (Proposal Directive 2019/1937) There is currently no clear timeline for implementation, but once clearly established, it will have to be adopted by all member states. (Handagama, 2021) Without going too much into details of the regulation, MiCA is believed to be a right step forward by providing more trust in the digital assets industry. MiCA allows this by demanding more licenses and reporting requirements from services providers to better protect investors. (Vermaak, 2021)

According to Vermaak, W. (2021), some believe that MiCA is not going far enough and that some grey areas surrounding AML and terror financing are not resolved within this framework. On top of that, some critics believe that some asset types are left out of the regulation, which would therefore require more future regulations. But it seems that the EU is interested in continuing its Digital Finance Strategy (DFS) to have Europe at the forefront of innovation in the world while simultaneously keeping investors safe.

5.1.2.4. Case study conclusion

To conclude, we have seen that among the three biggest markets, China is an outlier among the two western markets. But it seems that outside of China, most regions believe in the innovation of the technology. While there are still some steps to be taken before there is a general adoption, countries are moving towards innovation while simultaneously trying to keep investors safe.

5.1.3. Mifid & investor protection

When discussing digital assets, the concern is not only that there is a lack of transparency for governments to oversee the new asset class, but there is also a worry about protecting investors. This is also the case for traditional assets. This has been the case since 2004, when the European Union laid the foundation for the Markets in Financial Instruments Directive (MiFID).

According to the Corporate Finance Institute (CFI) (2020), it took three more years until 2007 for the directive to become effective around the continent. Reportedly, the goal of the directive was to create a unified and fair financial market by providing a certain code of conduct and requirements for financial institutions.

As specified by the European Securities and Markets Authority (ESMA) (n.d.), MiFID's objective was to regulate the requirements for investment firms, and the authorization necessary to get access to these regulated markets. Furthermore, the directive set out to enforce more regulatory reporting to avoid market abuse by mandating more transparency from institutions. In the report, the ESMA mentioned that after four years, the European Commission, which oversaw the directive, proposed a revision of MiFID. Therefore, in 2014, the European Union voted on a new directive labeled "MiFID II".

As stated by the ESMA (n.d.), MiFID II was an improved version of the first directive from 2004. The aim of the new directive was to make the financial market even fairer, safer and more efficient by enabling greater transparency for all participants. MiFID II was created to cover all possible players in the financial markets, whether it be investors, brokers, banks, traders, funds, or exchanges. On top of that, the Corporate Finance Institute (2020) mentions that all types of financial products are concerned by it: from equities to fixed income to derivatives and over-the-counter (OTC) products.

All in all, MiFID II implies that retail investors need to have access to enough information to make an informed decision. Therefore, brokers and banks are not able to push any kind of products to their customers that they would potentially not understand. Since digital assets are a new type of product, they are somewhat more complex than traditional assets. Therefore, this requires institutions to teach their clients more about these products before they can sell digital assets to them. While this seems simple, being compliant with these rules would also require a lot of time and resources for banks, which they could use otherwise and elsewhere.

5.2. Criminality

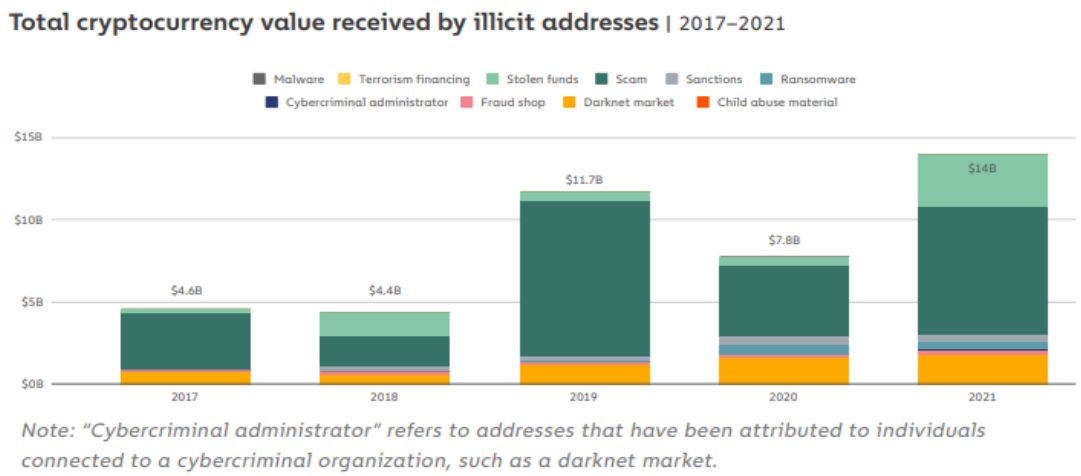
Digital assets are reportedly often linked to fraud, money laundering, tax evasion, and financing terrorism, among others. In this part, we will look at what is behind these claims to try to understand how common these occurrences are and if these implications could have long-term consequences on digital assets and their use in a portfolio.

5.2.1. Financing criminality

It is reported that according to **Figure 10** (Chainalysis, 2022), crime linked to digital assets fraud has exceeded USD 14bn in 2021. This amount is nearly doubling the amount from the previous year of USD 7.8bn. According to the report, the main bulk of criminal activity comes from scams and stolen funds. The report mentions that most scams (71%) came from the newly popular Decentralized Finance (DeFi) assets.

According to Murphy, C. (2022), the huge amount of criminal activity comes from the fact that digital assets still are in a period of "lawlessness and expansion" akin to the Wild West. This new asset class is characterized by strong volatility, meaning bigger risks, but it also has the potential for more rewards. As stated by Karkkainen, T. (2021), the speculative aspect of the asset class makes it so that investors are afraid of missing out on the "next wave" and therefore invest in smaller and riskier assets (in an already highly risky asset class) hoping to increase gains.

Figure 10 - Total cryptocurrency value received by illicit addresses from 2017 to 2021



Source: Chainalysis. (2022, February). *The 2022 Crypto Crime Report*. p. 3. https://go.chainalysis.com/rs/503-FAP-074/images/Crypto-Crime-Report-2022.pdf

But at the same time, sources suggest that the extent of illicit activities might be exaggerated compared to what public opinion believes. According to Cipher Trace (2021), in 2020, the total amount of money of digital assets linked to criminal activities was below USD 2bn (which differs from the reported amount in **Figure 10** (Chainalysis, 2022), which reports USD ~8bn), which is over 50% less than in 2019. This would suggest that either investors were more informed about this or that there was stronger protection against it. USD 2bn is a large sum of money, but according to Chainalysis (2022), the total amount of digital assets linked to illicit activities was less than 0.2% of all digital asset transactions in 2021.

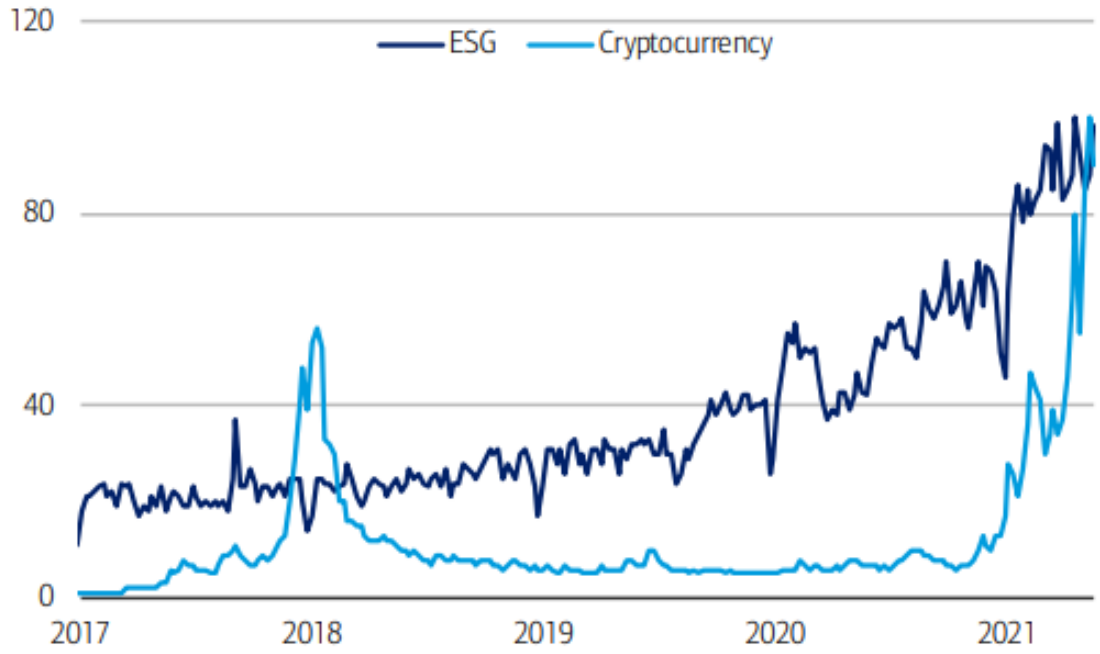
In a nutshell, there is indeed a lot of fraudulent activity going on around digital assets, but at the same time, it seems to only represent a fraction of the total activity. Since the asset class attracts many new investors, it also attracts illicit actors that want to prey on the new investors. When put into contrast, as stated by the United Nations (n.d.) and its office on drugs and crime, fiat currency illicit activities represent between 2% to 5% of all transactions. Meaning, that even though digital assets are used for criminal activities, comparatively, it is much less than fiat currency.

5.3. ESG.

According to Kumar, R. (2022), an increasing number of regulators and commissions have started acknowledging the importance of Environmental, Social, and Governance (ESG) aspects. ESG is a concept that has become popular in the last decade to promote and assess sustainability in companies and investment decisions. This assessment is made by both evaluating a company's production process and by analyzing the way the company behaves and is organized. The sustainability and long-term improvement that the ESG framework promises is something that most investors have started to value. This is because several studies have shown the importance of a good ESG assessment in forecasting long-term performance of companies. Therefore, it has become important for investors to invest in these types of securities.

Doing an ESG analysis offers a framework that is mainly used to analyze companies, but in this next part, we will try to transpose it to digital assets in order to understand where they lie and what the issues are. It is interesting to compare both, as according to **Figure 11** (Shah & Moss, 2021), the popularity of the two “movements” was nearly simultaneous. The figure compares the number of google searches for each of the two terms (“ESG” and “Cryptocurrency”) over the four years.

Figure 11 - Evolution of searches for the terms "ESG" and "Cryptocurrency" since 2017



Source: Shah, A., & Moss, A. (2021, October). *Global Cryptocurrencies and Digital Assets*. Bank of America Securities. p. 103 https://incrypted.net/wp-content/uploads/2021/10/Digital-Assets-Primer.pdf

5.3.1. Environment

It is no secret that the mining process, which is also the process responsible for the security of the network, is energy intensive. (Hamilton, 2021) According to Hinsdale, J. (2022), mining digital assets around the world consumes more energy than certain countries consume in total. The energy consumption mainly comes from the graphic cards trying to solve the algorithm during the mining process. This is a big issue in many "proof of work" consensus mechanisms since the amount of power at the disposal of a miner determines his odds of successfully mining a coin. (Hinsdale, 2022) As a reminder, Bitcoin, for example, is a proof of work consensus.

According to **Figure 12** (Shah & Moss, 2021), the present procedure of mining Bitcoin uses over 90 terawatt–hours (TWh) of energy yearly, which represents less than 0.1% of global energy consumption. This amount might go up if we continue to mine using current technologies because of the diminishing marginal returns from the mining processes. (Kelley, 2021) This excessive amount of consumption is one of the main points of criticism against digital assets. To put it into context, using 0.1% of global energy consumption means using as much energy as Finland or Belgium do. Research shows that if Bitcoin were a country, it would be the 35th biggest consumer of electricity. But if we were to compare the energy consumption of countries like China, Bitcoin consumes 1.4% of the Chinese energy consumption. China's energy consumption skyrocketed and now sits firmly as the biggest consumer at 6543 TWh yearly.

Figure 12 - Bitcoin power consumption compared to countries and companies

Name	Population (mn)	Annual Electricity Consumption (TWh)
China	1,446.2	6,543
United States	333.4	3,844
All of the world's data centers	-	205
State of New York	19.3	161
Bitcoin network	-	91
Finland	5.5	84
Belgium	11.6	82
Bangladesh	166.7	71
Google	-	12
Facebook	-	5
Walt Disney World Resort	-	1

Source: Shah, A., & Moss, A. (2021). *Global Cryptocurrencies and Digital Assets*. Bank of America Securities. p. 28 https://incrypted.net/wp-content/uploads/2021/10/Digital-Assets-Primer.pdf

Digital assets supporters believe that energy consumption will improve over time and is worth it when considering the future value compared to the potential devaluation of currencies. (Shah & Moss, 2021) Some advocates even compare it to the energy consumption of Christmas lights in the United States uses more than 6 TWh of energy yearly, which is greater than the energy usage of certain countries. (Shah & Moss, 2021)

Additionally, according to the Bitcoin Mining Council (2021), in the third quarter of 2021, over 57.7% of the energy consumed for mining was from a renewable source. However, other sources believe this value to be lower than in previous years. According to Blandin, A., et al. (2020), in 2020, the amount of mining energy consumed from renewable sources was 39%. Assuming that both figures are accurate, this would suggest that the mining process has become significantly greener in just a year. When comparing these values to the percentage of renewable energy used by European Countries in 2020, the only country using more renewable energy than digital assets would be Sweden with 60.1%. (INSEE, 2022)

The drawback of the potential of swapping from the energy-intensive proof of work consensus mechanism to the less energy-intensive proof of stake mechanism is the fact that the network's safety would be weakened and more vulnerable to potential attacks from malicious attackers. (Hamilton, 2021)

5.3.2. Social

5.3.2.1. Financial inclusion

As stated before, there are some risks that digital assets open investors up to come across more illicit activities. According to Parino, F. et al. (2018), digital assets can have a strong social impact due to their fast transactions and low fees without needing a banking system. Therefore, it is believed that fundamentally, in the long-term, digital assets offer strong, lasting social benefits such as financial inclusion, the democratization of finance, and more stakeholder capitalism.

Democratization of finance is a term that signifies increasing access to capital markets for ordinary individuals, giving them access to better financial stability. (Erturk et al., 2007) This means that the

democratization of finance, also called financial inclusion, would mean removing intermediaries for individuals to have access to financial markets. This, according to the article, might be a double-edged sword since individuals might have more opportunities and freedom to make financial choices. But at the same time, they might be less informed and therefore make poorer decisions. (Erturk et al., 2007) The paper goes further on how to make the democratization of finance a success which means implementing more financial literacy programs to ensure that this access is also beneficial for these investors and not just an uninformed gamble.

Historically, the democratization of finance has been an issue that governments have continuously tried to tackle. (Global Partnership for Financial Inclusion, 2017) According to the World Bank Group (n.d.), in 2017, there were still over 30% of the global adult population that had no bank accounts. In the United States, it is believed that over 30 million citizens are not participating or have limited access to traditional financial institutions (with 8.4 million unbanked households). (Berkeley Economic Review, 2019) The issue is that previously the traditional banking system was less interested in having low to middle-income individuals, which would not have been profitable for the banks. (Berkeley Economic Review, 2019)

This is where financial technologies (Fintechs) come into play. Fintechs' goals are to improve the use of financial services through technologies to help individuals (or companies) to better manage their financials. (Kagan, 2020) The added value of Fintech, and therefore also digital assets, is that they lack the rigidity of traditional financial services and offer an alternative. (Berkeley Economic Review, 2019) Therefore, the lack of barriers to entry would allow more individuals to have access to financial services by, for example, having access to microlending for underprivileged individuals, which in turn would help the overall economy. (Njiraini, 2015)

5.3.2.2. Remittances

According to the International Monetary Fund (IMF) (n.d.), remittance is the money transferred from one individual living abroad (usually in a country with better professional opportunities) to another individual (usually a family member living in a disadvantaged community) at home. The report mentions the importance of these worker remittances for certain economies. The World Bank Group (2021) has reported that in 2021, the total amount of remittances is projected to reach USD 589 billion, which underlines the importance of remittances for the global economy, especially for low- and middle-income countries.

As stated by Metzger, M. (2019), digital assets could improve global development by providing an alternative channel for international remittance transactions. Currently, as reported by IMF (2021), the remittance transaction process requires an intermediary institution (called a Money Transfer Operator (MTO)) that transfers the money from the sender to the beneficiary. For these services, the MTO asks for a transaction fee which, on average is 7% (but they can go up to 20% depending on the beneficiary's country).

The issue is that some countries heavily rely on remittances for their economy. According to the World Bank Group (2021), this includes countries such as Tonga (43% of Gross domestic product (GDP)), El Salvador (26%), Honduras (26%), Samoa (21% of GDP), and many more. For a country whose GDP is 30% dependent on remittances, paying a 7% fee represents 2.1% (or 7% of 30%) of the country's GDP.

What digital assets can offer is eliminating the intermediary and therefore reducing (or eliminating) the transaction fees of 7% depending on the digital assets used. (Upadhyay et al., 2021) Therefore, we can suggest that digital assets could help developing countries and disadvantaged communities by offering a peer-to-peer service that would reduce their remittance fees.

But for this to work, there are still some crossroads ahead. As mentioned by Flore, M. (2018), once the digital assets are in the hands of the beneficiary, the issue is that they might still have to change it into their local currency in countries where digital adoption is lower, which might be more complex than expected. Additionally, the potential risk due to the lack of robustness from the financial infrastructure and lack of compliance with AML legislation might challenge the adoption.

5.3.3. Governance

According to S&P Global (2020), in the governance framework, one of the key aspects is transparency and reporting, the code and values, and the stability of the decision-making body. The issue is that the governance variable is not easily transposable to digital assets. As seen previously, most digital assets are decentralized by design. Yet the governance, in the ESG framework, aims to analyze the centralized governing body of an entity.

One possibility to analyze the governance of digital assets is to analyze the company that is active in the sector to use as a proxy. Another possibility would be to analyze the code of the technology itself. (Robbins, 2021) As we can see, it is quite complex to truly assess the governance of digital assets. Analyzing the code and the developers of the code might be the closest one could get to understand digital governance, but it also requires a deeper understanding of coding and informatics technology which is not the point of this thesis.

Since the industry is mainly decentralized, some players in the sector have decided to self-regulate. (Crypto Climate, 2021) One of those self-regulations is the Crypto Climate Accords (CCA), which is focused on digital assets becoming fully green by 2030. (Crypto Climate, 2021) While this self-regulation is centered around environmental emissions, it is still a good precedent for similar future accords.

5.3.4. ESG Analysis conclusion

To conclude the ESG analysis, we can observe that digital assets are facing major headwinds regarding their functioning. The asset's carbon emissions being the biggest issue in a world trying to curb emissions is a setback. But as we have seen, the industry is acting to reduce its emissions similarly to other global institutions by aiming to become carbon-free by 2030. Socially the new asset class has the potential to be beneficial to society in the long run by enabling better financial inclusion and reducing the need for financial intermediaries. The governance framework is the least applicable to digital assets as they are, by definition, decentralized. Therefore, the only way to analyze an asset's governance would be to fundamentally analyze the asset's source code. This requires a deeper understanding of information technologies which is not the aim of this thesis. Therefore, it might be applicable for further research.

5.4. Pricing

As has been defined previously, digital assets offer an alternative to the traditional financial system. A concept that is disruptive since it pushes the paradigm from a centralized system to a decentralized one. A concept highly criticized by famous Nobel prize-winning economists such as Paul Krugman and Joseph Stiglitz, who strongly argue against digital assets. (Treiblmaier, 2021) Krugman, P. (2020) points out that the reason that fiat currencies, such as the US Dollar, have an underlying value because they are enforced by an armed centralized government that accepts the currency as a payment method for tax liabilities. On top of that, Joseph Stiglitz criticizes the lack of stability of digital assets compared to traditional securities and currencies. (Haan, 2019) While these criticisms appear to be draconian, they bring up compelling arguments, and it seems that there are two main points to put forwards:

- Are digital assets a bubble that is waiting to burst?
- Do digital assets have an underlying value?

In this chapter, we will analyze these criticisms to further our understanding of what lies behind the new asset class.

5.4.1. Are digital assets a bubble?

In this section, we are going to analyze the definition of a financial bubble to further understand whether digital assets are a bubble or just a highly volatile and speculative asset class.

Kindleberger, C. P. (1996) analyzed the various steps in the creation of a financial bubble. From this analysis, we can derive the definition of the term financial bubble. A financial bubble occurs when an asset realizes a sharp pricing increase, the initial price hike is setting an unjustified expectation for future price increases. This expectation would then attract new investors who would be interested in trading in the assets to make some profits. The definition, therefore, implies that investors rely on momentum to buy the asset and rapidly resell it at a higher price.

Garber, P. M. (1990) adds another dimension to the definition of a bubble by linking the asset's price to its fundamental value. By linking the asset's price to its underlying value, a bubble is defined by the mismatch between the two values when for example, the price's movement is unexplainable when considering the underlying value of the asset.

Therefore, it seems that public perception also plays a role in whether an asset is currently in a bubble. According to a survey by Shah, A., & Moss, A. (2021), in September 2021, 67% of institutional investors viewed Bitcoin as a bubble. 67% still represents a large majority even though the value is down from their survey in June, where 81% of investors believed it to be a bubble.

But to truly understand if digital assets are a bubble, we first need to understand the underlying value of digital assets and see if there is a mismatch with current prices.

5.4.2. Underlying value of digital assets and how to price it?

If we were to follow the general opinion of the industry, digital assets have no underlying value; they are just a sequence of bytes stored in a computer. (Reuters, 2021) But, as pointed out by Treiblmaier, H. (2021), silver and gold coins were, in ancient times, also believed to have no underlying value compared to the barley of the time, akin to how digital assets are considered today. As the paper points

out, plainly looking at the intrinsic value might not paint the whole picture of the complexity of human needs and evolution.

To understand whether digital assets have value, we first need to define what value is. According to Investopedia (2021), intrinsic value is a hypernym for the value of an asset which is estimated by accomplishing certain technical analyses based on mathematical and financial models. For example, when valuing equity securities, the most common method to determine intrinsic value is to use the Discounted Cash Flow (DCF) method. (Investopedia,2021) This method does not work with digital assets since they do not offer any cash flows required for a DCF.

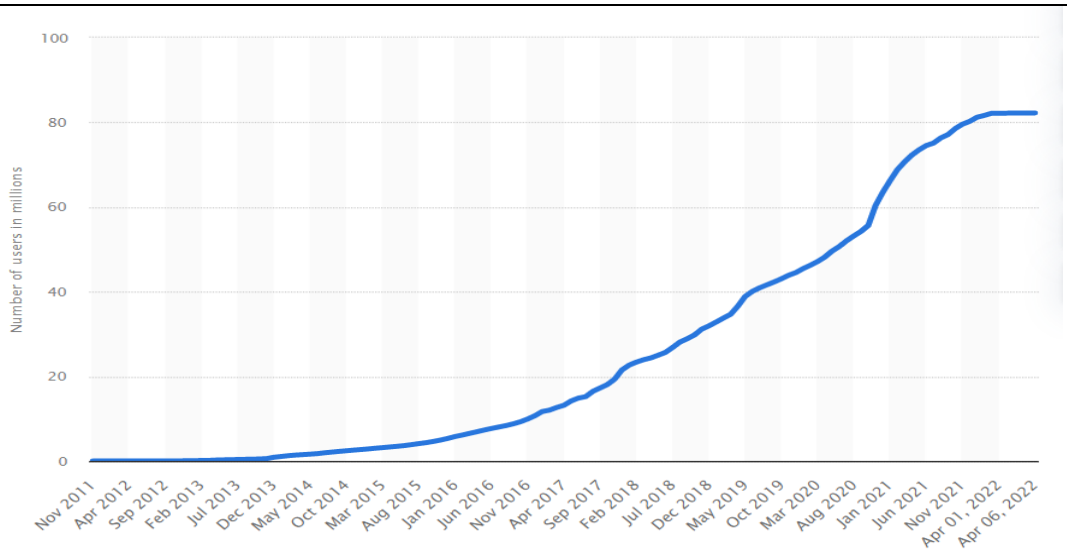
Therefore, to analyze digital assets, we would have to find a methodology to value their fundamentals. Yet, one of the difficulties is that "digital assets" is the umbrella term for a multitude of securities having different specificities. According to Kraken (n.d.), one of the leading cryptocurrency exchange platforms, digital assets offer a diverse ecosystem of securities, with each having its custom classification and specificity. There exist assets focused on payment, assets that are pegged to traditional assets, and even some whose aim is to uphold an infrastructure. Because of this diversity, it might be difficult to find one model that considers all these specificities. For that reason, we must look at different methods to try to value digital assets.

5.4.2.1. Offer and demand

Previously, we have seen that digital assets offer similar features to currency or even gold. The value of money is not necessarily its intrinsic value but the traits the currency has. According to Treiblmaier, H. (2021), one of the key reasons that digital assets have value is because they are scarce while offering currency-like traits.

Malik, V., & Bandyopadhyay, S. (2020) stated that since digital assets do not derive value from cash flows or earnings, their value lies entirely on the investor's willingness to acquire them. As mentioned previously, the supply of certain digital assets is capped. (Nakamoto, 2008) This implies that the assets follow economic rules of supply and demand. Therefore, digital assets have value if there is demand, and the value increases if the demand increases more than the supply.

Figure 13 - Number of Bitcoin network users since 2011



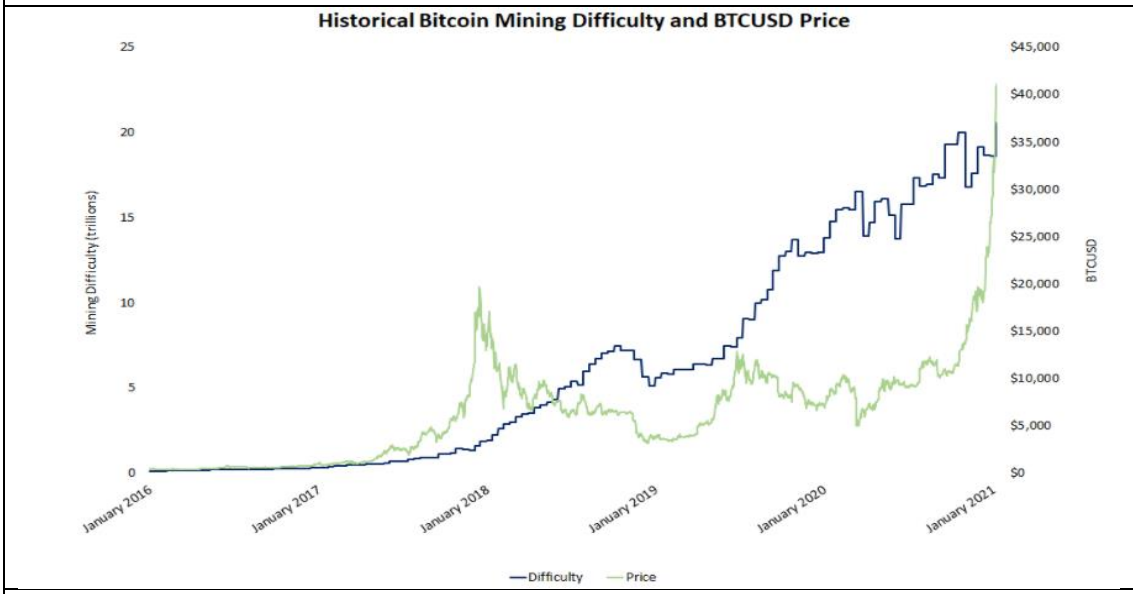
Source: de Best, R. (2022, April 7). *Unique cryptocurrency wallets created on Blockchain.com as of April 6, 2022*. Statista. https://www.statista.com/statistics/647374/worldwide-blockchain-wallet-users/

According to **Figure 13** (de Best, 2022), we can observe that since 2020, the number of unique digital asset addresses (the number of users) has increased from 40 million users to 80 million in 2022. This suggests that there is an increasing demand for digital assets. And as we have seen, as long as people invest in the asset and the demand is growing, the asset has value.

5.4.2.2. Mining cost as a proxy

For this method, we will look at if proxying the necessary cost and investment for mining digital assets is a good measurement of the underlying value for this asset class. Treiblmaier, H. (2021) has stated that the mining process is nothing more than the process of ensuring the network's security. Miners are incentivized to do this because, as a reward, they receive a token, such as Bitcoin, from the network. The paper goes on to say that the cost and amount of labor might determine the value of the asset. The argument, as miners have become more professional, is not saying that the cost of mining represents the value of securities but rather that miners are making informed investment decisions. Therefore, the cost of mining represents the miner's expectation of the future value of the assets.

Figure 14 - Historical Bitcoin mining difficulty and Bitcoin price (in USD) since 2016



Source: Voell, Z. (2021, January 9). *Bitcoin Mining Difficulty Hits Record High Amid Miner Revenue Surge*. CoinDesk. Retrieved July 25, 2022, from https://www.coindesk.com/markets/2021/01/09/bitcoin-mining-difficulty-hits-record-high-amid-miner-revenue-surge/

As we can see in **Figure 14** (Voell, 2021) there seems to be a strong correlation between the mining difficulty and the price of a Bitcoin. According to the article, mining difficulty is the metric used to define the cost of mining and the requiring of hardware necessary to mine one Bitcoin. Therefore, one possible proxy to understand the price of digital assets would be the cost of mining the asset. While it does seem like an appealing approach, with each additional mined Bitcoin, for example, the mining process becomes increasingly difficult. (Hong, 2022) Which would suggest that the price would continuously increase as difficulty increases. Simultaneously, on average, every four years, the rewards are halved, making the process more energy-consuming for fewer rewards. (Hong, 2022)

5.4.2.3. On-chain variable to predict prices

Jagannath, N. et al. (2021) state that one main issue digital assets face is the fact that their value is unpredictable and based on social sentiments. Therefore, the article suggests using technical analysis to further our understanding of different factors affecting the pricing of digital assets. Since most digital assets function on an open-source basis (Bratspies, 2016), the data on the blockchain can be analyzed to understand inherent network characteristics called the "On-Chain Metric". The article defines On-chain metrics as the information derived from data points on a blockchain network. This information can be about the network itself, its properties, or even its activities (for example, the hash rate, number of active addresses, the value of transactions).

Jagannath, N. et al. (2021) continues explaining that on-chain metrics can be used as financial tools to compare different networks, the same way investors would compare companies. According to Robbins, C. (2021), with on-chain data, investors can derive some sort of multiples from analyzing networks.

The article mentions two types of multiples that we will look at, but there exist many more additional multiples for different aspects.

- **Network Value to Transaction ratio (NVT)**: This ratio compares an asset's market capitalization to the total transaction volume of a set period. According to Oinonen, T. (2021), the NVT indicator functions for digital assets similar to the P/E for equities. The multiple therefore shows if an asset is over or undervalued.

- **Market Value to Realized Value ratio (MVRV)**: The ratio is calculated by dividing the market value (market capitalization) by the realized value. The realized value is looking to quantify the value of digital assets that existed the last time those coins were moved on-chain. (Bitcoin Magazine, 2021) This implies that it does not take into account tokens that might be stuck or abandoned in inactive wallets. The ratio indicates whether a token is overvalued or undervalued. If the asset's MVRV is below 1 it is believed to be undervalued (Market bottom); an MVRV above 3.7 is believed to signify that an asset is overvalued (Market Top). (Oinonen, 2021)

As we can see, multiples offer additional value by analyzing certain aspects of digital assets, which might help investors to make more informed investment decisions. But, similarly to multiples for equities, they are indications but not necessarily precise enough to make an informed decision. (Goedhart et al., 2005)

In a nutshell, we have seen that digital assets are often believed to be a bubble waiting to burst (Shah & Moss, 2021), while to be defined as a bubble, one would have to see if the price corresponds to the underlying value of an asset. Analyzing the underlying values of digital assets is more complicated than it sounds, and there are different methods possible to achieve that. In the end, it is still unclear whether digital assets are a bubble or not. But it seems that, as long as the demand is growing, so will prices. (Treiblmaier, 2021)

6. Conclusion of the theoretical part

At this point, in my theoretical research on digital assets as an asset class and its implications for the optimization of portfolio construction with digital assets, we can already come to a few preliminary conclusions on the subject.

- First, we looked at the background and different definitions of digital assets. Some of the early forms were already prevalent in the 20th century, although they have only recently been widely known in mainstream consciousness. We have characterized digital assets as blockchain-based technologies with a tradable virtual value that occasionally exhibits properties like those of a currency. Then we examined in more detail the main categories of digital assets in order to better grasp them. This has shown us there exists a spectrum of digital assets, making it challenging to clearly define one fitting definition.

- Despite being often called “cryptocurrency”, in the second section, we evaluated whether digital assets should be considered a currency or an asset class. Our analysis has shown that, generally speaking, digital assets have difficulties in fulfilling the requirements to be a currency due to their volatility and, as such, should be considered as an asset class. We can observe that digital assets do not fit into any of the existing asset classifications. As a result, digital assets ought to be regarded as a new asset class.

- We have shown in the third section of this thesis that the development of digital assets is taking place in a favorable macroeconomic context. One of the main development factors for the asset class is the increasing interest from all economic stakeholders around the globe. Furthermore, when we examined the financial sector, we can observe that the pandemic pushed the economy into an uncomfortable situation. Risk of stagflation while most stock markets are at their historical peaks and low levels of interest rates led some investors to adopt a pessimistic outlook. Due to these circumstances, we could assume that investors may find digital assets becoming an appealing alternative.

- Consequently, we then reviewed the literature on digital assets’ portfolio diversification potential. We have found many sources suggesting that digital assets offer a low correlation to other asset classes, which would imply a strong diversification potential. On top of that, some papers even suggest that digital assets offer a good hedging potential against inflation. However, these attributes are also still debatable.

- Ultimately, the controversial aspects of the asset class potential outweigh the financial benefits. We have reviewed the opaque legal framework in which digital operate globally (AML, MiFID, …), and the often-cited criminal activities linked to the asset class are not painting a positive picture. On top of that, digital assets’ immense pollution ensures them a poor ESG performance. However, there are some signs that energy consumption will become more sustainable in the future and that digital assets might have some positive social impact. The last issue is the difficulty of pricing them. We have seen three potential methods to be used as proxies for the price. But, in the end, these can only indicate a price but are not enough to make an informed decision.

In a nutshell, it has become clear that digital assets have the potential to one day be regarded as a distinct asset class. But overall, digital assets still must overcome many hurdles to be fully accepted by investment professionals. We have seen that despite their astonishing high returns, they also have tremendous risks associated with them. As such, our research question is the following "Is the marginal addition of digital assets a useful strategy to diversify the risk-return profile of a standard portfolio?”. The research question makes us assess whether the risk-adjusted return of digital assets and their low correlation to standard asset classes make it an interesting alternative for portfolio managers to include digital assets in their portfolios. We will analyze the marginal inclusion as the risk profile of digital assets, and the various hurdles make us consider this as the more sensible choice. We will examine this question in the second part of this thesis.

Part 2: Empirical Analysis

1. Introduction

In the theoretical research section of this thesis, we have stated that the interest in digital assets is peaking as various stakeholders are driving their growth and the recent price hikes. These various stakeholders are retail investors, businesses, investment firms, and governments around the world. Furthermore, we have observed that investment firms and especially hedge funds are interested in digital assets. (PricewaterhouseCooper, 2021) A market survey has shown that over 20% of hedge funds have invested in digital assets. (PricewaterhouseCooper, 2021) These hedge funds can take on these risky assets as they are less regulated than publicly available funds. (Agarwal & Naik, 2005) This implies that hedge funds usually are authorized to make more complex investment strategies than traditional investment funds. However, we have seen that digital assets have a worrisome volatility, they also offer tremendous risk adjusted returns. (Brière et al., 2015) As such, this begs the question, what if investment funds were authorized to invest in digital assets?

This is basically the reason why we choose to concentrate on the research question; “Is the marginal addition of digital assets a useful strategy to diversify the risk-return profile of a standard portfolio?”. To put it in another way, we will examine if the marginal addition of digital assets to a standard portfolio enhances its risk-adjusted performance.

We believe that this research question is relevant as digital assets are expected to have a low correlation to most traditional asset classes while simultaneously having excellent risk-adjusted performance. However, we believe that it is sensible to examine the marginal inclusion and its impact on the standard portfolio’s performance as digital assets are tremendously risky and still face many non-financial constraints.

The main focus in the following part of the thesis will be oriented toward analytical research. We will start off by outlining the theory of portfolio diversification. Then, we will go over the methodology we will use in this thesis in order to analyze the impact of digital assets in a portfolio. For our empirical analysis, we will explain the approach, the data used, and the different calculations and methods employed to evaluate the incorporation of digital assets in a conventional asset-based portfolio. We will use the Royalton Crypto Index (CRIX) as a proxy for digital assets and use it to ascertain and analyze the potential financial effects that digital assets may have on a portfolio.

2. Methodology

To answer the research question, we will conduct a quantitative analysis. We will utilize the Modern Portfolio Theory to create an optimal portfolio based on a multitude of asset classes. Once the optimal risky portfolio is created, we will analyze the impact on the risk-reward profile of the marginal inclusion of the CRIX. The CRIX is an index that we will use to represent the entire class of digital assets. We will analyze the impact of adding between 0% and 5% in increments of 0.5% to the portfolio, which is already considered “optimal”.

The impact of adding Bitcoin to a portfolio is nothing new. What we consider different is the marginal inclusion of digital assets (CRIX) in an optimal portfolio and the time frame we will use for our analysis.

For example, Gangwal, S. (2016) analyzes different optimal portfolios with Bitcoin and their risk-reward profile, but the portfolios have a Bitcoin weight between 12,5% in an equally weighted portfolio to 345,6% in an optimal unconstrained portfolio. As such, we believe that our analysis offers a new point of view (in terms of quantity, time frame, and analyzed asset class) where there currently is a literary gap. But to do this, we must first understand the theory behind creating an optimal portfolio.

2.1. Modern Portfolio Theory (MPT)

2.1.1. Portfolio diversification

As we have seen in the literary review, the importance of good portfolio construction is based on the diversification of the underlying assets held in the portfolio. (Markowitz, 1952) The key to optimizing a certain portfolio is to utilize a multitude of assets that offer different risk-return profiles while also showing a lower correlation between the assets. (Mangram, 2013) Therefore, diversification is only possible if the relationship between the assets' return (or correlation) is not perfect. (Hight, 2010) The target is that the diversified portfolio offers a maximized return while minimizing the risk, therefore outperforming non-diversified portfolios on a risk-reward basis. (Mangram, 2013)

We have seen that digital assets supposedly have a low correlation to most other asset classes while showing good risk-adjusted performance, which would therefore improve diversification. (Baur et al., 2018 & Brière et al., 2015) As such, our analysis would analyze the improvement of the marginal inclusion of digital assets to a standard Modern Portfolio Theory optimal risky portfolio and the impact on the portfolio risk-reward profile.

2.1.2. Efficient Frontier and optimal portfolio selection

As stated by Mangram, M.E. (2013), constructing the portfolio's efficient frontier is the target of portfolio optimization. Predicated by Markowitz's theory, the efficient frontier illustrates a map of every feasible optimal portfolio combination to maximize the return for a certain level of risk (or minimize risk for a certain level of return). As such, for a portfolio to be considered efficient, it must lie on the efficient frontier. To achieve the efficient frontier, we will use the Excel Solver to determine the efficient portfolio of 7 asset class proxies that maximizes the return for a certain level of risk.

After having created the efficient frontier, we will determine the "optimal risky portfolio" by employing the capital allocation line (CAL). To find the CAL, we require an efficient frontier and the market's risk-free rate. (Chen et al., 2010) The CAL represents the line from the risk-free rate to goes tangent to the efficient frontier. The point where the CAL meets the efficient frontier is considered the "optimal risky portfolio". (Chen et al., 2010) We will again use the excel solver to determine the CAL tangent to the efficient frontier.

Once we have determined this theoretical optimal portfolio, we will analyze it to see the impact of adding 0% to 5% of digital assets to this portfolio. The objective is to better understand the impact of this addition on various performance and risk metrics. We analyze this marginal implementation, as according to Brière, M., et al. (2015), digital assets recent rise to popularity might skew their future expected return while undervaluing the underlying investment risk (non-survival risk, legal risk…). Therefore, to be cautious, we chose to analyze the marginal implementation to see if even a small addition might offset the potential risk. To determine whether this impact of the addition of digital assets is tangible, we will compare the portfolio with digital assets to the efficient frontier without digital assets.

2.2. Portfolio

To create our efficient frontier and find the optimal risky portfolio, we will base ourselves on 7 investable assets, which will be proxies for 5 key asset classes: Equity, Fixed Income, Currency, Commodity, and Real Estate. We will see each asset in more detail in **Part 2 – 3. Data (p.55)**. The excel solver will determine the optimal weight allocation to each asset class proxy. For our analysis, we will suppose that the "optimal risky portfolio" is the tangent between the CAL and the efficient frontier. Once we have determined this "optimal risky portfolio", we will create 10 additional portfolios, each following having a 0.5% incremental allocation of CRIX. Therefore, we will, in total, have 11 portfolios with a CRIX allocation varying from 0% to 5% in marginal increments of 0.5%.

One important point to note is that our portfolio strategy will be "long-only". A long-only investment strategy implies that the portfolio only purchases and holds securities with the expectation that their value would increase. (Hayes, 2021) As a result, in our optimization model, there is a restriction that the asset's individual weights must be equal to or larger than zero.

2.3. Royalton Crypto Index (CRIX)

In the digital assets market, there is such a variety and multitude of assets that move in quite distinct ways from one another. (Elendner et al., 2018) As such, it is rather difficult to attempt to manually show a complete picture of the industry. Therefore, for the purpose of our analysis, we will utilize the CRIX as a proxy for the digital assets market. In this section, we will explain why we believe the CRIX to be a relevant index to capture the entire digital assets market.

2.3.1. Origin and methodology

The CRIX was developed in 2015 by two researchers (Wolfang Härdle & Simon Trimborn) from the Humboldt University in Germany, which they mentioned for the first time in a paper titled "CRIX or Evaluating Blockchain Based Currencies". (Härdle & Trimborn, 2015)

To capture as much as possible of the digital assets market, the index follows a Laspeyres index construction methodology. To simplify, a Laspeyres index construction bases itself on the weight of the index's constituents on their relative market capitalization. The goal is that the CRIX is only impacted by changes in price and not by the number of coins available. (Härdle & Trimborn, 2015) But a standard Laspeyres value would be influenced by the change of constituents. (Trimborn & Härdle, 2018) As such, the CRIX takes a similar approach to how the S&P 500 or DAX do it with their equity indices and uses an adjusted Laspeyres. (Trimborn & Härdle, 2018) More details on the portfolio construction methodology can be found in **Appendix 1 – CRIX detailed methodology**.

According to Härdle, W.K. & Trimborn, S. (2018), the CRIX follows a monthly rebalancing strategy to better represent the volatility in the market. They believe that this offers a twofold advantage for the index. First, it can better reflect the volatility in the market. Secondly, the index could, therefore, better capture the momentum in the market. On top of that, the CRIX is dynamic as the number of constituents is not fixed and gets revisited quarterly. Their reason for this is that the market is too volatile to have a fixed number of constituents. Historically, the lowest number of constituents was at 5 and the highest was 15. (Royalton Partners, 2022)

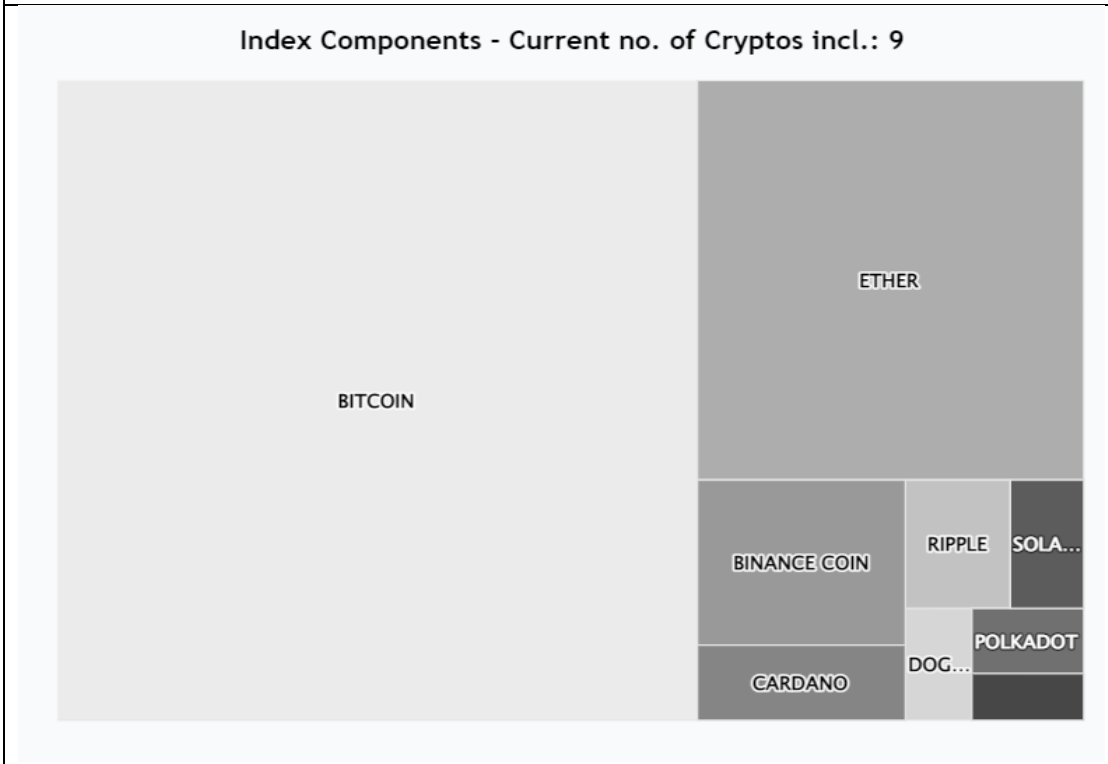
The index is designed to closely represent the return characteristics of the total market while excluding stable coins and derivatives. (Royalton Partners, 2022) By doing so, the index acts as a benchmark for investors who want to simulate a digital asset investment strategy. (Royalton Partners, 2022) This implies that the CRIX is not directly investable but can be used as a guideline for investors.

2.3.2. Current situation

According to **Figure 15** (Royalton CRIX, 2022), at the time of writing this paper, the CRIX was composed of 9 constituents. The weight of each constituent is as follows:

- Bitcoin: 62.40%
- Ether: 23.57%
- Binance Coin: 5.19%
- Cardano: 2.25%
- Ripple: 2.11%
- Solana: 1.45%
- Dogecoin: 1.14%
- Polkadot: 1.10%
- Lido Staked ETH: 0.80%

Figure 15 - Composition of the CRIX in March 2022



Source : Royalton CRIX. (2022). *CRIX - VCRIX*. Retrieved March 9, 2022, from https://www.royalton-crix.com/

One thing we can clearly observe is the dominance of Bitcoin in the CRIX, with 62.4% of the index's total weight. On top of that, we can also notice that ether weighs 23.57% of the index. This means that the two biggest digital assets weigh 85.97% of the index. This dominance is stronger than in the actual market capitalization, where Bitcoin and ether weighed ~60% of the total market capitalization in March 2022. (**Figure 3** (Coinmarketcap, n.d.)) This is probably because the index only contains the nine largest constituents, whereas the total market capitalization accounts for all thousands of digital assets. As such, we will assume that the index is representative of the current digital assets market and all derived assets (such as NFTs) from the digital asset industry.

2.3.3. Performance compared to its biggest weights

We don't have much information on the historical evolution of constituents, but according to Härdle, W.K. & Trimborn, S. (2018), we know that in August 2014, the weight of Bitcoin was at 96% and has gradually decreased to 81% in March 2017 as altcoins have become more prominent in the market. Since then, we have seen that the current weight of Bitcoin is down to 62.4%. As such, we can assume that CRIX has a strong correlation with Bitcoin over the period.

According to Elendner, H. et al. (2018), the CRIX offers an advantage compared to the use of individual digital assets. The paper argues that digital assets offer low correlation between themselves and therefore allow for diversification. As such, the paper showed that the CRIX offers lower risk than any individual digital assets while offering similar returns. However, other papers suggest that the internal correlation between digital assets is rather high when accounting for the conditional tail-risk of these assets. (Borri, 2019) Nonetheless, the same paper also found that the digital assets' idiosyncratic risk has a strong internal diversification potential. (Borri, 2019)

Figure 16 shows the performance of the CRIX[1] compared to its two major assets (together, they represent 85.97% of the index). Unsurprisingly, we can observe that Bitcoin and CRIX nearly completely mirror each other, while in the end, CRIX outperforms Bitcoin[2]. Over the five years, CRIX grew 3786% while Bitcoin grew 3555%. This is probably mainly because of the other assets in the index that enabled CRIX to outperform Bitcoin. The data used for Bitcoin and Ethereum[3] was retrieved from Bloomberg, while the data from the CRIX was retrieved from Royalton CRIX.

[1] *Royalton Partners. (2022). CRIX performance data 2022-4-19 Royalton CRIX Crypto Index Values. Unpublished internal company data.*

[2] BTC date gathered from Bloomberg. (2022). *Bitcoin Spot Price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=45c742c7-157c-11ed-8bf0-7443547a4e44&url=L3F1b3RlL1hCVDpDVVI=

[3] ETH data gathered from Bloomberg. (2022). *ETH spot price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=d1f1d0b3-157c-11ed-b00f-6e6754416242&url=L3F1b3RlL1hFVDpDVVI=

Figure 16 - Performance of Bitcoin, Ethereum and CRIX from 2017 to 2022

2.3.4. CRIX conclusion

For all the reasons previously mentioned, we consider that the CRIX is a good proxy for the digital asset class. The fact that the index was started in 2015 and has evolved since allows us to have a better representation of the market without any bias. This is mainly because of the index's monthly rebalancing and quarterly reevaluation of the constituents. Finally, we have also seen that the index has a weight allocation that is relatively similar to the actual total market capitalization. All in all, this makes us confident that the CRIX is a good index for our analysis.

2.4. Measurements

We will base our study on a few important widely used metrics to quantify the statistical performance of the financial assets in order to complete our analysis for the MPT and provide answers to our research questions.

2.4.1. Expected return

The expected return is the forecasted revenue that an investor expects to get over a certain time horizon, in this case, annual. (Omisore et al, 2012) To calculate the expected return of a portfolio, we must first analyze the expected return of each individual asset in the portfolio. The performance of the chosen assets will be determined by averaging their daily returns over the last five years. The daily values of each asset have been taken from Bloomberg and Refinitiv. When necessary, the values have been corrected for any applicable dividend payments and splits. As a result, the return will be computed as follows:

$$Ri_{(daily)} = \frac{P_{i(t)} - P_{i(t-1)}}{P_{i(t-1)}}$$

Where $P_{i_{(t-1)}}$ is the price of asset i at t-1, and $P_{i(t)}$ is the price of asset i at t. After calculating the daily returns, we will use the following method to get our assets' average return for the whole period:

$$\overline{R}i_{(daily)} = \frac{1}{n}\sum Ri$$

With n standing for the number of periods, in this instance n=1295 days because the duration is 5 years and profitability is calculated daily. Additionally, we will annualize our average returns using the following method to make comparisons easier:

$$E\left(R_{i(annual)}\right) = \left(1 + \overline{R_i}_{(daily)}\right)^p - 1$$

p is the number of days the stock market is open each year. The average number of days that the stock market is open is 252 days. (Asset Macro, 2017) Therefore, in our analysis *p* is equal to 252. This is also called the expected annual return for an asset. Now that we have each individual asset's expected annual returns, we can compute the portfolio's expected return. A portfolio's expected return is computed as follows:

$$E\left(R_p\right) = \sum\left(w_i \cdot E(R_i)\right)$$

With w_i being the weight of asset i in the portfolio and were $\sum w_i = 1$. As we can observe, the expected return of a portfolio is the weighted sum of each individual asset's expected return. (Chen et al, 2010)

2.4.2. Standard deviation

The standard deviation serves as a risk gauge for investment assets. Given that it shows the dispersion in an asset's return compared to its average return. (Hargrave, 2022) But before being able to assess the risk profile of the portfolio, we must assess the risk profile of each individual asset in the portfolio. Standard deviation is the square root of an asset's variance. It is a crucial component to consider while optimizing a portfolio. (Hargrave, 2022) The formula for the daily standard deviation is as follows:

$$\sigma_{i\,(daily)} = \sqrt{\frac{\sum\left(R_{i(daily)} - \overline{R}i_{(daily)}\right)^2}{n}}$$

When an investment's standard deviation is large, it means that the asset's returns fluctuate a lot and, as such, are perceived as riskier and less risky when the standard deviation is lower. (Hargrave, 2022) As mentioned previously, standard deviation assesses the risk of an investment. The risk, in this case, is that the actual return might be different from the expected return. (Omisore et al, 2012) The annualized standard deviation is calculated as follows:

$$\sigma_{i\,(yearly)} = \sigma_{i\,(daily)}\sqrt{p}$$

Similarly, the formula to annualize the return, p is equal to 252. Now that we have each asset's annual standard deviation, we determine the portfolio risk profile. The formula is the following:

$$\sigma_p = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n} w_i\, w_j Cov\left(R_i\,,\, R_j\right)}$$

A portfolio's standard deviation is equivalent to the value of the square root of the weighted average covariance of the returns of its assets. (Chen et al, 2010) As we have seen, the standard deviation is an investment asset volatility measurement. But to understand the risk associated with a portfolio, we must assess the link between the movement of return of these individual assets, their covariance, and correlation.

2.4.3. Covariance Matrix

To determine if two variables are connected, a covariance matrix is constructed. The covariance matrix is a statistical metric that examines whether the returns of two assets move together or further apart from one another. (Mangram, 2013) This relationship between two assets can be negative, positive, or unrelated. If the relationship is negatively related, the covariance will be negative, and the returns move in opposing directions, and vice versa if the covariance is positive. (Mangram, 2013) For a good portfolio construction, it is important to invest in assets that have low covariance with each other. (Markowitz, 1952) The formula for our covariance matrix is as follows:

$$Cov\left(R_x, R_y\right) = \frac{\sum\left(R_{xi} - \overline{R_x}\right)\left(R_{yi} - \overline{R_y}\right)}{n}$$

2.4.4. Correlation Matrix

Similarly, the correlation coefficient is also a statistical measure that illustrates the degree of relationship between the returns of two assets. (Mangram, 2013) This coefficient of correlation is between [−1,1]. There is a negative relationship between two financial assets if the correlation is –1. This implies that while one's asset return increases, the other's decreases by the same amount. Vice

versa if the coefficient is 1. When the coefficient is 0, it means that the relationship between the assets is unrelated. (Mangram, 2013) The correlation coefficient between two assets is measured as follows:

$$Correlation_{xy} = \frac{Cov(R_x, R_y)}{\sigma_x \sigma_y}$$

2.5. Performance

For the second part of our analysis, it is crucial to gauge the performance of the portfolio and the effect on the performance by marginally including the CRIX in it. As a result, we have chosen six indicators to gauge this impact. Four of these indicators measure a risk-adjusted return taking into account different types of risk for each of them.

2.5.1. Sharpe ratio

Created by William Sharpe in 1966, the Sharpe ratio provides a measurement to analyze the risk-adjusted performance of an asset or portfolio. (Fernando, 2022) The ratio is measured as the average return of an asset or portfolio above the risk-free rate divided by its standard deviation, or total risk. (Fernando, 2022) The formula is as follows**:**

$$Sharpe\ ratio\ = \frac{E(R_p) - R_f}{\sigma_p}$$

Where:

$$E(R_p) = Expected\ return\ of\ the\ portfolio$$

$$R_f = Risk - free\ rate$$

$$\sigma_p = S\tan d\ ard\ deviation\ of\ the\ portfolio$$

It is favorable to have a larger Sharpe ratio, as a larger ratio implies a better risk-adjusted return, especially if the assets have similar risk profiles. (Fernando, 2022) In the MPT, a good diversification implies an improvement of the Sharpe ratio, as the risk is expected to be diversified, and therefore lower. The Sharpe ratio aids in determining if a portfolio's excess returns are the consequence of wise investment choices or due to higher risk-taking. (Fernando, 2022) Generally speaking, a Sharpe ratio of 1 or better is considered good, and a Sharpe ratio above 2 is considered very good. (Lioudis, 2022)

2.5.2. Sortino ratio

The Sortino ratio is a variant of the Sharpe ratio. But instead of using the asset's total standard deviation, the Sortino ratio uses only the asset's downside deviation. (Kenton, 2020) The downside deviation (also called semi-standard deviation) is the negative volatility of an asset that is below a certain minimum acceptable return. The aim is to not punish an asset's positive volatility where it outperforms expectation. (Kenton, 2020) The formula for the Sortino Ratio is as follows:

$$Sortino\ Ratio\ =\ \frac{E(R_p) - R_f}{\sigma_d}$$

Where:

$$\sigma_d\ =\ Downside\ deviation$$

The annualized downside deviation of an asset is calculated as follows:

$$\sigma_d\ =\ \sqrt{\frac{\sum \left(Min(0,\ R_p - R_f)\right)^2}{n}} \cdot \sqrt{p}$$

To calculate the downside deviation, one must only account for returns that are below a certain minimum acceptable return. For our analysis, we supposed that the minimum acceptable return is the risk-free rate. The Sortino ratio is usually the preferred ratio when analyzing the risk-adjusted return of more volatile assets. (Corporate Finance Institute, 2022) The Sortino ratio's interpretation is akin to the one of the Sharpe Ratio, a larger ratio implies a better risk-adjusted return.

2.5.3. Maximum Drawdown

According to Hayes, A. (2022), a portfolio's maximum drawdown is the highest loss that may be seen between a portfolio's peak and trough before a new high is reached. It, therefore, is a measure of downside risk over a certain time period. Nevertheless, the author points out that the ratio only gauges the magnitude of the greatest loss while ignoring the frequency or the time frame of the loss. The formula to calculate the Maximum Drawdown is as follows:

$$Maximum\ Drawdown\ =\ \frac{Asset\ Peak\ High - Asset\ Trough\ Low}{Asset\ Peak\ High}$$

2.5.4. Treynor ratio

Another ratio we will be using to support our analysis is the Treynor ratio. The Treynor ratio is designed to measure the portfolio's excess return per unit of systematic risk taken, measured by the portfolio's beta. (Kenton, 2020) The Treynor ratio is used to measure a portfolio's performance relative to the overall stock market. (Maverick, 2021) The ratio is interesting as only using systematic risk implies that the idiosyncratic risk has been diversified and that only the systematic risk remains. (Corporate Finance Institute, 2022) The formula for the Treynor ratio is the following:

$$Treynor\ Ratio\ =\ \frac{R_p - R_f}{\beta_p}$$

β_p is the portfolio's beta compared to the stock market. To specify, we will be using the Morgan Stanley Capital International World index to represent the stock market. This is also the index that will represent the equity asset class which we will see in the next part. The formula to calculate the portfolio's beta is as follows:

$$\beta_p\ =\ \frac{Covariance\left(R_p\ ,\ R_m\right)}{Variance\ (R_m)}$$

R_m is the stock market's return. Similarly, as to the Sharpe ratio and the Sortino Ratio, the Treynor ratio is not utilized to calculate the added value of a portfolio, but it is primarily utilized as a ranking criterion. (NDGD, n.d.) As such, the larger the Treynor ratio, the better it is. (Kenton, 2020) One drawback of the Treynor ratio is that it is heavily sensitive to the market index used for the analysis. (Marhfor, 2016)

2.5.5. Jensen's Alpha

Jensen's Alpha is a performance indicator that seeks to identify a portfolio's exceptional performance compared to what the capital asset pricing model (CAPM) anticipates. (Chen, 2020) The CAPM anticipates a certain level of return for a specific amount of risk taken. (Chen, 2020) The formula for Jensen's Alpha is as follows:

$$Jensen's\ Alpha\ =\ E\left(R_p\right) - \left[R_f + \beta_p\left(R_m - R_f\right)\right]$$

If the coefficient is positive, the portfolio has a higher rentability than what is expected by the framework, considering both market rentability and risk-free interest rates. (NDGD, n.d.) If the opposite is true (a negative alpha), the investment has performed below the theoretical return that the market offers for this level of risk. (NDGD, n.d.)

2.5.6. Calmar ratio

The last ratio we will utilize to bolster our research is the Calmar ratio. As stated by Kenton, W. (2022), the Calmar ratio was developed in 1991 by Terry Young to measure the risk-adjusted return of investment funds. The ratio compares a portfolio return above the risk-free rate to its maximum drawdown. As such, the ratio uses the maximum drawdown as the risk of the portfolio. The formula of the Calmar ratio is as follows:

$$Calmar\ ratio\ =\ \frac{E(R_p) - R_f}{Maximum\ Drawdown}$$

If the result gives a high Calmar ratio, it indicates that there is very little chance of the maximum drawdown affecting the portfolio's return. (Corporate Finance Institute, 2021) However, the potential of a drawdown affecting the portfolio's return is increased when the ratio is low. (Corporate Finance Institute, 2021) What makes this ratio intriguing is its emphasis on the maximum drawdown, but therefore also suggests that it is somewhat less mathematically relevant. (Kenton, 2022)

3. Data

3.1. Asset based portfolio

To answer our research question and to ensure that our portfolio is well diversified, we have decided to use an asset class allocation strategy. In an asset class allocation strategy, the portfolio manager holds a variety of asset classes with diverse risk profiles rather than picking individual stocks. (Idzorek & Kowara, 2013) We collected data on the daily historical prices from sources such as Bloomberg and Refinitiv. For the data from CRIX, we received the data from Royalton CRIX themselves, as the publicly available data does not go back further than 2017. As a reminder, we only use the data from weekdays during which the stock market is open, which on average means 252 days per year. (Asset Macro, 2017)

For the time frame of our analysis, we analyze the daily price value of the portfolio over a 5-year period commencing on the 27th of February 2017 and running through to the 11th of February 2022. There is a total of 1295 daily observations.

We used 2017 as the starting point, as we have seen in the first part of this paper, 2017 was the first year in which digital assets came to mainstream consciousness. (DeMatteo, 2022) The total digital assets market capitalization went from USD 17 billion in January 2017 to over USD 550 billion in December 2017. (CoinMarketCap, n.d.) The reason being that at that time, digital assets would be considered a "large cap". A large cap is a publicly traded company whose market capitalization exceeds USD 10bn. (Chen, 2022) This implies that it would start to pique the interest of institutional investors. Institutional investors usually are more interested in trading in larger volumes and have the ability to trade in riskier assets. (Chen, 2021) For the aforementioned reasons, we believe that 2017 is the first year we should consider portfolio managers' ability to invest in digital assets.

We base our allocation strategy on 6 asset classes: equity, fixed income, commodity, currency, real estate, and digital assets. In total, we will be analyzing 8 global indices to represent these asset classes.

3.1.1. Equity

The index we will use to represent the equity class is the Morgan Stanley Capital International World Index ("MSCI WO")[4]. The MSCI WO is a global index that includes mid and large cap equities from 23 developed markets. (MSCI, 2022) The index, which has 1 513 constituents, aims to capture about 85% of the market capitalization adjusted for free float in each of the markets in which it is active. (MSCI, 2022) As such, we believe that the index is relevant to reflect the equity market. The data was retrieved from Bloomberg.

3.1.2. Fixed Income

To reflect the fixed income asset class, we will utilize two indices. We used one index for government bonds and one for corporate bonds. For government bonds, we used the Bloomberg Global-Aggregate Total Return Index Value Unhedged USD ("LEGATRUU")[5]. And for corporate bonds, we used the Bloomberg Barclays U.S Corporate Total Return Value Unhedged USD ("LUACTRUU")[6].

LEGATRUU's objective is to monitor the performance of investment-grade fixed-rate bonds across the world in over 60 countries. (SSGA, 2022) These investment-grade bonds include governmental bonds from both developed and emerging markets. (SSGA, 2022) LEGATRUU is composed of 6 813 holdings, which have an average maturity of 8.68 years. (SSGA, 2022) The index's diversification in terms of regional diversification and in terms of constituents makes us confident that the LEGATRUU is a good indicator of the fixed income asset class for our analysis. The data was retrieved from Bloomberg.

The LUACTRUU index aims at tracking the performance of US Dollar denominated investment grade corporate bond market. (SSGA, 2020) The index holds 965 holdings from 18 countries with an average maturity of 12.3 years. (SSGA, 2020) Around 61% of the corporate bonds come from industrial companies around the world. (SSGA, 2020). For these reasons, we believe that LUACTRUU is an interesting index to reflect the corporate bond market in our portfolio.

[4] MSCI WO data gathered from Bloomberg. (2022). *MSCI WO spot price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=974806f6-157e-11ed-9205-5949536c6d45&url=L3F1b3RlL0RNV1JMREk6SUQ=#xj4y7vzkg

[5] LEGATRUU data gathered from Bloomberg. (2022). *LEGATRUU Spot Price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=02e1c552-157f-11ed-8109-4b616a775a65&url=L3F1b3RlL0xFR0FUUlVVOklORA==#xj4y7vzkg

[6] LUACTRUU data gathered from Bloomberg. (2022). *LUACTRUU Spot Price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=4e61bc40-157f-11ed-8968-5264786c5858&url=L3F1b3RlL0xVQUNUUlVVOklORA==

3.1.3. Commodity

For our asset-based research, we used two indices to fully represent the commodity asset class. We used one index for the price of Gold and a second index, the Bloomberg Commodity Index, to represent the various other commodities in the market.

The initial commodity that we have taken is a gold spot price ("XAU=X")[7] index from Refinitiv Eikon. (Reuters, 2022) Gold is a historic special commodity as it offers some safe haven and store of value benefits. (Baur & McDermott, 2016) Therefore, we believe it is interesting to include this asset class in our portfolio to contrast it to the addition of digital assets.

The second index we have chosen is the Bloomberg Commodity Index ("BCOM")[8]. We have taken this one additionally as it is a diversified global index on 23 physical commodities that can be classified into 6 main categories: Energy, Grains, Industrial Metals, Precious Metals, Softs, and Livestock. (Bloomberg, 2021) The index is tracking a worldwide benchmark valued at over USD 100bn. (Bloomberg, 2021) This gives us the confidence that this index will provide a global reach on the entirety of the global commodity market. The data was retrieved from Bloomberg.

3.1.4. Currency

To accurately represent the currency asset class, we choose as an index to be a part of the portfolio the Bloomberg Dollar Spot Index ("BBDXY")[9]. The BBDXY tracks the performance of a basket of the 10 top global currencies relative to the US dollar. (Bloomberg, 2022) The index includes major currencies from developed and developing markets based on their liquidity and trade flow with the United States. (Bloomberg, 2022) To keep up to date, the index uses a dynamic weighting and composition strategy. (Bloomberg, 2022) For this reason, we feel confident that the BBDXY is a good indicator of the currency asset class in our portfolio. The data was retrieved from Bloomberg.

3.1.5. Real Estate

The index we used for our Real Estate analysis is the MSCI World Real Estate Index ("MXWOORE"). This is Morgan Stanley's global index that consists of medium or large sized Real Estate Investment Trusts (REITs) from 23 developed countries. (MSCI, 2022) The index has 96 constituents REITS from countries such as the United States of America, Japan, Hong Kong, Australia, and many more. (MSCI, 2022) Therefore, we believe that the index is a good global indicator of the global real estate market. The data was retrieved from Bloomberg.

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[7] XAU=X data gathered from Reuters. (2022, July 13). *Gold spot*. Retrieved July 13, 2022, from https://www.reuters.com/markets/quote/XAU=X/

[8] BCOM data gathered from Bloomberg. (2022). *BCOM Spot Price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=8fb00448-157f-11ed-94ae-666559497875&url=L3F1b3RlL0JDT006SU5E

[9] Bloomberg. (2022). *BBDXY Spot Price*. Retrieved August 6, 2022, from https://www.bloomberg.com/tosv2.html?vid=&uuid=eddcaac7-157f-11ed-9a23-57685a584e72&url=L3F1b3RlL0JCRFhZOklORA==

3.1.6. Digital assets

We have already mentioned that we will be using the Royalton Crypto Index ("CRIX") as a proxy for digital assets. For more information on the CRIX, see **Part 2 - 2.3 Royalton CRIX (p.46)**. Nonetheless, we feel confident that CRIX is a reliable indication of the digital assets class in our portfolio.

3.1.7. Risk Free rate

To conclude our portfolio optimization while using the MPT framework, we have decided to choose the 3-Month Treasury Bill ("T-Bill") as the risk-free rate. In MPT, the risk-free rate is the rate of return of a security that theoretically has no volatility (risk). (Schmidt, 2021) Having a maturity of one year or less, a Treasury Bill is a short-term obligation of the United States government guaranteed by the US Treasury Department. (Hayes, 2022) Treasury Bills are frequently viewed as safe and low-risk investment options. (Hayes, 2022) As such, we believe that the 3-Month Treasury Bill is a relevant risk-free rate for our analysis. For our analysis, we will use the risk-free rate from February 11th, 2022, where the 3-month T-Bill rate was at 0.37%. (FRED, 2022)

3.2. Summary of the portfolio

To summarize the assets in our portfolio, we can hereby find **Table 1** with the name, the ticker, the asset class, and the denomination we will use for each asset. MSCI WO, the equity index we used, will be called "Equity" in the remainder of our research. LEGATRUU will be named "Gov Bonds". LUACTRUU will be named "Corpo Bonds". BBDXY will be called "Currency". BCOM will be called "Commodity". XAU=X will be called "Gold". MXWOORE will be called "Real Estate". And finally, the CRIX will remain "CRIX".

Table 1 - Summary of the assets in the portfolio

Name of the financial asset	**Ticker**	***Asset Class***	***Denomination***
Morgan Stanley Capital International World Index (MSCI World)	MSCI WO	Equity	"Equity"
Bloomberg Global-Aggregate Total Return Index Value Unhedged USD	LEGATRUU	Fixed Income	"Gov Bonds"
Bloomberg US Corporate Total Return Value Unhedged USD	LUACTRUU	Fixed Income	"Corpo Bonds"
Bloomberg Dollar Spot Index	BBDXY	Currency	"Currency"
Bloomberg Commodity Index	BCOM	Commodity	"Commodity"
Gold Spot	XAU=X	Commodity	"Gold"
MSCI World Real Estate Index	MXWOORE	Real Estate	"Real Estate"
Royalton Crypto Index	CRIX	Digital Assets	"CRIX"

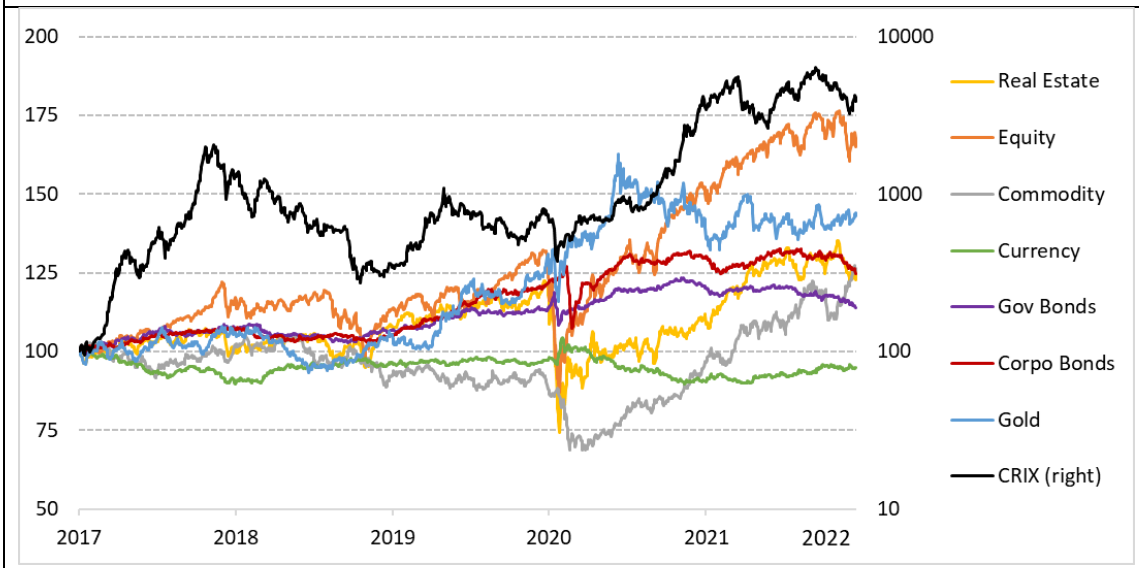
4. Analysis of results

4.1. Descriptive statistics

4.1.1. Performance of the various assets over the period

Figure 17 displays the cumulative performance of the eight assets that make up the portfolio from 2017 to 2022. What we can observe is that CRIX has the strongest cumulative performance over that period. Over the 5 years, the CRIX grew by 3786%, while the second biggest increase was Equity, which grew by 65% over the same period. The worst performing asset is Currency, that over the time period decreased by 5%. One interesting thing to note is that Currency, Corpo Bonds, and Gov Bonds all have relatively straight lines showing these assets' low volatility. This is especially noticeable when compared to CRIX, which has large variations in its cumulative performance.

Figure 17 - Cumulative performance of the assets from 2017 to 2022



4.1.2. Descriptive statistics and performance of individual assets

Table 2 provides the descriptive statistics of the individual assets over the analyzed period. The return from CRIX really exemplifies the growth and volatility digital assets have experienced in the last 5 years. The annual mean return from CRIX stands at 172.9%, with an annual standard deviation of 76.2%. These exorbitantly large numbers illustrate the risk associated with the investment in digital assets. To put into perspective, the second highest return over that period is Equity, with an annual mean return of 11.7% and a standard deviation of 16.0%. Only one asset has a negative expected return, Currency, with an annual expected return of –0.9%.

Something statistically interesting to note is that CRIX has the second highest skewness (-0.1) while also having the second lowest excess kurtosis (2.9). This implies that the distribution of returns from CRIX is only slightly skewed while having a somewhat of a moderate excess kurtosis. Nonetheless, both times the CRIX is behind Currency, which has a skewness of 0.1 and a kurtosis of 2.1. Excluding CRIX, the average skewness of the seven other assets is –1.0, with an average excess kurtosis of 13.8. The excess kurtosis was especially high for Real Estate (31.9), Equity (23.3), and Corpo Bonds (22.7).

When comparing the performance of the individual assets, one item that stands out is the lack of any other asset with a positive Sharpe ratio than CRIX (2.26). The two closest assets are Corpo Bonds (0.79) and Equity (0.71). The Sortino ratio, Calmar ratio, and Jensen's Alpha offer similar results. Usually, the second-best performing asset is Corpo Bonds. Besides Currency, which offers a negative average return, the worst asset is Real Estate which is at the bottom of nearly all metrics.

All these performance metrics indicate that it is reasonable to assume that CRIX has the necessary attributes to maximize the risk-return of a portfolio. But one thing to keep in mind is that CRIX has by far the highest Maximum Drawdown of –87%, which it reached on the 14th of December 2018. In comparison, the average of the other seven assets lies at –24%. One item to consider on this subject is that the Maximum Drawdown was mainly affected by the pandemic in March 2020. Nonetheless, we can still observe that CRIX has a Maximum Drawdown over thrice as large as the other assets' average.

Table 2 - Descriptive statistics of individual assets from 2017 to 2022

	Real Estate	*Equity*	*Commodity*	*Currency*	*Gov Bonds*	*Corpo Bonds*	*Gold*	*CRIX*
Mean	0.022%	0.044%	0.021%	-0.003%	0.010%	0.018%	0.032%	0.399%
Ann. Mean	5.6%	11.7%	5.5%	-0.9%	2.6%	4.5%	8.3%	172.9%
Median	0.067%	0.073%	0.069%	-0.007%	0.016%	0.028%	0.040%	0.225%
Maximum	8.3%	8.8%	3.4%	1.6%	1.5%	1.8%	4.9%	20.9%
Minimum	-13.4%	-9.9%	-4.2%	-1.9%	-2.2%	-3.9%	-5.4%	-23.9%
Std. Dev.	1.1%	1.0%	0.8%	0.3%	0.3%	0.3%	0.8%	4.8%
Ann. Std. Dev.	16.8%	16.0%	13.0%	5.2%	4.1%	5.3%	13.2%	76.2%
Volatility	2.8%	2.5%	1.7%	0.3%	0.2%	0.3%	1.7%	58.1%
Skewness	-1.9	-1.2	-0.6	0.1	-0.9	-2.0	-0.4	-0.1
Kurtosis	31.9	23.3	3.1	2.1	8.6	22.7	4.9	2.9
Sharpe ratio	0.31	0.71	0.39	-0.24	0.56	0.79	0.60	2.26
Sortino ratio	0.41	0.95	0.53	-0.34	0.77	1.05	0.84	3.37
Max Drawdown	-39%	-34%	-35%	-14%	-9%	-15%	-19%	-87%
Treynor ratio	0.06	0.11	-1.06	-0.50	1.81	39.76	0.84	1.86
Jensen's Alpha	-4.2%	0.0%	5.6%	-1.5%	2.1%	4.2%	6.9%	162.1%
Calmar ratio	0.13	0.33	0.15	-0.09	0.26	0.27	0.42	1.99
Beta	0.83	1.00	-0.05	0.02	0.01	0.00	0.09	0.93
Observations	1295	1295	1295	1295	1295	1295	1295	1295

4.1.3. Covariance and Correlation matrix

Table 3 displays the correlation and covariance between the various assets in the portfolio. The table shows that CRIX has a relatively low correlation to the other assets. The CRIX's average correlation coefficient comes in at 0.07. This is very low and indicates a good diversification potential, as the ideal diversification of a portfolio is the addition of assets that have a very low correlation with each other to minimize the volatility. (Mangram, 2013) The three assets that show the biggest correlation with the CRIX are Equity (0.19), Real Estate (0.13), and Gold (0.12). Even though the CRIX has a low correlation with the other assets, one thing to note is that over this time frame, it does not have a negative correlation with any other asset.

However, according to Brière, M., et al. (2015), correlation analyses must be viewed with ware, given that they were calculated during a strong growth period (CRIX mean annual return of 172.9%). This might imply that this correlation is rather fragile as it can drastically alter during crises.

Table 3 - Correlation and Covariance matrices for the various asset's returns

Correlation Matrix - Coefficients

	Real Estate	*Equity*	*Commodity*	*Currency*	*Gov Bonds*	*Corpo Bonds*	*Gold*	*CRIX*
Real Estate	1.00							
Equity	0.79	1.00						
Commodity	-0.03	-0.06	1.00					
Currency	0.09	0.08	-0.01	1.00				
Gov Bond	0.12	0.05	0.01	-0.02	1.00			
Corpo Bond	-0.02	0.00	-0.06	0.04	0.02	1.00		
Gold	0.17	0.11	0.00	0.07	0.16	0.04	1.00	
CRIX	0.13	0.19	0.03	0.01	0.01	0.02	0.12	1.00
Average	0.30	0.17	-0.02	0.04	0.05	0.01	0.10	0.07

Covariance Matrix - Coefficients

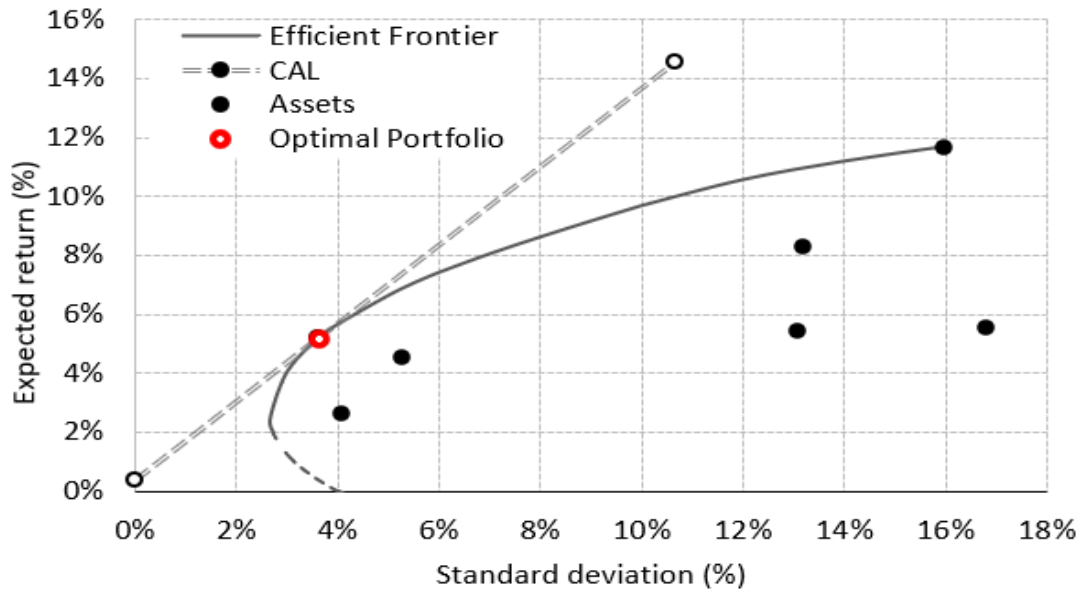
	Real Estate	*Equity*	*Commodity*	*Currency*	*Gov Bonds*	*Corpo Bonds*	*Gold*	*CRIX*
Real Estate	1.12E-04							
Equity	8.43E-05	1.01E-04						
Commodity	-3.01E-06	-4.86E-06	6.76E-05					
Currency	2.96E-06	2.50E-06	-1.67E-07	1.06E-05				
Gov Bond	3.33E-06	1.26E-06	1.81E-07	-1.34E-07	6.53E-06			
Corpo Bond	-7.78E-07	1.06E-07	-1.61E-06	4.20E-07	1.82E-07	1.10E-05		
Gold	1.49E-05	9.51E-06	2.10E-07	1.82E-06	3.36E-06	1.10E-06	6.90E-05	
CRIX	6.46E-05	9.37E-05	1.06E-05	1.95E-06	1.10E-06	2.84E-06	4.82E-05	2.31E-03

4.2. Optimal portfolio construction under MPT without digital assets

Now that we have all the necessary data, we can focus on the construction of the optimal portfolio according to the MPT framework. As our research question is to measure the impact of the marginal addition of digital assets to a standard portfolio, we established the mean-variance efficient frontier of the various assets excluding digital assets. To establish this efficient frontier in **Figure 18**, we used the Excel Solver to find the optimal weight of the portfolio that maximizes the return for a certain level of risk (or minimizes the risk for a certain level of return). As mentioned in our methodology, we exclude short selling in our portfolio, and as such, the weights of the individual assets are between 0% and 100%.

Once the efficient frontier is established, we use the Capital Allocation Line (CAL) to find the optimal risky portfolio. The CAL helps identify the ideal asset allocation, which shows all the combinations that are accessible. (Chen et al., 2010) Consequently, the goal is to find the portfolio that is the tangent between the CAL and the efficient frontier that maximizes the slope of the CAL. (Chen et al., 2010) The formula of the slope of the CAL is $\frac{E(R_p)-R_f}{\sigma_p}$, as mentioned previously, that we assume a risk-free rate of 0.37%. (Chen et al., 2010) To simplify, the optimal risky portfolio is the one with the highest Sharpe ratio. (Chen, 2020) We assume that the optimal portfolio is the optimal risky portfolio.

Figure 18 - Mean-variance efficient frontier of the assets (excluding CRIX)



In **Table 4** we can observe the allocation of the optimal portfolio. One thing to note is the high amount large weight of fixed income in the portfolio (70.4%). The biggest weight is Corpo Bonds (40.6%), closely followed by Gov Bonds (29.8%). Then close together comes Equity (11.2%), followed by Commodity (9.8%), and lastly, Gold (8.6%). Something interesting is the lack of allocation to Real Estate (0%) and Currency (0%). Both assets have the lowest Sharpe ratio, and Currency even has a negative return, as such, this might be expected for portfolio optimization. The optimal portfolio has an annual return of 5.2% and a standard deviation of 3.6%. In the end, this is the portfolio with the highest possible Sharpe ratio at 1.33.

Table 4 - Optimal portfolio composition

Optimal Portfolio Allocation								
	Real Estate	*Equity*	*Commodity*	*Currency*	*Gov Bonds*	*Corpo Bonds*	*Gold*	*Total*
Weight	0.0%	11.2%	9.8%	0.0%	29.8%	40.6%	8.6%	100.0%
Ann. Mean								5.2%
Ann. Std. Dev.								3.6%
Sharpe ratio								1.33

Thus, we can compare the performance of the optimal portfolio to the individual asset in **Table 5**. The optimal portfolio indeed follows the MPT, as the portfolio outperforms each individual asset. As we have seen, no individual asset has a Sharpe ratio above 1. At the same time, the optimal portfolio has a Sharpe ratio of 1.33. Similar observations can be made with the Sortino ratio and Calmar ratio. Something notable is that the portfolio has the lowest maximum drawdown of –8% and a relatively

low beta of 0.12. While the portfolio doesn't have the best (fourth in both categories) Treynor ratio (0.40) and Jensen's Alpha (3.5%), they nonetheless remain positive.

Table 5 - Optimal portfolio statistical description and performance

	Real Estate	*Equity*	*Commodity*	*Currency*	*Gov Bonds*	*Corpo Bonds*	*Gold*	*Optimal Portfolio*
Mean	0.022%	0.044%	0.021%	-0.003%	0.010%	0.018%	0.032%	0.020%
Ann. Mean	5.6%	11.7%	5.5%	-0.9%	2.6%	4.5%	8.3%	5.2%
Median	0.067%	0.073%	0.069%	-0.007%	0.016%	0.028%	0.040%	0.031%
Maximum	8.3%	8.8%	3.4%	1.6%	1.5%	1.8%	4.9%	1.6%
Minimum	-13.4%	-9.9%	-4.2%	-1.9%	-2.2%	-3.9%	-5.4%	-1.6%
Std. Dev.	1.1%	1.0%	0.8%	0.3%	0.3%	0.3%	0.8%	0.2%
Ann. Std. Dev.	16.8%	16.0%	13.0%	5.2%	4.1%	5.3%	13.2%	3.6%
Volatility	2.8%	2.5%	1.7%	0.3%	0.2%	0.3%	1.7%	0.1%
Skewness	-1.9	-1.2	-0.6	0.1	-0.9	-2.0	-0.4	-0.6
Kurtosis	31.9	23.3	3.1	2.1	8.6	22.7	4.9	7.4
Sharpe ratio	0.31	0.71	0.39	-0.24	0.56	0.79	0.60	1.33
Sortino ratio	0.41	0.95	0.53	-0.34	0.77	1.05	0.84	1.88
Max Drawdown	-39%	-34%	-35%	-14%	-9%	-15%	-19%	-8%
Treynor ratio	0.06	0.11	-1.06	-0.50	1.81	39.76	0.84	0.40
Jensen's Alpha	-4.2%	0.0%	5.6%	-1.5%	2.1%	4.2%	6.9%	3.5%
Calmar ratio	0.13	0.33	0.15	-0.09	0.26	0.27	0.42	0.58
Beta	0.83	1.00	-0.05	0.02	0.01	0.00	0.09	0.12
Observations	1295	1295	1295	1295	1295	1295	1295	1295

4.3. Portfolio optimization with digital assets

4.3.1. Statistical analysis between the two investments

We can now examine the marginal addition of digital assets to the portfolio. In **Table 6** we have summarized once again the descriptive statistics between the optimal portfolio and CRIX. When comparing the two, the volatility of the CRIX clearly stands out. The CRIX has a standard deviation approximately 20 times higher than the portfolio and a maximum drawdown 10 times higher. However, the risk-adjusted return for the CRIX is clearly above the one from the portfolio. The CRIX's Sharpe ratio is 70% better, and a similar analysis can be observed from the other metrics. This seems to indicate that the addition of CRIX to the portfolio would provide diversification and improve the risk-adjusted returns.

Table 6 - Descriptive statistics between CRIX and optimal portfolio

	Optimal Portfolio	CRIX	Variation
Mean	0.020%	0.399%	
Ann. Mean	5.2%	172.9%	3235%
Median	0.031%	0.2%	
Maximum	1.6%	20.9%	
Minimum	-1.6%	-23.9%	
Std. Dev.	0.2%	4.8%	
Ann. Std. Dev.	3.6%	76.2%	2011%
Volatility	0.1%	58.1%	
Skewness	-0.6	-0.1	
Kurtosis	7.4	2.9	
Sharpe ratio	1.33	2.26	70%
Sortino ratio	1.88	3.37	79%
Max Drawdown	-8%	-86.7%	946%
Treynor ratio	0.40	1.86	362%
Jensen's Alpha	3.5%	162.1%	4578%
Calmar ratio	0.58	1.99	243%
Beta	0.12	0.93	
Observations	1295	1295	

Table 7 shows that the correlation between CRIX and the portfolio is equal to 0.16. This represents a relatively low correlation between the two investments. This furthermore suggests that CRIX would offer diversification effects to the portfolio. As a reminder, a good portfolio diversification is done by putting together assets that offer low correlation to reduce the investment risk. (Mangram, 2013)

Table 7 - Covariance and Correlation matrix between CRIX and the portfolio

Covariance Matrix - Coefficients

	Portfolio	CRIX
Portfolio	0.0005%	
CRIX	0.0033%	0.2306%

Correlation Matrix - Coefficients

	Portfolio	CRIX
Portfolio	1	
CRIX	0.16	1

4.3.2. Marginal addition of CRIX to the portfolio

For our research, we will analyze the performance of 11 portfolios. Each portfolio has a different weight of CRIX from 0% to 5%, in increments of 0.5%. **Table 8** summarizes the weight of the various portfolios. For example, portfolio A is the optimal portfolio ("PF") which we found under MPT previously, and portfolio K is the portfolio composed of 95% of "PF" and 5% of CRIX.

Table 8 - Summary of the weight of the analyzed portfolios

Portfolio	A	B	C	D	E	F	G	H	I	J	K
PF	100%	99.5%	99.0%	98.5%	98.0%	97.5%	97.0%	96.5%	96.0%	95.5%	95%
CRIX	0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 9 shows the performance of each individual portfolio, starting with portfolio A, which is the MPT optimal portfolio we developed previously, to portfolio K (5% of CRIX). What can clearly observe is that each marginal addition of CRIX to the portfolio improves its return while also increasing its risk. Nonetheless, the performance metrics indicate a clear image, that the increase in returns is worth the additional risk. Each incremental addition improves the Sharpe ratio, Sortino ratio, Treynor ratio, and Jensen's Alpha. The Calmar ratio also improves with each addition of the CRIX, but this is the only ratio that after portfolio H (3.5% of CRIX) sees a decrease in the ratio. All the other ratios don't seem to have peaked and leave some potential room for improvement.

When comparing portfolio A (0% of CRIX) and portfolio E (with 2% of CRIX), it is noticeable that the return has grown by 3.2 percentage points (from 5.2% to 8.5%), yet the standard deviation has only gone up by 0.5 percentage points (from 3.6% to 4.1%). This stronger increase in return than in risk can be observed with the performance ratio, such as the Sharpe ratio going from 1.33 in portfolio A to 2.01 in portfolio E. The same can be observed with the other risk-adjusted performance ratios.

This improvement is prominently explained due to the diversification effect of the risk since there was a rather low correlation between the two investments (0.16). Additionally, we have seen that the CRIX has better performance ratios (Sharpe ratio of 2.26) compared to the optimal portfolio (Sharpe ratio of 1.33). As such, these two reasons explain why the addition of CRIX would improve the risk-adjusted performance.

Interestingly, Portfolio H (3.5% of CRIX) is the first portfolio that shows a performance metric superior to either of the investments with a Sharpe ratio of 2.27 (CRIX has a Sharpe ratio of 2.26). Then Portfolio I (4% of CRIX) is the first portfolio that has a better Sortino ratio of 3.40 (CRIX has a Sortino ratio of 3.37). Nevertheless, none of the other metrics outperform those from CRIX, but all outperform the performance metrics of the optimal portfolio.

Table 9 - Performance of the individual portfolios

Portfolio	A	B	C	D	E	F	G	H	I	J	K
Return	5.2%	6.0%	6.9%	7.7%	8.5%	9.4%	10.2%	11.1%	11.9%	12.7%	13.6%
St.dev.	3.6%	3.7%	3.8%	3.9%	4.1%	4.3%	4.5%	4.7%	5.0%	5.2%	5.5%
Sharpe	1.33	1.54	1.72	1.88	2.01	2.12	2.21	2.27	2.33	2.37	2.40
Sortino	1.88	2.19	2.46	2.70	2.90	3.07	3.20	3.31	3.40	3.47	3.52
Max Drawdown	-8.3%	-8.3%	-8.4%	-8.5%	-8.6%	-8.7%	-8.8%	-9.3%	-10.1%	-10.8%	-11.6%
Treynor ratio	0.40	0.46	0.51	0.56	0.60	0.65	0.69	0.72	0.76	0.80	0.83
Jensen's Alpha	3.5%	4.3%	5.1%	5.8%	6.6%	7.4%	8.2%	9.0%	9.8%	10.6%	11.4%
Calmar ratio	0.58	0.68	0.77	0.86	0.95	1.03	1.12	1.15	1.14	1.14	1.14
Beta	0.12	0.12	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16

We have seen the performance of each individual portfolio, but this begs the question of the effect of each implementation of 0.5% of CRIX on the previous portfolio. **Table 10** shows the variation of each metric compared to the previous portfolio. For example, we can observe that portfolio B (with 0.5% of CRIX) improves the return by 16% compared to portfolio A (0% of CRIX). Simultaneously, the standard deviation only increased by 2%. This strong increase in returns with a smaller increase in risk can also be observed in the performance metrics.

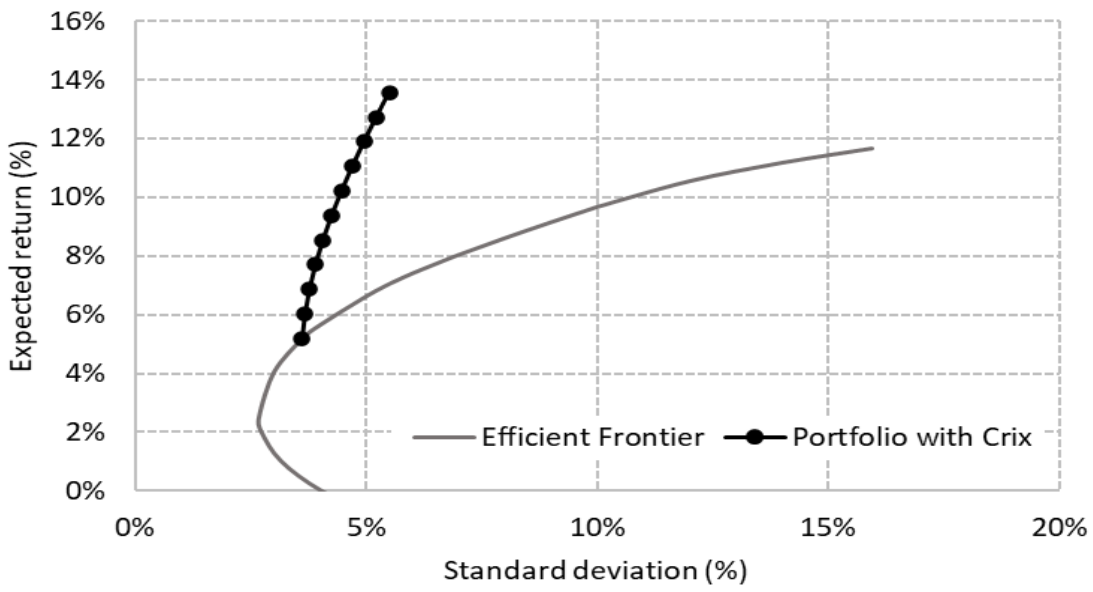
One interesting thing to note is that the marginal benefit of the incremental addition of digital assets to the portfolio is decreasing. Between portfolio A and portfolio B, the Sharpe ratio improves by 16%, while between portfolio J (4.5% of CRIX) and portfolio K (5% of CRIX), the Sharp ratio only improves by 1%. The reason behind this is that as the marginal increase in return slows down, the marginal increase in risk increases. Nonetheless, besides the Calmar ratio, even if the additional benefits decrease, the risk-adjusted performance continues to improve. This implies that the risk-adjusted performance has the most impact on the portfolio with the first added increment of CRIX.

Table 10 - Comparative marginal improvement of each following portfolio, in %

Portfolio	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***
Return		16%	14%	12%	11%	10%	9%	8%	8%	7%	7%
St.dev.		2%	3%	3%	4%	5%	5%	5%	5%	5%	5%
Sharpe		16%	12%	9%	7%	5%	4%	3%	2%	2%	1%
Sortino		16%	12%	10%	7%	6%	4%	3%	3%	2%	2%
Max Drawdown		1%	1%	1%	1%	1%	1%	6%	8%	7%	7%
Treynor ratio		14%	11%	9%	8%	7%	6%	6%	5%	4%	4%
Jensen's Alpha		23%	19%	16%	14%	12%	11%	10%	9%	8%	7%
Calmar ratio		17%	14%	12%	10%	9%	8%	3%	0%	0%	0%
Beta		3%	3%	3%	3%	3%	3%	3%	3%	3%	3%

Figure 19 shows the comparison between the Efficient Frontier, under the MPT, calculated previously to find the optimal portfolio and the various portfolios with CRIX. We can clearly observe that the CRIX improves the risk diversification of the portfolios. Due to the increases in return with just a small amount of added risk, the portfolios using CRIX almost resemble a vertical line. For example, on the efficient frontier, a portfolio with a standard deviation of 5% would provide a return of ~7%. In contrast, an optimal portfolio with CRIX at a standard deviation of 5% would offer a return of ~12%.

Figure 19 - Portfolio with CRIX compared to the efficient frontier



5. Conclusion of results

The result of our analysis has shown that the low correlation of digital assets, on top of their good risk-adjusted returns, implies that digital assets might conceivably have diversification capacities. We have used the Royalton Crypto Index (CRIX) as a proxy for digital assets in our analysis. It showed that from 2017 to 2022, digital assets have, on average, a correlation coefficient of 0.07 with the other analyzed assets. While digital assets offer very high returns (172.9%), the usual drawback is that they also have an extremely high risk (76.2%) compared to other assets.

Nonetheless, we have seen that over the period analyzed, the CRIX has very good risk-adjusted returns. The CRIX has a Sharpe ratio of 2.26, which indicates a very good excess return compared to the asset's total volatility. The same can be said about the other performance metrics in which the CRIX excelled, such as the Sortino ratio (a risk-adjusted metric that only considers negative volatility), the Treynor ratio (which considers only systematic risk), and this is also seen with the Calmar ratio (1.99) and Jensen's Alpha (162.1%).

As such, to assess the diversification benefits of digital assets to a standard portfolio, we have created an optimal portfolio based on the Modern Portfolio Theory (MPT) developed by Markowitz and Sharpe. Using 7 various assets to diversify the portfolio, the optimal portfolio, according to MPT, has 5.2% of expected return and a standard deviation of 3.6%. The portfolio nearly outperforms each individual asset when analyzing the performance metrics.

The examination of the marginal implementation of digital assets to the standard portfolio has shown that digital assets do have excellent diversification capabilities. The optimal portfolio had a relatively low correlation coefficient to the CRIX of 0.16. This allowed the marginal allocation of digital assets to the optimal portfolio to substantially increase the risk-return profile. As we have seen, the minimal introduction of 0.5% of CRIX to the optimal portfolio improved the portfolio return by 16% while only

increasing the standard deviation by 2%. This, in return, improved the risk-adjusted return metrics on average by 16% as well.

This incremental addition of digital assets continues to improve the risk-adjusted return until the 5% weight to which we limited ourselves. While each 0.5% additional allocation to digital assets does improve the risk-return of each following portfolio, the marginal benefit does decline (but remains positive).

These results are in line with a previous research paper done on Bitcoin alone by Brière, M. et al. (2015), which studied Bitcoin's diversification capabilities from 2010 to 2013. Their conclusion was similar to the one of Eisl, A. et al. (2015) that also analyzed the same capabilities of Bitcoin between 2010 and 2015. And this conclusion has also been observed by Gangwal, S. (2016), who analyzed this effect from 2010 to 2016. The main difference of our analysis was analyzing the effect of the entire digital asset class, with the CRIX as a proxy, and analyzing from 2017 to 2022. However, we still came to the same conclusion that digital assets offer good diversification opportunities even in incremental addition. Digital assets should nonetheless be considered as extremely risky investments. As such, it should be treated with caution.

6. Limits

As we have finished the analysis of our results, it is important to understand these results outside of the theoretical realm of the MPT. As such, in this section, we will discuss some potential limits of the analysis and some ways in which the results could be furthered.

6.1. Modern portfolio theory

In our analysis, we used the MPT framework to analyze the marginal effects of adding digital assets to a standard diversified portfolio. Yet, as we have seen in **Part 1 – 4.1.2. MPT Theoretical Assumptions (p.24)**, the MPT framework is highly criticized and believed to not be necessarily applicable to the reality of the market. However, we still decided to use the MPT as it still is a fundamental framework in finance that does help to quantify the effect of diversification on risk.

The results we have found are also heavily linked to the assets used for our analysis. We have used a basket of asset classes to diversify our portfolio, but potentially that different asset would have provided different results to our analysis. We tried to use broad indices to better reflect the global market, yet this is not a perfect representation.

Lastly, in our methodology, we decided to first develop an optimal portfolio using the MPT framework and then analyze the marginal addition of digital assets. The aim was to analyze whether a standard portfolio could benefit from digital assets. In the end, this meant that the optimal portfolio had no allocation to real estate or currency assets and has a substantial weight (over 70%) in fixed income. As such, it could be argued that our optimal portfolio is a rather defensive portfolio. Furthermore, this would not be the optimal way to allocate weights in case we would have created an efficient frontier with digital assets in mind. As such, these portfolios do not optimally diversify the idiosyncratic risk of digital assets.

6.2. Rebalancing of portfolio over time

Another limit of our methodology is that we created a passive portfolio in which we didn't account for any rebalancing. Usually, a portfolio has weight margins for which a portfolio is periodically recalibrated. This implies a more active type of portfolio management. However, to simplify, we used a passive optimal allocation to which we added incremental weights of digital assets. This enabled us to have a good understanding of the impact on a static portfolio. Nevertheless, not rebalancing a portfolio is not an optimal strategy as it gives the lowest risk-adjusted performance. (Tsai, 2001) Therefore, a methodology using a more dynamic portfolio with a rebalancing strategy might find another conclusion.

6.3. Danger of using the past to predict the future

As we have seen, when assessing the performance of digital assets, the risk-adjusted returns look very promising and outperform the other asset classes. However, these returns were in the past and should not necessarily be considered as good indicators for the future. (Brière et al., 2015)

For example, our results have also shown that digital assets offer a low correlation (average of 0.07) to the other asset classes. Yet, correlation is a dynamic statistic that evolves over time. The correlation which we have found for the past five years might differ in the following five years. Therefore, it is possible that the diversification capabilities digital assets are showing in the past might alter in the future. Furthermore, we used a simple correlation analysis and not a conditional variance model. According to Klein, T. et al. (2018), conditionals models show that the low correlation digital assets exhibit is only during a growth period but is a lot higher during market crashes. Therefore, the results of the research should be utilized with discretion.

The underlying risk with digital assets is that it is difficult to understand their underlying value. As such, while we evaluate the volatility of these assets, the data should be used cautiously as it could represent a seed period before being a firmly established asset class. (Brière et al., 2015)

6.4. Time frame

Similar to the previous limit, another potential issue is the number of years to which we have looked back. For our analysis, we justified the analysis of 2017 to 2022, five years. We justified this reasoning by arguing that 2017 was the first year in which digital assets became "investable" due to their market capitalization. However, 5 years might not be enough to paint a clear picture of the new asset class. The analysis of digital assets in a portfolio and their long-term benefits might require further years to be better understood. As such, we would require more data to have a better understanding, we could have gone earlier than 2017 for more data, but digital assets seemed to still be in their infancy stage at that point and would not provide a coherent view of the asset classes. As such, even though we could have analyzed 10 years of data, we believe that the market was still immature at the time and would potentially skew the analysis.

Therefore, we believe that each following year, after 2022, could provide a further understanding of the potential benefits of the implementation of this assets class in a portfolio. Consequently, the result of the same analysis in the future by using data from 2017 to 2027 might find completely different results than ours.

General Conclusion

This thesis sought to address the question, “Is the marginal addition of digital assets a useful strategy to diversify the risk-return profile of a standard portfolio?” by assessing the investible capabilities of digital assets. The aim of the thesis was to understand whether digital assets, as an asset class, despite their dramatically high risk, might provide a standard portfolio with a better risk-adjusted return due to their equally high returns. This analysis was, therefore, to determine the impact on the performance of the portfolio when only using a marginal allocation of digital assets. We will approach this conclusion by returning to the key points of each major section of this thesis.

Conclusion from the theoretical part

Digital assets are still a relatively contemporary and controversial idea. While the subject becomes progressively more researched as mainstream adoption of these assets continues, there still remain many questions on the future and the potential of digital assets. While some see digital assets as the future for the economy and the financial sector, others consider it a bubble. Nonetheless, one thing remains clear; the sector is evolving and becoming inevitable in a financial context.

In the first section of the theoretical part, we have seen the history and the various definitions of digital assets. While they have come into mainstream consciousness only over the past decade, some first variants already appeared in the 20th century. We have defined digital assets as blockchain-based technologies which have a virtual value that can be traded digitally, which sometimes offers similar characteristics to currencies. Afterwards, we have seen in more detail the various major events that shaped digital assets into what they are currently. We have analyzed them since the release of the Bitcoin white papers by Satoshi Nakamoto in 2008 until the end of 2021.

Then, to better understand digital assets, we have examined in more detail the four main categories of digital assets: Bitcoin, Altcoins, Stable coins, and NFTs. In this part, we have seen that Bitcoin still overall dominates digital assets in market capitalization compared to the other assets. Nonetheless, we have seen that digital assets exist on a spectrum which makes it difficult to classify them together.

Thereafter, in the second section, we assessed whether digital assets are a currency or an asset class. Digital assets are often categorized as currencies. Even their mainstream appellation is “Cryptocurrency”, which would imply them being a currency. On top of that, Bitcoin, the first digital asset, was developed as a peer-to-peer payment system. However, to be considered a currency, one must fulfill three conditions: it must be a medium of exchange, a store of value, and a unit of account. The majority of digital assets can be seen as a medium of exchange and relatively as a unit of account (which is also debatable). However, most digital assets struggle as a store of value due to their extremely high volatility.

But, as mentioned previously, digital assets exist on a spectrum. Therefore, digital assets, defined as stable coins, are pegged to another value (such as the US Dollar), eliminate this volatility, and would fit in the category of currency. Nonetheless, if we were to generalize based on market capitalization, digital assets cannot be considered as a currency.

Thus, digital assets should be considered as an asset class. Compared to the definition of the various asset classes that currently exist, we can observe that digital assets do not fit in them. Consequently, digital assets should be considered as a new asset class.

In the third section of the first part, we have seen that digital assets are evolving in a favorable macroeconomic environment. First of all, retail investors, businesses, investment firms, and governments all have a growing interest in digital assets, which is one of their key growth drivers. Secondly, when analyzing the financial market, we can see that the economy overheated during the pandemic. After the pandemic, most economies have historically low interest rates while simultaneously having stock markets at an all-time high. Stagflation fears have pushed some investors to have a cynical outlook. This situation might make digital assets an attractive alternative to the traditional financial market.

Accordingly, in the fourth section, we analyzed whether digital assets might increase in attractiveness, examining the asset class's potential capabilities to diversify a portfolio. When using the Modern Portfolio Theory framework, developed by Harry Markowitz and William Sharpe, the key to a good diversification is a low correlation between the assets. A high number of sources have shown that digital assets offer a very low correlation to various assets. This suggests that digital assets should be considered during portfolio construction. Additionally, some papers even claim that digital assets have a significant potential for inflation hedging. However, these are attributes that are still openly debated as digital assets' correlation to the market is stronger during periods of heightened uncertainty.

Ultimately, whether digital assets offer a good diversification to a portfolio or not, in this final section, we have investigated the controversial aspects of the asset class. We first have reviewed the legal framework where the first constraint is that digital assets struggle with overcoming most Anti-Money Laundering (AML) laws around the world. On top of this, the complexity of the asset class makes it difficult to offer them to clients, especially in Europe, where MiFID requires investors to understand the assets in which they invest. Lastly, most governments do not have precise regulations on the subject. They seem to allow digital assets a certain grey area while they are trying to determine the best way going forward.

Moreover, not only are digital assets statutorily contingent, but they are also regularly linked to criminality. This criminality can be theft, scams, financing crime, or many other forms. In 2021, USD 14bn was linked to criminal activities. The majority were linked to fraudulent digital assets. The asset class is already highly speculative and highly complex, which makes it easy prey for malicious individuals. However, certain sources report that the extent of the criminal activity is exaggerated (only 0.2% of all transactions). When compared to fiat currencies, where criminal-linked activity is expected to represent between 2% and 5%, digital assets would only represent a fraction of that.

One of the key drawbacks of digital assets is their poor ESG performance. This poor performance is mostly linked to the energy consumption necessary to uphold digital assets. Bitcoin's network alone supposedly consumes more energy than the country of Belgium. Nonetheless, digital assets supporters expect the consumption to improve with technological innovations in addition to a gradual conversion to renewable energies, which is already expected to be at 58% in 2021. The social aspect of digital assets has the potential to accelerate financial inclusion around the globe by bypassing traditional hurdles, especially in developing countries. However, the criminality and security issues remain key issues. Lastly, the Governance factor is not easily quantifiable as, by definition, most digital assets are decentralized. Overall, the ESG score of digital assets is rather poor, but the potential for improvement is there.

To conclude, the last controversial aspect of digital assets is that it is difficult to price them. As such, many believe digital assets to be a bubble waiting to burst. To better understand whether digital assets are indeed a bubble or not, we tried to understand their underlying value. To do so, we analyzed three common ways digital assets are priced.

The first method is to analyze the supply and demand. It supposes that an asset has value as long as there is demand for it. This implies that as the demand for digital assets is there, they have value. Of course, this methodology is rather fragile; if the public opinion switches, the value would be lost.

The second method is to use to cost of production (or mining) as a proxy for the price. This is an in interesting alternative as there seems to be a historical correlation between the cost of mining and the price of digital assets. Nevertheless, this does not imply that the price of digital assets grows when the production cost increase, rather that miners make informed investment decisions and mine a digital asset if the return is worth the cost.

The third method we have analyzed is using on-chain variables to predict prices. This methodology is similar to multiples when analyzing equities. This method uses information on the activity on the network to predict the popularity of certain digital assets. However, these are mainly indications but not enough to make an informed decision.

Conclusion from the empirical analysis

For our quantitative analysis, we based our research on the MPT framework. We empirically established a standard optimal portfolio using the concepts of MPT. The optimal portfolio is well-diversified as it is made up of global benchmarks from several asset classes, which are: Equity, Fixed Income, Commodities, Currency, and Real Estate. The aim of the thesis was to analyze the impact of adding marginal amounts of digital assets to such a standard portfolio. To better represent digital assets, we used the Royalton Crypto Index (CRIX) as a proxy. We examined the data over a five-year period (from 27th February 2017 to 11th of February 2022). We determined that 2017 would be the starting point of our research as it was the year when the market capitalization of digital assets exceeded the large capitalization definition. We believe this to be the moment in which digital assets became investable.

Our results showed that digital assets indeed offer a low correlation to traditional asset classes. Additionally, we have observed that digital assets offer the best risk-adjusted performance of all the asset classes. This implies that digital assets might offer diversification capabilities to a portfolio despite their huge volatility.

To assess the impact of adding CRIX to a portfolio, we used six performance metrics: Sharpe ratio, Sortino ratio, Maximum drawdown, Treynor ratio, Jensen's Alpha, and Calmar ratio. We then analyzed 11 portfolios, each with varying weights of CRIX (from 0% to 5%, per 0.5% increments). The analysis showed that each additional increment of CRIX to the portfolio greatly improved the portfolio's risk-adjusted return. This is true for all performance metrics, besides the Calmar ratio, which peaked at a CRIX weight of 3.5%. Each portfolio's return greatly improved while its volatility remained relatively stable. This leads to believe that the returns outweigh the risk of taking a marginal amount of digital assets.

However, we have observed that the marginal benefit of each increment is decreasing. This demonstrates that while it is interesting and possible to improve the portfolio risk-return until the CRIX weight of 5%, the biggest impact on the performance is the first increment of 0.5%. In the first

increment, the portfolio's return improved by 16%, while the standard deviation only increased by 2%. With each following increment, the return increased less while the standard deviation increased more.

All in all, our empirical analysis indicates that digital assets should be considered during the construction of a portfolio for their diversification purposes and risk-adjusted returns. Even just marginal additions have a significant impact on the portfolio's risk-return profile. It is worth mentioning that these results were in line with various previous papers which were focused on Bitcoin during previous periods.

Results in a financial context

Despite the fact that our findings are intriguing, the result of our research is based on the MPT framework. We thought that it would be crucial to assess digital assets under the assumptions of an efficient market to better understand price movements. We have seen that digital assets have diversification capabilities which would improve the risk-return profile of a standard portfolio. However, these assumptions are limited in reality. Therefore, to arrive at more precise results, a more in-depth analysis of the correlation between digital assets and the portfolio might be a more appropriate indicator of their diversification capabilities. This implies a better understanding of the risks linked to investing in digital assets. Additionally, in our analysis, we based our methodology on a passive portfolio management. It could be interesting to analyze if the results would be similar in a more actively managed portfolio.

However, we expect that several additional problems must be resolved before digital assets can be considered by institutional investors. In the theoretical part, we have seen that there remain many legal, criminal, and environmental issues linked to the asset class. As such, investors would require the regulatory framework to clear up the legality of investing in digital assets. Even then, the environmental issues would still exclude most sustainable investors. This year's global political environment has highlighted the energy fragility of certain countries. This could hinder the adoption of digital assets which are notoriously energy intensive. Nonetheless, digital assets are at their core a technological innovation that sooner or later will be implemented by all businesses or governments. Therefore, betting against digital assets might be similar to betting against human innovation. This is not to say that digital assets and blockchain technologies are currently perfect, but they foster innovation which can be observed by the number of altcoins in existence.

Contributions and further research

In the introduction of this thesis, we mentioned that the aim of this paper was to provide investors with a better understanding of digital assets while also determining the diversification capabilities of the asset class. What our analysis revealed is that digital assets improved the risk-adjusted performance of a standard portfolio, even in small increments. Furthermore, we have outlined the diversification capabilities of digital assets in a standard portfolio. These results are in-line with similar research papers which focused on Bitcoin during previous time periods. Nonetheless, an important addition of this paper is the importance of the various risks of digital assets.

For the methodology used to come to this conclusion, we based ourselves on past statistical returns. However, finance is about discounting the future and not extrapolating the past. As such, it might not make sense to expect digital assets to have the same growth in the following five years. We have seen that a core difficulty linked to digital assets is to price them. However, this begs the question of whether there is a way to accurately estimate the value (or utility) of a digital asset. Financially,

investors are able to put a price tag on trademarks or on a source code. Both are intangible similar to digital assets. Therefore, it could be interesting to assess how an investor should assess the future value (or utility) of digital assets.

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