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Algorithmic Trading and Cryptocurrency- a literature review and key findings

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ABSTRACT

Algorithmic and high-frequency trading gained significant popularity in traditional financial market transactions in the early 2000s. While cryptocurrency was introduced in 2009, it was not until 2015 that cryptocurrency trading experienced explosive growth due to advancements in technologies supporting the cryptocurrency ecosystem and economic uncertainties. Algorithmic trading strategies and high-frequency automated trading have been used in cryptocurrency trading. However, the lack of historical data and the volatility of the cryptocurrency market create unique challenges and impact the performance of these models and strategies. Additionally, cryptocurrency is an unregistered security, and cryptocurrency exchanges remain unregulated, which has generated significant concerns for global securities governing bodies. This research provides a literature review and document analysis of peer-reviewed journal articles and professional literature and identifies themes regarding algorithmic trading and the cryptocurrency ecosystem.

Keywords

Blockchain, disruptive technology, algorithmic trading, cryptocurrency, cryptocurrency exchange, emerging technology.

INTRODUCTION

Algorithms have been around for many years and are defined as a set of operations allowing us to find a solution to a problem (Martinez et al., 2018). Expanding this definition to the stock market, algorithms can be described as a set of calculations predicting the price of stocks. This algorithm would allow automatic investment decisions in bots, trading algorithms, and artificial intelligence (AI).

Automated trading systems started in the 1980s and expanded in the 2000s (Hilbert & Darmon, 2020). Algorithmic trading systems provide an uninterrupted presence in the stock markets, following strict sets of operations based on technical analysis not influenced by human emotions that can cause errors (Park & Irwin, 2007). Algorithmic trading represents one of the most deliberate and sudden shifts of intellectual labor from humans to machines (Cliff et al., 2010). One application of automated trading systems is the algorithmic trading of cryptocurrency.

Cryptocurrencies have been a hot commodity in recent years (Ahmad et al., 2020). Digital currencies, such as Bitcoin (BTC), Ethereum, and Litecoin, function in a distributed system without any central authority, such as the Federal Reserve. The value of international currencies depends on interest rates, inflation, and the balance of trade for a particular country. In contrast, the value of cryptocurrencies is impacted by demand, media speculation, the hype of the technology, and acceptability (Nyuyen et al., 2018). Cryptocurrencies are designed to operate in a distributed system without the requirement of a third party. The underlying technology of cryptocurrencies is blockchain.

According to Garcia-Corral et al. (2022), published literature relating to Bitcoin, cryptocurrency volatility, and underlying cryptocurrency technologies has consistently doubled or tripled in size yearly from 2016 through 2018. Additionally, a recent Google trends analysis shows a consistent increase in global searches "algorithmic trading," "cryptocurrency", and "blockchain" keywords since 2016. This motivates research as it appears to be an appropriate time to review the literature. Reviewing peer-reviewed journal articles and professional literature helps identify trends in the popularity of specific topics and themes within those topics and provides sociocultural, political, and economic context for the topics being researched (Bowen, 2009). Therefore, this research aims to provide a literature review and document analysis of peer-reviewed journal articles and professional literature and identify overarching themes regarding algorithmic trading and the cryptocurrency ecosystem.

The remainder of this paper is structured as follows. First, the adopted research method is discussed. Secondly, an overview of algorithmic trading, cryptocurrency, and blockchain is provided. Lastly, significant themes, concerns, and challenges from the literature survey are presented.

METHODOLOGY

This research used an abbreviated form of content analysis, as discussed by Neumann et al. (2021) and Sayed et al. (2020). A literature review and content analysis are critical components of the research process and the advancement in the understanding of research topics (Winchester & Salji, 2016, Boote & Beile, 2005). A comprehensive literature review provides the reader with knowledge from research performed to date and should be systematically structured to ensure that a complete enumeration of relevant literature is gathered (Webster & Watson, 2002). For this research, keyword searches were performed on "algorithmic trading," "cryptocurrency," and "blockchain" from January 01, 2010, through December 31, 2020. The search was completed first using single search terms and then repeated using combinations of search terms to deepen the results. Figure 1 shows the number of published peer-reviewed and professional literature from 2010 through 2020.

The first search iteration produced an average of 975 peer-reviewed journal results in total for "algorithmic trading" and "cryptocurrency" single search terms using Metropolitan State University's (MSU) library search and an average of 12,185 peer-reviewed journal and professional literature total results for the same search term using Google Scholar. As shown in Figure 1, algorithmic trading peer-reviewed journal articles and professional literature has a constant increase over the 11-year period. However, cryptocurrency experienced a significant rise in peer-reviewed journal articles and professional literature beginning in 2016, with a plateau or slight decrease starting in 2019.

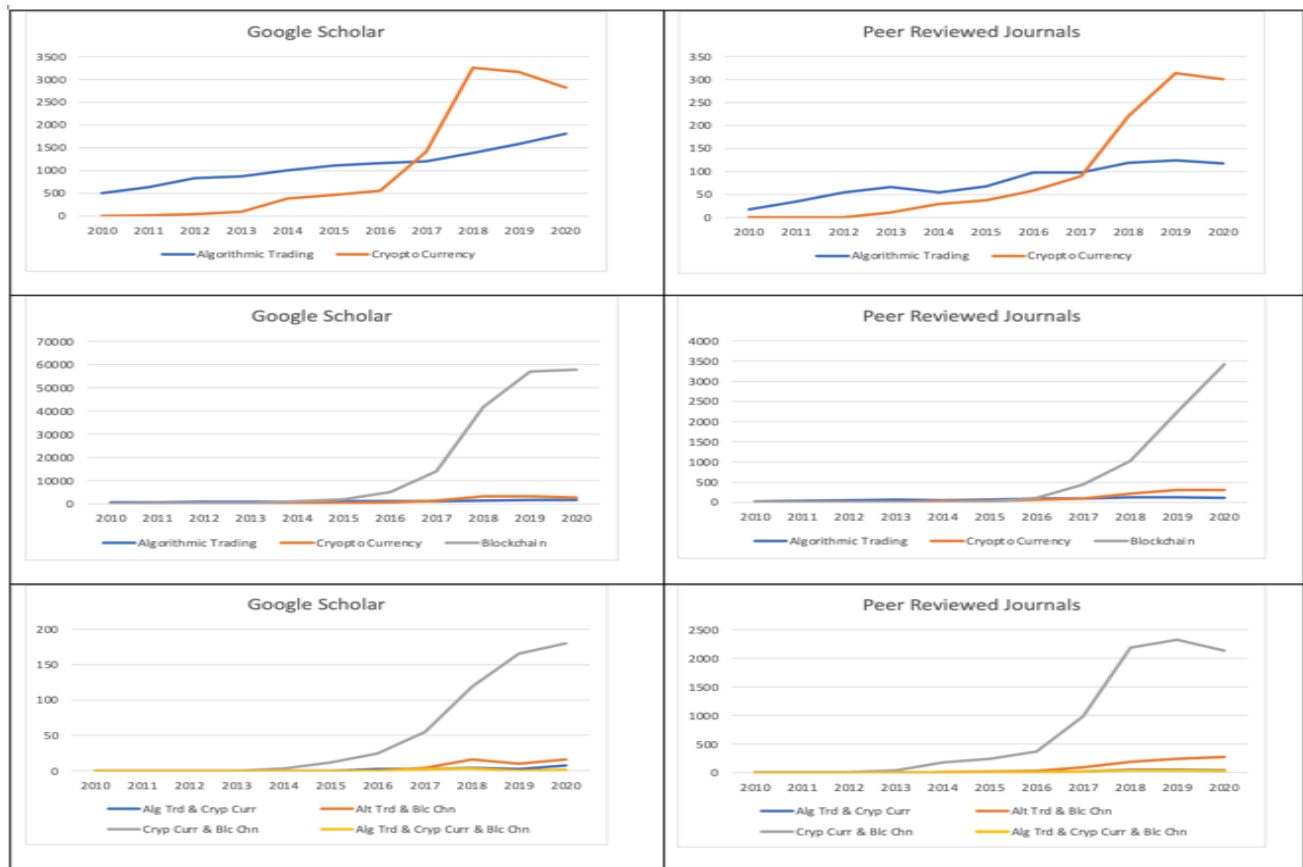


Fig. 1 Search results by keyword

A combination of search terms was then used to deepen results and provide a more comprehensive census of published literature. Search results varied significantly when a combination of search terms was used on Google Scholar and MSU library search engines. Peer-reviewed articles and professional literature results were most prolific for the combination of "cryptocurrency" and "blockchain," producing over 8,484 results from the MSU library and 559 results from Google Scholar from 2010 through 2020. Additionally, 168 results for a combination of "algorithmic trading" and "cryptocurrency" search terms and 848 search results for a combination of "algorithmic trading" and "blockchain" were documented during that period. Search results were then filtered down based on the keyword or keywords appearing in the title to ensure a valid data set. Next, the article abstract or a web clipping was reviewed to determine its applicability to research. Lastly, articles were selected from the first five pages of search results because articles beyond the fifth page of search results were duplicate articles, articles beyond the scope of this research, or articles not relevant to this research.

OVERVIEW OF KEY TECHNOLOGIES

Algorithmic Trading

Algorithmic Trading (AT) refers to tools used by investors using sophisticated algorithms or programmed systems, automating some or all of the investor's trading activity (Treleven et al., 2013; Ahmad & Schmidt, 2012). AT automates investing in various assets, including currencies, bonds, and stocks (Admad et al., 2021). An algorithm can be defined as an orderly and finite set of operations that allows an individual to solve a problem (Gomez Martinez et al., 2019; Kronsjo, 1987). AT uses digitally automated information processes following deterministic local rules that respond to learned patterns of programmed instructions, not influenced by human emotions.

Automated trading started in the 1980s when the digitization of the financial markets spread, and since 2000, trading based on algorithms distributed through retail investors accessing these digitized markets (Martinez et al., 2019). It is part of a more significant trend of using computer-based automation to improve efficiency by lowering costs, removing human error, and increasing productivity. Securities trading venues have been called "the world's largest and most powerful techno-social system" (Johnson et al., 2013). The introduction of AT has been the main driver of technological change in the securities markets over the last decade (Hilbert & Darmon, 2020). This type of trading has significantly impacted how trading financial assets change hands. The overall trading activity became more predictable, complex, and uncertain simultaneously. We will look at three broad trading algorithms; algos, high-frequency trading (HFT), and market-making.

Trading Algorithms

"Algos" are execution algorithms consisting of computer code allowing humans to set the parameters for a security trade. The parameters may include a specific timeframe, volume patterns, prices between stocks, and risk-adjusted real-time market conditions. Their goal is to minimize the cost, risk, and reliability of executing a set strategy, automating much of the trading activity. "Algos" typically use machine learning to understand market patterns, buying and selling securities over days or months.

Algo trading has generated some controversy. In May 2010, the stock market experienced a sudden and dramatic fluctuation, referenced as a 'flash crash' (MacMenzie, 2011). Prices of some of the largest and most heavily traded companies in the world saw a steep decline and rapid recovery, all in a matter of minutes. Other high-profile algorithmic issues included Facebook's initial public offering in March 2012 being delayed and an electronic error by Knight Capital Group in August 2012, costing the company over \$400 million (Kirilenko & Lo, 2013).

High-Frequency Trading (HFT) algorithms focus on high volume order-to-trade ratio (Easley et al., 2013). It is a form of AT that takes advantage of computing and telecommunications power and maturity to complete millions upon millions of trades per day, automated to act on certain operations according to preset conditions on the market. HFT accounts for 4 to 60 percent of all trades across all trading platforms in the financial markets (Tabb, 2012). HFT takes advantage of slight differences in price and risk before other traders, creating scale by volume and frequency. These algorithms may respond to media reports on the market or other sources of information. However, most high-frequency trading algorithms look at changes in market volume and price (Biais & Woolley, 2011).

The third type of trading algorithm is market-making. Market makers take advantage of the fact that supply and demand are not equal everywhere and for everyone all the time (Baldacci et al., 2019). Hence, an intermediary participates in the buying and selling securities to smooth out temporary imbalances of supply and demand. Market makers operate in high liquidity markets where the spread, the margin derived from buying at the bid price and selling at the asking price, is small (Hayes, 2020). Taking advantage of computing speed reduces the risk of the market moving against the market maker between buying and selling the security.

Market making is a high-risk activity due to price fluctuations and adverse selection (Barzykin et al., 2021). Prices may move unexpectedly against the market makers, causing them to sell their stock at a loss. A market-making algorithm creates, updates, and cancels orders to buy and sell a stock, capturing the bid while managing risky inventory. They need to track demand-supply imbalances, costs of trading and access fees, margin requirements, and the cost of money. Those with the best connectivity, algorithms, and access to customer order flow generate the best cash flow.

Cryptocurrency

Cryptocurrency is a digital currency typically utilizing a public blockchain to verify and maintain records instead of a central bank (Ward, 2018). Often referred to as "crypto", cryptocurrencies allow a buyer and seller to complete a payment transaction for products or services over the internet by transferring a specified amount of cryptocurrency through a digital payment infrastructure. Bitcoin, introduced in October 2008, is the oldest and most recognized global cryptocurrency; however, more than 12,170 cryptocurrencies exist, each with its own use case (Sephton, 2021). Table 1 below lists the top 10 global cryptocurrencies in November 2021 (Tretina & Schmidt, 2021).

Cryptocurrency exchanges, also known as digital currency exchanges, allow users to buy or sell cryptocurrencies using other cryptocurrencies or standard currencies (U.S. dollars) as a form of payment. There are approximately 504 cryptocurrency exchanges globally and about 18,998 markets that trade cryptocurrencies (Zammit, 2021). Not only do these exchanges trade cryptocurrencies, but many have specialized offerings related to cryptocurrencies. For example, bitFlyer is known for high-volume trading, EXMO is a platform known for day trading cryptocurrencies, and ByBit is an exchange known for trading cryptocurrency derivatives. Table 2 below provides a shortlist of cryptocurrency exchanges and their identified most substantial offering according to Cryptimi (n.d.).

Investors in cryptocurrencies face many risks, including fraud, scams, volatility of cryptocurrencies, and operational glitches within cryptocurrency exchanges. Based on the increased interest in cryptocurrency trading over the past ten years, international government agencies and special interest groups are calling for regulation and compliance measures to be put in place to govern cryptocurrencies and the exchanges or platforms that allow cryptocurrency trading. For example, in May 2021, Coinbase and Binance, two of the largest cryptocurrency exchanges, experienced service outages due to network congestion resulting in losing \$1 trillion of market value over two weeks (Leising, 2021). A list of countries with proposed or passed legislation regarding cryptocurrency and cryptocurrency exchanges is presented below (Orjo, 2021, Henshaw, 2021).

KEY FINDINGS

Algorithmic Trading Models and Strategies

Models for algorithmic trading rely on clean, real-time, and historical data from financial, economic, news, and social media sources to identify potential trade opportunities. The algorithms used in models are typically time-consuming to create and include pre-trade analysis of the collected data to identify patterns and predict securities behavior; quantification of risk exposure of individual securities and the entire portfolio; estimation of transaction costs associated with trades; and selection of the order type, exchange, and execution of the trade (Treleven et al., 2013). When used for cryptocurrencies, algorithmic trading models are often challenged by the lack of historic data available as many new currencies are less than three years old and the lack of trading information when cryptocurrency exchanges are down (Brown et al., 2021).

Algorithmic trading strategies vary based on many factors that include risk tolerance, analysis of trends and patterns, and market behavior theory with popular trading strategies including mean reversion, pairs trading, basket trading, and arbitrage (Pavchenko et al., 2018). Most important to note is that investment returns are dependent on transaction fees and the selected strategy used in algorithmic trading (Ahmad et al., 2020). Trading strategies relying heavily on machine learning and sentiment analysis is a growing area for research, with new strategies being built and tested to examine social signals gathered from Twitter and other social media sources (Garcia & Schweitzer, 2015, Colianni et al., 2015, Lamon et al., 2017). Additionally, in conjunction with machine learning, big data is also being researched related to algorithmic trading. Gomez Martinez et al. (2019) used data mining software to gather information on investors' moods based on social media posts. Gomez Martinez et al. (2019) observed positive returns relating to investors' moods and that big data algorithmic trading platforms outperformed traditional trading systems.

High-Frequency Trading

High-frequency trading using executable algorithms allows for purchasing, holding, and selling assets within microseconds, all without human intervention. A primary benefit of high-frequency algorithmic trading is that it increases market efficiency by improving liquidity in the market (Arnoldi, 2016). However, critics of high-frequency trading using executable algorithms claim that it leads to increased volatility within the market and potential market manipulation. Typically, these executable algorithms underpin trading strategies where trading speed is a competitive advantage. The trading speed allows users of high-frequency trading algorithms to learn and react to market information that may not be available to all market participants.

High-frequency trading has been used in traditional markets as early as 2009, and it is estimated that 50%-70% of trading within the U.S. exchanges are, in fact, high frequency executable algorithmic trades (Arnoldi, 2016, Lenglet, 2011). High-frequency trading has been slowly gaining popularity within the cryptocurrency market as more companies offer colocation of servers near or in the same facility as exchange servers allowing for up to 100 times faster executable trades (Baydavoka, 2019). However, according to a study by Petukhina et al. (2021), activity patterns show that the trading of cryptocurrencies is still driven mainly by human interaction and not algorithms.

Adoption and Stability of Blockchain and Cryptocurrency

Even though interest in blockchain within the business community continues to grow, it has not yet been widely adopted as of the writing of this research. Current business use cases for blockchain are primarily found in supply chain networks to store transactions, track items, and improve efficiency or in the financial services industry for processing and validating transactions (Casadro-Vara et al., 2018, Iansiti & Lakhani, 2017). Despite blockchain growth forecasts and the proposed endless potential of its application, Min (2019) observed that many top executives do not have a firm understanding

of the technology or its proposed benefits. Additionally, concerns about blockchain fatigue due to immature technology and an incomplete blockchain ecosystem are challenging many projects to move beyond the pilot or test phases (Omale, 2019). The scalability of blockchain technologies is of utmost importance to building out the ecosystem required to process the volume of transactions that will come with widespread adoption. However, this scalability depends upon other emerging technologies, such as the Internet of Things (IoT), that will allow for interoperability and interconnectedness of platforms with the blockchain ecosystem.

Cryptocurrencies, underpinned by blockchain technologies, face similar concerns over their adoption and longevity from a global perspective. Cryptocurrency and cryptocurrency exchange scalability have unique challenges for users and investors alike. Difficulties in purchasing, holding, and selling cryptocurrency currently hinder overall scalability. Additionally, the limited capability to manage large amounts of data in a short time frame on the blockchain is also a contributing factor. To solve this challenge, scalability solutions include increasing the block size to increase the carrying capacity of the overall system and using the Lightning Network protocol to conduct the operation in real-time (Makarenko, 2018).

The destabilization of paper currencies in China, India, and Venezuela during 2016, combined with global economic uncertainties due to Donald Trump's presidency and Brexit, has been attributed to the rise of interest and value in cryptocurrencies (Swanson, 2017). However, the volatility in cryptocurrency prices and inefficiencies in the cryptocurrency market are prominent causes of low adoption rates. While there is no consensus on the causes of volatility in cryptocurrency prices, Walther et al. (2019) concluded that no single variable causes volatility. Instead, it is a network of factors, such as Chinese policy changes and global financial stress.

Additional research has shown that the volatility of Bitcoin prices is predictable based on past values and the trading volume of Bitcoin in the open market (Aalborg et al., 2018). Research into the causes of inefficiencies in the cryptocurrency market has indicated that liquidity, volatility, and the infancy state of cryptocurrencies contribute to market inefficiencies (Urquhart, 2016, Al-Yahyaee et al., 2020). Additionally, transactional issues, including cyber-attacks and privacy concerns; technological issues, including lack of global high-speed internet access and the lack of storage devices required to hold massive amounts of data; and the amount of energy consumption needed to mine cryptocurrency all play a significant role in inefficient usage of cryptocurrency on a global scale (Wu, 2018).

Trust in the Cryptocurrency Ecosystem

The cryptocurrency ecosystem includes wallets, payment systems, cryptocurrency exchanges, blockchain technologies, and mining systems (Rehman et al., 2020). Trust in the cryptocurrency ecosystem is created by awareness, knowledge, and confidence in the underlying technologies and their implications. Negative coverage and information about cryptocurrencies linked to illegal and terrorist activity, volatility of cryptocurrency prices, and security issues have plagued cryptocurrency for several years. The use of cryptocurrency to conduct illicit activity typically occurs on "darknet" marketplaces. It is signaled by numerous transactions at smaller values. Foley et al. (2019) found that nearly one-quarter of all users and approximately one-half of all cryptocurrency transactions are linked to illegal activity. In Central and South America, there is an ongoing concern about using cryptocurrency by drug cartels to carry out money laundering and trafficking activities. In 2018 investigators tracked a money-laundering scheme between drug traffickers in Columbia and Spain, and in 2019 authorities found a separate drug tracking ring using an underground bitcoin mining operation (Henshaw, 2021).

Trust in the cryptocurrency ecosystem remains cautious on a global landscape at best. Some countries limit cryptocurrency use, and others outright ban all cryptocurrency transactions (Orjo, 2021). In June 2021, El Salvador became the first country to adopt bitcoin as a legal form of payment. Cryptocurrency has gained popularity in Central and South America due to a large population that does not have a traditional bank account. However, El Salvador is ranked 74th out of 120 countries regarding internet availability and affordability, and no country in Central and South America ranked within the top 20 countries on the list (The Economist, 2021). Continued adoption of cryptocurrency and other technologies within its ecosystem will depend on having access and a solid connection to the internet. In addition, El Salvador's government promises training and mechanisms for bitcoin adoption. However, there has been no release of information on their inclusion and training strategy (Henshaw, 2021).

Confidence in cryptocurrency exchanges is constantly challenged due to continued operational failures and downtime, especially during significant market fluctuations. These exchanges are also vulnerable to hackers and malware that can cause additional disruption. In 2014, Tokyo-based exchange Mt. Gox filed for bankruptcy after hackers stole an equivalent of \$460 million worth of bitcoin (McMillan, 2014). During his testimony at the Committee on Banking, Housing, and Urban Affairs of the United States Senate (2018), Dr. Roubini called cryptocurrency the mother of all scams and shared research that 81% of initial coin offerings were scams and then spoke at length about the price volatility of Bitcoin and other major cryptocurrencies. To improve trust in cryptocurrency exchanges, significant developments within exchanges are required to ensure an equal opportunity for all investors, no matter their size, and that the investor's trades are safe and secure (Rehamn et al., 2020).

Wallets and payment systems technologies, at this point, appear to be the most trusted components due to widespread use and adoption outside of the cryptocurrency ecosystems. A study performed by Hileman & Rauchs (2017) estimated that

between 5.8 to 11.5 million cryptocurrency wallets are in use, and approximately 86% of participating payment companies use bitcoin for cross-border transactions. During his testimony at the Committee on Banking, Housing, and Urban Affairs of the United States Senate (2018), Mr. Van Valkenburgh argued that corporate payment intermediaries are becoming fewer, larger, and more powerful. Hence, the need to have a decentralized ledger that can transfer cryptocurrency from one account to the next without a corporate intermediary is in the public's best interest. However, payment systems and blockchain development are required to manage large transactions, highlighted by bitcoin only being able to complete five transactions per second. In contrast, Visa can perform nearly 25,000 transactions during the same time frame (Committee on Banking, Housing, and Urban Affairs of the United States Senate, 2018).

Regulatory and Legal Challenges

Algorithmic trading, cryptocurrency, and the exchanges they trade continue to pose new ethical, validity, and purpose challenges from social and political viewpoints (Coeckelbergh et al., 2018). While automation in the trading process, spurred by algorithmic trading, has reduced cost, reduced human error, and increased productivity, it has also been plagued with frequent technical malfunctions, fraud, and increased price volatility due to its use (Kirilenko & Lo, 2013). Examples include the flash crash of 2010 due to mistakes made during automated trades; the reported loss of nearly \$400 million by Knight Capital Group in 2012 due to algorithmic trading; and an electronic broker who was involved in off-shore market price manipulation using high-frequency trading algorithms (Kirilenko & Lo, 2013). Additional malfunctions occurring during algorithmic trading came before The Singapore Court of Appeals in a case in which a seller's and buyer's separate algorithmic trading programs transacted a trade at 250 times the current market rate of the cryptocurrency (Loke, 2020). Because cryptocurrency exchanges are currently unregulated, the Court's ruling cautioned investors to review the cryptocurrency exchange's asset holding arrangement to understand better the property rights assigned to the investor and whether or not the cryptocurrency exchange holds the cryptocurrency on trust during the transaction (Loke, 2020). A review of global regulatory announcements from 2017 through 2019 by Shanaev et al. (2020) found that the United States, the United Kingdom, and Japan accounted for over 49% of all events which covered topics such as anti-money laundering, exchange regulation, and issuance regulation. The study's findings also showed that when increased regulation events were announced, there was a corresponding negative impact on the cryptocurrency market; conversely, hands-off, self-regulatory event announcements positively impacted the cryptocurrency market (Shanaev et al., 2020).

CONCLUSION

Algorithmic trading has been used since the 1980s. However, cryptocurrencies have only existed since 2008, and many of the technologies within its ecosystem are immature. Even though there is evidence of successful strategies and models for algorithmic trading for cryptocurrencies, the performance of the models and strategies is challenged due to the lack of historical information, price volatility, operational failures, and downtime of cryptocurrency exchanges. Adopting cryptocurrency on a global scale is currently being hindered due to its continued link to illegal and terrorist activity, volatility of cryptocurrency markets, and security and privacy issues of cryptocurrencies and the trading process. Opportunities to increase adoption include developments at the cryptocurrency exchange level to ensure that the investor's trades are safe and secure; improvements in payment systems and blockchain technologies to manage large transactions; adoption of several global regulatory initiatives relating to anti-money laundering, exchange regulation, and issuance regulation.

Despite the contribution from this research, it does have limitations. Firstly, cryptocurrency and topics related to cryptocurrency are an emerging fields of research, and this research excluded published literature that was not available in an online format. Performing a forward and backward reference search may expand cryptocurrency and algorithmic trading knowledge. A forward reference search may help identify follow-up studies or new findings on these topics. Likewise, a backward reference study may lead to identifying academics or institutions that are experts in these topics.

Additionally, while MSU's library search includes the most popular academic databases, it may not have access to all academic databases. Thus search results are limited to the databases available through MSU. Utilizing an all-encompassing educational database search tool may enrich search results and increase the understanding of cryptocurrency and algorithmic trading. Lastly, this research produced an average of 12,185 peer-reviewed journal and professional literature results, and only a sample was used in the literature review. Employing advanced search tools through academic databases and expanding upon the inclusion criteria would lead to a more extensive review of the published literature.

Finally, additional research topics such as high-frequency trading, automated trading bots, and algorithmic sentiment trading should be considered as popularity and use continue to grow. Continued global regulations also need to be monitored to understand the short-term and long-term impacts on cryptocurrency adoption and its implications for the cryptocurrency market.

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