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The Law of One Price and its Impact on Arbitrage Opportunities for Cryptocurrencies

Francis Edmond Taylor
Walden University

Walden University

College of Management and Human Potential

This is to certify that the doctoral dissertation by

Francis E. Taylor

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Review Committee
Dr. Raghu Korrapati, Committee Chairperson, Management Faculty
Dr. Karina Kasztelnik, Committee Member, Management Faculty

Chief Academic Officer and Provost
Sue Subocz, Ph.D.

Walden University
2024

Abstract

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Dissertation Submitted in Partial Fulfillment

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Abstract

Understanding the unprecedented growth of cryptocurrency has challenged professionals and scholars. This study involved addressing the existence of arbitrage opportunities in the Canadian cryptocurrency market. The purpose of this study was to test the theory of the law of one price (LOP) on cryptocurrency in Canada. The LOP demonstrates the value of a financial asset should be the same across different markets. The research questions for this study examined if different exchanges cause arbitrage opportunities in the Canadian cryptocurrency market and if volatility and liquidity were influencers of the arbitrage opportunities between Canadian cryptocurrency exchanges. A quantitative nonexperimental cross-sectional research design was employed with a sample population of almost 3,000 data points collected for four cryptocurrencies across four cryptocurrency exchanges. The data analysis techniques were predictive modeling and a binary logistic regression model. The study results indicated that arbitrage opportunities were found almost 100% of the time, and volatility and liquidity were weak influencers of the arbitrage opportunities. Professionals will become better equipped to protect average and inexperienced investors in cryptocurrency from the study results. The positive social change implications can enable professionals to gain greater insights into supporting and educating investors in high-risk cryptocurrencies who lack risk management knowledge or financial stability to lose a portion or all of their savings.

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Dedication

I dedicate this achievement to my family. To the loving memory of my mother and father – Annemarie and Michael Taylor: when the going was hard, you stuck by me, no questions asked, and this achievement was meant to be my thank-you. To my son Marco, who thought it was "really cool" that his dad was going to be a doctor, but sadly did not get to physically see this final achievement. To the rest of my family: Marea, Taiya, Zoe, Charlie, Shiloh, Lorelei, and Koa: I have been obsessed with completing this, I have been grumpy from lack of sleep, you picked up my slack during my Dissertation Isolations; the content of these pages belong to each of you. Finally, to my sister, Hannah – not only have you done a behemoth job of proofreading all my writings (including this Dedication), but you have also been my biggest cheerleader.

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Chapter 1: Introduction to the Study

Cryptocurrency's rise from a conceptual possibility for blockchain technology in 2008 to a key financial asset by the mid to late 2010s has been unprecedented. Though it is a relatively new financial asset, cryptocurrency is one of the most important financial instruments in the world today (Duczmal & Skomorovski, 2021). Cryptocurrency is the technological advancement of currency into a digital format. While the currency has roots in the internet, the recent success of cryptocurrencies is not based on the currency's seamless ability to be used in online formats.

The advantages of cryptocurrency go beyond its natural online applications. Core characteristics of cryptocurrencies are that transactions are decentralized, unregulated, and anonymous (Inci & Lagasse, 2019). The fact there is no mechanism of regulation or accountability guiding different markets may be driving cryptocurrency growth. These advantages may also be causing cryptocurrencies to break away from conventional ways of understanding financial markets.

An example of discontinuity between cryptocurrency, cryptocurrency markets, and conventional financial thinking is arbitrage opportunities in these markets. Recent studies have found arbitrage opportunities between cryptocurrency markets and noted the role the lack of uniform global regulatory frameworks played in allowing arbitrage to exist (Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Pieters & Vivanco, 2017). The topic of this study is arbitrage opportunities for cryptocurrency as a financial asset. This topic is important to study because the noted types of characteristics and outcomes for cryptocurrencies undermine commonly accepted financial principles, which unwittingly expose average and inexperienced investors to undesirable risk to reward propositions. Gaining a better understanding of arbitrage in cryptocurrency markets will have the positive social impact of better preparing professionals to protect average and inexperienced investors in terms of use of cryptocurrencies to maximize their portfolio performance.

The issue of arbitrage was addressed using the Law of One Price (LOP), which is that assets should be fairly priced by market forces. The LOP is a key principle for understanding financial markets (Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Persson, 2008; Pieters & Vivanco, 2017). The organization of the chapter will cover the background of the topic, problem statement, purpose, research questions, theoretical framework, and research design used to support the study. This is followed by a review of definitions, assumptions, scope, limitations, and significance of the study.

Background of the Study

The concept of money has been around for a long time, and its characteristics and purpose have adapted with the evolution of civilization. Money has been a part of civilization since the 3000 B.C.E., but its role at that time was more of a "social lubricant" (Surowiecki, 2012, p. 46). At the time, money was used more to stimulate social interactions, allowing for markets and fairs to form. It would not be until more current events that money would take on a more important role in the local and global economies.

As the Gregorian calendar turned to the common era, the key economic role of money started to transform. Surowiecki (2012) noted it was not until the seventh century, when standardized metal coins first appeared, that money started to be used as it is today. In the 1600s, as multi territorial and national commerce became more prevalent in local and global economies, adoption of paper money became more widespread (Surowiecki, 2012). These early paper monies suffered from instability and fraud due to overprinting and misrepresentation of the gold or silver that backed the currencies. This led to further evolution of the role and regulations for paper money.

By the 1800s, to help combat concerns over paper money, developed economies introduced financial regulatory bodies, such as the Bank of England and the U.S. Federal Reserve. These regulatory bodies adopted the gold standard. The gold standard is a policy whereby monies are guaranteed to be backed by gold, and paper money holders' notes can be redeemed for gold upon demand (Ross et al., 2022). Concerns regarding deflationary pressures resulting from the gold standard along with new economic realities brought on first by World War I and then the Great Depression ended the gold standard's economic dominance.

By the end of the Great Depression, economies replaced the gold standard with fiat currencies. Fiat currencies are types of money that are not backed by any one commodity, such as gold, but rather has its value based solely on the issuing government's monetary policy and the country's economy (Ross et al., 2022). Money has been able to maintain its financial purpose for thousands of years because of its ability to continuously evolve with the world's economic changes and needs. Fiat currencies remained the dominant source of money until technological changes.

Money has demonstrated resilience by evolving with the rise of current day economic demands. Over the years, technological advances have made the material substance of money less important (Surowiecki, 2012). In its place, electronic payment methods have been adopted (Bezhovski et al., 2021). While electronic payment methods, such as credit/debit cards, digital wallets, payment gateways, and bank transfers, still use fiat currencies, adoption of these types of payment methods by both the business community and the public fostered a demand for further innovation of technology. Bringing into question the role that money plays in the economy.

Current popular opinion places a moral as well as a fundamental criteria on money. Modern economic theory denotes that the worthwhileness of money is based on the three main roles it plays in the economy: storage of value, unit of account, and medium of exchange (Ross et al., 2022). While fiat currencies maintains these three roles, there are concerns that fiat currency leads to too much power for governments and promotes class discrimination (Surowiecki, 2012). Current innovations of money have been pushed to address these concerns, while still maintaining money's current roles. One such innovation is digital currencies.

Digital currencies have been available for over 30 years. Several digital currencies were created but were not adopted, such as DigiCash (1990), e-Gold (1996), and Liberty Reserve (2006), and it was not until 2009 that the first successful digital currency was introduced (Trautman, 2014). Bitcoin, introduced in 2009, was the world's first decentralized cryptocurrency. Being decentralized, cryptocurrencies are neither backed by a government nor a commodity.

Fiat currencies rely on governments and financial regulators to manage risk. Financial risk management history demonstrates that the maintenance of the economy through generally accepted financial principles has been a way for countries to mitigate risks involving inflation, trade, jobs, and overall consumer sentiment (Khan et al., 2019). This has been enabled by regulations of the centralized banking system and markets (Kabašinskas & Šutienė, 2021). Recent technological advances in currency markets have changed the way nations and investors understand financial risk and the theories and principles governing it. This would in turn bringing rise to cryptocurrency adoption.

A recent addition to the financial markets has been the introduction of cryptocurrencies. Cryptocurrencies, which were originally created as a means to safely and securely manage digital transactions, have transitioned into a widely-accepted form of currency (Inci & Lagasse, 2019). Unlike traditional currencies, cryptocurrencies are most notably characterized as being decentralized, unregulated, and anonymous (Inci & Lagasse, 2019). These characteristics have made cryptocurrency markets not only a haven for illicit activities, but a bane for financial and governmental risk managers. Bringing into question the need to regulate cryptocurrency and cryptocurrency markets.

There is no regulation mechanism guiding cryptocurrency markets. This has allowed cryptocurrencies to break away from conventional ways of understanding money and the economy, and eliminated concerns over giving governments too much control and using money for class discrimination. While the benefits of cryptocurrency has been universally recognized, adoption has been limited (Bezhovski et al., 2021; Liang et al., 2021). What hinders adoption of cryptocurrency are concerns regarding how this form of money will meet expectations based on traditional uses of money and generally accepted financial principles. These concerns have gain the attention of professionals and scholars alike.

Cryptocurrency has gained the interest of both professional and scholarly communities. There have been several current studies on cryptocurrency pertaining to illicit activities (Dawson, 2020; Didenko & Buckley, 2018; Foley et al., 2019; Trautman, 2014), financial/governmental regulations (Pieters & Vivanco, 2017; Yin et al., 2019), and investment opportunities as a financial asset (Baur, Dimpfl, et al., 2018; Baur, Hong, et al., 2018; Bayram et al., 2020; Bedi & Nashier, 2020; Corbet et al., 2018; Inci & Lagasse, 2019; Zaher et al., 2020). Findings from these studies are reinforcing the fact that cryptocurrencies are breaking away from generally accepted financial principles. This has generated concerns over the unknown risks associated with cryptocurrency.

One type of risk that has arisen from cryptocurrency's disconnection with generally accepted financial principles within cryptocurrency markets is the opportunity for arbitrage. Arbitrage opportunities arises when investors are able to make profits from simultaneously buying assets in one market and selling them in other markets (Zaher et al., 2020). Recent studies have found arbitrage opportunities between cryptocurrency markets and noted the role that a lack of uniformed, global regulatory framework played in allowing arbitrage to exist (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Pieters & Vivanco, 2017). While these studies have demonstrated the existence of arbitrage, gaps still exist within literature regarding this topic. These gaps have led to the goal of this study.

The goal of the study was to grow the body of knowledge regarding cryptocurrency by focusing on arbitrage opportunities in the Canadian cryptocurrency market. Due to the relative newness and seemingly boundless expansion of different cryptocurrencies and cryptocurrency markets, recent studies have concluded that further studies are required to fully understand arbitrage in these markets (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Pieters & Vivanco, 2017). These conclusions are the foundation of the topic of this study. This topic is important to study because the noted types of characteristics and outcomes for cryptocurrencies undermine generally accepted financial principles, which unwittingly expose average and inexperienced investors to undesirable risk to reward propositions. Gaining a better understanding of arbitrage in cryptocurrency markets will lead to positive social change in terms of better preparing professionals to protect average and inexperienced investors regarding use of cryptocurrencies to maximize their portfolio performance. To address this topic, a research problem statement must be formed.

Problem Statement

The specific research problem that was addressed through this study was: Does arbitrage opportunities exist in the Canadian cryptocurrency market? While cryptocurrency has experienced professional and academic attention due to its unprecedented growth, unlike traditional asset classes, cryptocurrency is most notably characterized as being riddled with high price volatility, burst bubbles, fraud, and collapsed currencies and exchanges (Bruzgė & Šapkauskienė, 2022b). These characteristics fuel the high-risk-high-reward speculative nature of cryptocurrency (Baur, Dimpfl, et al., 2018). Selection of this research problem was based on the underlying social problem created by cryptocurrency's increasing popularity as the evidence of its significance to the financial community, and notable gaps in current literature. This evidence is justification of the importance of this topic to the professional and academic communities. The next section will look at each of the noted social problem to be addressed by this study.

The social problem that prompted this study was that average and inexperienced investors may be accepting unnecessary and increased risks by adding cryptocurrencies to their financial portfolios, due to expectations of improved performance. The characteristics of cryptocurrency and many of its investors undermines the use of commonly accepted financial principles required to understand the risk to rewards relationship associated with an investment (Almeida & Gonçalves, 2023). Such as investors being assured they are getting the market price for their investment. Making cryptocurrency a highly volatile and risky investment that need to be researched to better understand and protect average and inexperienced investors.

While cryptocurrency has gained a lot of attention from both the professional and scholarly communities, there are still a lot of gaps within literature involving arbitrage opportunities for cryptocurrency as a financial asset. Several recent studies have recognized the noted gap within the literature. Zaher et al. (2020) noted there has been a recent research lull in the field of arbitrage in the currency markets that has not kept up with the technological advancement of cryptocurrency. Duczmal and Skomorovski (2021) noted while cryptocurrency is, to date, one of the world's most important financial instruments, there is a need for examination of cryptocurrency and influences that account for arbitrage. Additionally, recent studies involving arbitrage in cryptocurrency markets have noted the need for continued research due to the relative newness and the vastly changing environment of cryptocurrency environments and markets (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Pieters & Vivanco, 2017). Finally, recent blockchain technology and cryptocurrency studies have denoted the need for more and continued research in the field due to the limited amount of empirically backed knowledge on the topic (Liang et al., 2021; Yin et al., 2019; Yuan & Wang, 2018), and to foster the legitimacy of the technology in order for it to be accepted as a real financial instrument (Dawson, 2020; Inci & Lagasse, 2019). The research problem of this study would help to address these noted gaps within the literature. Next, to address the research problem, the intent of the study must be clearly stated by defining the purpose of the study.

Purpose of the Study

The purpose of this quantitative study was to test the theory of the Law of LOP on cryptocurrency and cryptocurrency markets in Canada. LOP models that identical goods must be sold for identical prices at different locations. As a key financial principle, recent studies have indicated the need to continue to study arbitrage in the cryptocurrency markets through LOP theoretical lens (Kabašinskas & Šutienė, 2021; Pieters & Vivanco, 2017). These studies demonstrate the connection between the problem being addressed and the purpose of this study. To fully understand the purpose, the intent of the study needs to be reviewed.

The intent of the study was to compare daily closing price of individual cryptocurrencies between different Canadian cryptocurrency exchanges. The LOP involves comparing the market value of cryptocurrencies across different markets to see if there are arbitrage opportunities. If there are arbitrage opportunities, then the LOP has been violated. The dependent variable, which was daily arbitrage opportunity, was measured as a dichotomous value (yes or no). The independent variable was daily closing prices of different markets. This demonstrated if there were arbitrage opportunities for cryptocurrency within the Canadian market, but did not demonstrate possible influences of such opportunities.

If arbitrage opportunities are found, a subsequent intent of the study would be to demonstrate probable influencers of arbitrage opportunities among Canadian cryptocurrency exchanges. Where arbitrage opportunities were found, relationships measures for volatility and liquidity were tested. The dependent variable was daily arbitrage opportunity (yes or no). Independent variables of this test would be the measurements for volatility and liquidity. To fully realize the intent of the study, the study must answer its research questions.

Research Questions and Hypotheses

In this study, I used the following research questions:

RQ1: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market?

$H_0 1$: Daily closing prices by exchange does not cause arbitrage opportunities in the Canadian cryptocurrency market.

H_a1: Daily closing prices by exchange does cause arbitrage opportunities in the Canadian cryptocurrency market.

The dependent variable of the hypothesis is daily arbitrage opportunity. This is a dichotomous variable (Yes or No to arbitrage opportunity) and is a nominal level of measurement. The independent variable of the hypothesis is the daily closing prices of cryptocurrencies by the different Canadian cryptocurrency exchanges. This is a discrete variable and is a ratio level of measurement. To test if daily arbitrage opportunities do exist (dependent variable), the daily closing price of a cryptocurrency from one exchange was compared to the daily closing price of another exchange (independent variable). If the prices were the same, then the dependent variable will equal No. If the prices were different, then the dependent variable will equal Yes. If it is concluded that arbitrage opportunities do exist between Canadian cryptocurrency exchanges, then a second research question will be tested.

RQ2: To what extent does volatility and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges?

H_02: Volatility and liquidity do not influence arbitrage opportunities between Canadian cryptocurrency exchanges.

H_a2: Volatility and liquidity do influence arbitrage opportunities between Canadian cryptocurrency exchanges.

The dependent variable of the hypothesis was daily arbitrage opportunity. This is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement. The independent variables of the hypothesis were the volatility (based on

Beta) and liquidity (based on bid-ask spread) by cryptocurrency by different Canadian cryptocurrency exchanges. These are discrete variables and are both ratio level of measurement. Based on the results from the initial research question's test, when arbitrage opportunities are found a second set variables for volatility and liquidity will be added to test if there is a relationship between the variables and the occurrence of arbitrage opportunities. If daily volatility and/or liquidity does not have an influence on the existence of arbitrage opportunities, then the null hypothesis will be accepted. If daily volatility and/or liquidity does have an influence on the existence of arbitrage opportunities, then the null hypothesis will be rejected. To understand how the dependent and independent variables are being tested to answer the research question, this study leverages a theoretical framework.

Theoretical Foundation

The theoretical framework that grounded this study was the LOP. While the intellectual history of LOP dates to mid-1700s France, Persson (2008) and Miljkovic (1999) attribute current economic contextualization of LOP to Giovannini (1988). Giovannini (1988) defined the LOP as a model that demonstrates the value of an asset such as currency should be the same value regardless of the market, and should fluctuate between markets. The LOP is a key financial principle that helps investors understand inner workings of market prices.

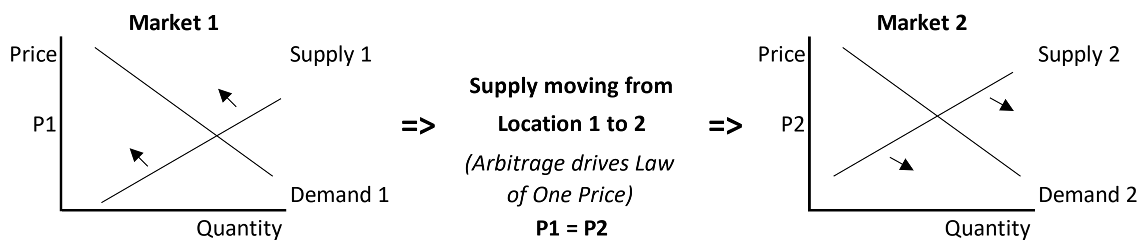
Investors rely on key financial principles to help them understand markets and risk-to-reward relationships. The LOP is a fundamental and unifying economic principle for understanding workings of financial markets and their valuations (Giovannini, 1988;

Kabašinskas & Šutienė, 2021; Kristoufek, 2019; Makarov & Schoar, 2020; Miljkovic, 1999; Persson, 2008; Pieters & Vivanco, 2017; Shynkevich, 2021; Witzel, 2005). LOP ascertains that identical goods must be sold for identical prices regardless of the market. If there are price differences between markets, then the markets' price variance would be quickly corrected through arbitrage.

Arbitrage is the practice of moving supply between markets for profit, which involves buying assets in one market and simultaneously selling them for profit in another market. Transferring the supply from one market to another causes shifts in price for both markets based on supply and demand economics: the decreased supply will cause an increase to the price in the original market; the increased supply will cause a decrease to the price in the destination market. This continues until there are no longer price incentives to transfer supply from one market to another (see Figure 1).

Figure 1

How Arbitrage Sustains the LOP



Misaligned to its label, LOP is not a law of economic and financial theory, but an explanation that is not always maintained. While the LOP is frequently violated, it is still considered a key building block of current financial and economic theory (Giovannini, 1988; Miljkovic, 1999). The LOP is commonly maintained for highly traded commodities and currencies, such as gold and the U.S. dollar (Miljkovic, 1999; Rogoff, 1996). The theory demonstrates that if the LOP is respected between cryptocurrency markets within Canada, then no arbitrage opportunities will be found. This aligns the theoretical framework to the research question of this study, which will be further discussed in Chapter 2. Recent quantitative studies have used the LOP framework to examine if arbitrage opportunities exist between cryptocurrency markets (Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Shynkevich, 2021). This aligns the theoretical framework to the nature of the study, which will be discussed further in the following section, as well as in Chapter 2.

Nature of the Study

To address the research question, a quantitative methodology was used. Recent studies have shown that arbitrage opportunities for cryptocurrencies can be successfully researched using a quantitative method (Bruzgė & Šapkauskienė, 2022b, 2022a; Duan et al., 2021; Foley et al., 2023; Kabašinskas & Šutienė, 2021; Kristoufek & Bouri, 2023; Leung & Nguyen, 2019; Makarov & Schoar, 2020; Shynkevich, 2021; Wątorek et al., 2021; Zaher et al., 2020). The specific research design used followed the work of Bruzgė and Šapkauskienė (2022a, 2022b) and was a nonexperimental cross-sectional research design. These studies successfully demonstrated arbitrage opportunities between cryptocurrency markets. Furthermore, these studies have guided how this study was developed to address the research question.

To answer research questions, daily closing prices and bid-ask spreads of cryptocurrencies were compared to different Canadian cryptocurrency exchanges. The dependent variable was arbitrage opportunities. This is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement. The independent variable was daily close price by individual cryptocurrency of different cryptocurrency exchanges. These are discrete variables and are a ratio level of measurement. To test if daily arbitrage opportunities existed (dependent variable), daily closing prices of a cryptocurrency were compared by different cryptocurrency exchanges (independent variable). If arbitrage was found, a second test was used to validate the relationship between the dependent variable and measures for volatility and liquidity was conducted.

Data for this study came from a secondary source. Daily closing prices and bid-ask spreads are readily available across exchanges. I collected this data on the four leading cryptocurrencies in Canada (Bitcoin, Ethereum, Cardona, and Dogecoin) from six leading Canadian cryptocurrency exchanges (Bitbuy Canada, Bitvo, Coinsquare, Netcoins, Newton, and Wealthsimple). The decision to use data only from after 2018 was made to address mixed results of current studies focused on the maturity of cryptocurrency and inconclusive conclusions if arbitrage opportunities disappeared for cryptocurrency between cryptocurrency markets after 2018 (Krückeberg & Scholz, 2020; Shynkevich, 2021; Vidal-Tomás & Ibañez, 2018). This dataset can easily be entered into IBM SPSS or Microsoft Excel for data measurement and statistical analysis.

The use of daily data is not uncommon. Bruzgė and Šapkauskienė (2022a, 2022b) studies focused on analyzing a dataset that had tickertape level records (prices compared at the seconds time intervals). Hansen et al. (2024) study used daily closing price for its analysis. For this study, daily closing prices and bid-ask spreads were used. The decision to use end-of-day data was made to address findings noted by Foley et al. (2023) and Wątorek et al. (2021). These studies found that inefficiencies in terms of flow/documentation of data/information from cryptocurrency exchanges may be the cause of findings that have shown arbitrage opportunities between cryptocurrency markets. Focusing on daily closing prices will eliminate any information flow and documentation concerns by addressing data points that are static. To fully understand the noted research design and other components of this study, a comprehensive list of definitions of the terms used in this study will be reviewed next.

Definitions

In this study, I used the following terms:

Arbitrage: The action of making a profit by simultaneously buying an asset in one market and selling it in another market (Zaher et al., 2020). For this study, arbitrage is the dependent variable.

Bid-Ask Spread: A key concept in financial markets which represents the difference between the highest price a buyer is willing to pay for a security (bid price) and lowest price that a seller is willing to accept (ask price) at a given point in time (Ross et al., 2022).

Beta Coefficient: Measure of the systematic risk or volatility of a particular financial asset in relation to the overall market (Ross et al., 2022). Also referred to as Beta or β.

Bitcoin: Launched in 2009, Bitcoin was the first and currently the most popular cryptocurrency in terms of valuation and transaction volume, and it led to the possibility for future cryptocurrencies (Almeida, 2021).

Blockchain Technology: Digital historical ledger of unalterable and transparent logs of information that was launched in 2008 (Liang et al., 2021).

China Shock: In 2017, Chinese authorities attempted to control cryptocurrency markets by using regulations to illegalize cryptocurrency. These actions had large spillover effects into other cryptocurrency markets, notably South Korea and Japan (Borri & Shakhnov, 2020).

Cybercriminality: Illicit activities that are facilitated or financed via the dark web or criminal digital networks (Corbet et al., 2019).

Cryptocurrency: Digital based currency where transactions are verified and records are maintained via a decentralized system using blockchain technology (Makarov & Schoar, 2020).

Daily Market Value: End-of-day market price for a financial asset.

Dark Web/Deep Web: A component of the Internet that is only accessible by specialized software and operations that are anonymous and untraceable (Dawson, 2020).

Decentralized Currency: For a currency to be considered decentralized, it must be both immune to intervention and manipulation by a trusted third party (bank) or its creator (government) (Khaki et al., 2023).

Digital Currency: Form of currency that is in a digital or electronic format (Surowiecki, 2012).

Diversification/Portfolio Diversification: An investment strategy that reduces risk by collectively holding assets that are negatively correlated, meaning volatility and valuation of two different assets have opposite reactions under similar market scenarios (Markowitz, 1952). This is also referred to as the principle of diversification.

Effective Market Hypothesis: The hypothesis that new information should immediately be reflected in current valuations of financial assets (Celeste et al., 2020).

Fiat Currency: Type of money that is not backed by a commodity but is formally controlled (Makarov & Schoar, 2020). Both U.S. and Canadian dollars are considered fiat currencies.

Financial Asset: Physical and nonphysical assets that derive valuation from an underlying market or market efficiencies (Inci & Lagasse, 2019). Traditionally, these types of assets include commodities (gold), currencies (U.S. dollar), equities (stocks), and contracts (insurance). Recently, cryptocurrencies have started to be considered financial assets (Baur, Dimpfl, et al., 2018; Bouri et al., 2020; Chemkha et al., 2021; Nedved & Kristoufek, 2023).

Hedge: A financial asset that is negatively correlated with just one other financial asset (Markowitz, 1952).

Kimchi Premium: Notable higher price for cryptocurrency in South Korea in comparison to the price of cryptocurrency in the United States (Lee & Oh, 2022).

Law of One Price (LOP): The theory that there is a uniform price for same goods, regardless of where they are traded (Crépellière & Zeisberger, 2020).

Liquidity: Measure of how quickly financial assets can be turned into cash (Brauneis & Mestel, 2018). The inverse of liquidity is illiquidity.

Price Efficiency/Price Discovery: refers to the Efficient Market hypothesis, a financial principle that assumes that market prices for financial assets which openly reflect all available information (Kang et al., 2022). The inverse of price efficiency is price inefficiency.

Price Parity: The theory that the price of goods or services should be consistent across all markets (Rogoff, 1996). The inverse of price parity is price disparity.

Safe Haven: Financial asset that is negatively correlated to another financial asset in times of turmoil (Markowitz, 1952).

Systematic Risk: Risk that is global or inherent to financial markets (Ross et al., 2022).

Systematic Risk Principle: Reward for bearing the risk of a financial asset depends solely on the financial asset's systematic risk (Ross et al., 2022).

Ticker Tape Prices: Up-to-date electronic price quotes for financial assets. This is also referred to as tick-level data.

Unsystematic Risk: Risk that is unique to an individual or small group of financial assets, such as a company or an industry (Ross et al., 2022).

Volatility / Price Volatility: Amount of risk associated to a financial assets based on fluctuations to its market price (Ross et al., 2022).

Assumptions

I assumed markets were dominated by mature investors, rather than speculators and gamblers. This allowed for generally accepted financial and economic principles such as the LOP to be regarded as guiding actions of the market.

I assumed all transaction costs were openly known to all investors. This ensured differences in transaction costs were not confused in terms of arbitrage opportunities and their removal from daily market price was justified.

Scope and Delimitations

The scope of a dissertation structures the study to address the research question (Theofanidis & Fountouki, 2018). The focus of this study was Canadian cryptocurrency and cryptocurrency exchanges. This means that the study was bounded by the criteria in which the cryptocurrencies and cryptocurrency exchanges were selected. The selection criterion for the selection of cryptocurrencies used in the study was the most popular cryptocurrencies in Canada. The selection criteria for Canadian cryptocurrency exchanges were the exchanges were required to support selected cryptocurrencies, prices were quoted and paid out in Canadian dollars to remove foreign exchange costs, and exchanges had to be approved by Canada’s largest security committee, which was the Ontario Security Committee.

Delimitations of a study limit or narrow parameters to help meet objectives (Theofanidis & Fountouki, 2018). I disregarded unpopular cryptocurrencies and exchanges that do not support the selected cryptocurrencies, prices that were not quoted in or paid out in Canadian dollars, and exchanges that had not been approved by the Ontario Security Committee.

Based on the scope the delimitations, the potential generalizability of the study refers to how well the findings of the study can be applied to the broader population. Based on other recent studies (Bruzgė & Šapkauskienė, 2022b; Makarov & Schoar, 2020), the expectation was this study would replicate the findings of inter-market arbitrage opportunities for cryptocurrency as a financial asset within the Canadian market. In turn, the findings added to current knowledge regarding arbitrage opportunities for cryptocurrencies and potential influencers of the arbitrage opportunities. Understanding the scope and delimitations of the study has demonstrated the boundaries of the study. The next section will review any potential constraints within the boundaries of the study.

Limitations

Data required for this study were free and readily available to the general public. The financial theory and Excel knowledge required to analyze the data is possessed by the author who has two accounting designations. Therefore, the feasibility and permission required to collect and analyze the data were solely linked with the decision to complete the study or not. This decision was based on the potential of this study to not only add to the current knowledge of cryptocurrencies theories by addressing limitations of other current studies, but by also demonstrating positive potential for managerial and social gains.

The benefit of this study had both managerial and social impacts. Understanding existence of arbitrage for cryptocurrencies and, therefore, the violation of LOP, will help practitioners and educators demonstrate how exchange rate risk between cryptocurrency exchanges can be managed or mitigated to create optimal application and portfolio management opportunities for cryptocurrencies. Knowledge of arbitrage between cryptocurrency markets can be the foundation for institutionalized regulations between markets to ensure fair pricing. This will lead to social change via giving knowledge to professional investors and educators to help protect average and inexperienced investors when investing in cryptocurrency.

The main limitation to this study was that past performance is not fully indicative to future performance. This is due to the fact that cryptocurrencies are most notably characterized as being decentralized, unregulated and anonymous, and therefore synonymous to illegal activities (Inci & Lagasse, 2019). The evolving nature of cryptocurrencies and their markets was noted as a limitation in many of the current studies (Inci & Lagasse, 2019; Kabašinskas & Šutienė, 2021; Pieters & Vivanco, 2017; Zaher et al., 2020). A change to any one of these characteristics could have drastic effects on the future behaviors of cryptocurrencies and render data collected on past behaviors redundant. These limitations did not diminish the significance of the study.

Significance of the Study

Cryptocurrency was not the first attempt to create a unique digital currency. DigiCash (1990), e-Gold (1996), and Liberty Reserve (2006) were introduced to the financial markets, but failed to gain acceptance over more traditional forms of digital payment systems such as debit and credit cards or payment gateways, such as PayPal (Trautman, 2014). The reason for the lack of adoption was that these digital currencies did not offer any unique characteristics to attract users away from their traditional payment forms. With the creation of Blockchain technology in 2008 and the subsequent introduction of Bitcoin, the first Blockchain based cryptocurrency, in 2009, the landscape of digital currencies changed drastically.

As a decentralized currency, cryptocurrency offers several unique characteristics that its predecessors and fiat currencies do not. Most notable of these unique characteristics of a decentralized currency is that its transactions are unregulated and anonymous (Inci & Lagasse, 2019). The intention behind the initial cryptocurrency, Bitcoin, was to create a peer-to-peer payment system that could process payments without the costs or regulations from third parties (Nakamoto, 2008). Conversely, it was not the cost effectiveness of Bitcoin that fostered the unprecedented speed of its acceptance and growth – it was the decentralized and anonymous characteristics of blockchain technology that fostered unprecedented speed of acceptance and growth.

Since its introduction in 2009, cryptocurrency has seen unparalleled acceptance and growth. The growth of cryptocurrency from being worthless in 2009 to over $2 trillion U.S. dollars in 2021 has made it into one of the most important technological advancements of the information age (Duczmal & Skomorovski, 2021; Yuan & Wang, 2018). The growth of cryptocurrency since Bitcoin's introduction in 2009 has been exponential. Table 1 demonstrates the drastic growth of cryptocurrencies from 2018 to 2022, with the number of users increasing 1,049%, number of cryptocurrencies increasing 462%, and market capitalization of cryptocurrencies increasing 556% (de Best, 2022). In fact, Delfabbro et al. (2021) noted growth of cryptocurrencies is happening so rapidly that any data cited as recently as 3 months earlier can be considered outdated.

Table 1

Cryptocurrency Growth From 2018 to 2022

	2018	2019	2020	2021	2022	Growth from 2018 to 2022
Number of Users (millions)	35	101	106	306	402	1,049%
Number of Cryptocurrencies	1,658	2,817	4,501	7,557	9,310	462%
Cryptocurrency Market Cap (billions USD)	128	191	752	2,369	841	556%

The attention cryptocurrency has gained has not been all positive. While advocates of cryptocurrency emphasize its ability to improve biased and corrupt financial systems, opponents of cryptocurrency identify its role in cybercriminality and other illicit activities (Corbet et al., 2019). The meteoric rise of cryptocurrency has been marked by high price volatility, burst bubbles, fraud, and collapsed currencies and exchanges (Bruzgė & Šapkauskienė, 2022b), thus fueling high risk, high reward speculative nature of cryptocurrencies (Baur, Dimpfl, et al., 2018). These characteristics of cryptocurrency have made it a topic of interest for professionals and non-professionals. This increased attention has served to increase the acceptance of cryptocurrency.

The high risk, high reward characteristic of cryptocurrency has given the financial asset a sense of excitement and uncertainty to the financial markets. The increased excitement and uncertainty of cryptocurrency has attracted substantial attention from professionals, scholars, governments, and the general public (Angerer et al., 2021; Bedi & Nashier, 2020; Bruzgė & Šapkauskienė, 2022b; Jeris et al., 2022; Zhang et al., 2018). The increased attention for cryptocurrency is demonstrating how little is known about this relatively new financial asset. Putting into question what is actually driving the acceptance of cryptocurrency.

The adoption of cryptocurrency as a financial asset cannot be questioned. While cryptocurrencies are being accepted as a new form of payment systems and financial asset, there still remains “skepticism and a lack of understanding of their nature” (Charfeddine et al., 2020, p. 198). One topic of incomplete knowledge surrounding cryptocurrencies is the existence of arbitrage opportunities between cryptocurrency markets (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Krückeberg & Scholz, 2020; Makarov & Schoar, 2020; Shynkevich, 2021). The significance of this study was the advancement of the knowledge of arbitrage opportunities for cryptocurrency as a financial asset. To demonstrate how the knowledge advanced the theory, practice, and social change contribution of this study will now be reviewed.

Significance to Theory

Theoretically, cryptocurrency is a relatively new but critical phenomenon, and has garnered much discussion in current literature. Recent studies have focused on cryptocurrency as a financial asset (Corbet et al., 2019), its relationship with other financial assets (Nedved & Kristoufek, 2023), enhancing portfolio performance (Inci & Lagasse, 2019), governmental and financial regulations (Borri & Shakhnov, 2020; Lee & Oh, 2022), cybercriminality (Dawson, 2020; Foley et al., 2019), and arbitrage (Bruzgė &

Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020). Advancing knowledge regarding how to analyze arbitrage opportunities between cryptocurrency markets through traditional financial theory would help to increase the integrity of cryptocurrency as a financial asset (Krückeberg & Scholz, 2020) and the efficiency of financial markets (Shynkevich, 2021). The expectation is that the academic theory would be advanced by scholars adhering to the conclusion of the noted studies. Bringing into question the completeness of the current body of work on this topic of interest.

The academic literature for arbitrage opportunities for cryptocurrency as a financial asset is lacking. Duan et al. (2021) noted that studies on arbitrage opportunities in the cryptocurrency market are surprisingly “scant” (p. 1). Recent studies have generalized these findings and have noted that research has not kept up with either the technological advancements involving cryptocurrency or influencers of arbitrage opportunities for cryptocurrency as a financial asset (Duczmal & Skomorovski, 2021). This study is significant in that it will address this gap in literature. This will allow for scholars to better inform practitioners of the nature and influences of cryptocurrencies.

Significance to Practice

Despite being 15 years old, cryptocurrency is a relatively new financial asset. In comparison to other financial assets, cryptocurrencies and their markets are considered to be in their infancy (Bruzgė & Šapkauskienė, 2022b). Bringing into question how cryptocurrency may change as it develops into a mature financial asset. In practice, this developmental characteristic of cryptocurrency should be mitigated by the low level of impact cryptocurrency has on the financial markets.

There is an imbalance between the financial magnitude of cryptocurrency and what is known about the financial asset. Despite early development status, cryptocurrency as a financial asset has had an immense impact on the financial markets (Bedi & Nashier, 2020; Bouri, Gil-Alana, et al., 2019; Bruzgė & Šapkauskienė, 2022b; Leung & Nguyen, 2019; Makarov & Schoar, 2020). Wątorek et al. (2021) concluded cryptocurrency markets are less synchronized in comparison to other financial markets due to a lack of understanding of influences of the market. This is evident by the belief that arbitrage opportunities are available between cryptocurrency markets. Giving rise to the questions if arbitrage opportunities exist and, if so, what is influencing arbitrage opportunities for cryptocurrency as a financial asset.

Gaining a better understanding of arbitrage opportunities for cryptocurrency as a financial asset will help professional investors better manage cryptocurrencies. Recent studies have denoted that a more current and expressive understanding of arbitrage opportunities in cryptocurrency markets will enable investors to gain a better understanding of how to use important financial indicators and instruments, such as interrelationships between markets (Bruzgė & Šapkauskienė, 2022b; Wątorek et al., 2021), trading strategies (Kabašinskas & Šutienė, 2021; Leung & Nguyen, 2019; Makarov & Schoar, 2020), price assumptions for adaptation to Futures markets (Shynkevich, 2021), optimal portfolio management (Bianchi et al., 2019; Krückeberg & Scholz, 2020), hedging strategies (Bruzgė & Šapkauskienė, 2022b; Salisu et al., 2019), and portfolio diversification (Charfeddine et al., 2020; Inci & Lagasse, 2019; Mensi et al., 2019). I planned to advance the practice of investing in cryptocurrency by gaining a better understanding of the extent of arbitrage opportunities for Canadian cryptocurrency exchanges. This will in turn allow for financial analysts and other professional investors to better serve and direct their customers and the general public.

Significance to Social Change

With the rapid growth of cryptocurrencies, both experienced and inexperienced investors are being attracted to invest (Delfabbro et al., 2021). The danger is that average and inexperienced investors have neither the risk management nor the financial stability to lose a portion or all their savings. An increased understanding of cryptocurrency as a financial asset needs to be created by professional investors and scholars to help protect average and inexperienced investors.

Due to cryptocurrency's high volatility, social media misrepresentations, and a lack of generally accepted financial principles to support trading rituals, average and inexperienced traders may be exposing themselves to unwanted or even unnecessary risks. Recent studies have found that cryptocurrency investments are mostly made for speculation purposes and may be unwittingly exposing average and inexperienced financial investors to unwanted or unnecessary risk (Baur, Dimpfl, et al., 2018; Baur, Hong, et al., 2018; Corbet et al., 2018). This risk is compounded by the fact that non-professional investors in cryptocurrency erroneously regards their investment to have the same characteristics as more common, traditional assets (Kim et al., 2020). These characteristics demonstrate that there are more influences on certain investor's behaviors than just inexperience. To protect investors, these other influences need to be reviewed.

Overexposure to risk may not be due to inexperience, but rather the mental state of the investor. Recent studies have likened the behaviors of non-professional investors of cryptocurrencies to that of online gamblers (Delfabbro et al., 2021; Mills & Nower, 2019), risk-seekers (Pelster et al., 2019), and irrational investors (Almeida & Gonçalves, 2023; Ballis & Drakos, 2020; Kaiser & Stöckl, 2020; Tjondro et al., 2023). Almeida and Gonçalves (2023) and Delfabbro et al. (2021) noted the need for professionals and scholars to gain a better understanding of strategies to protect average and inexperienced cryptocurrency investors from harm, while still allowing them to benefit from investing in cryptocurrencies. As noted in the prior two sections, a greater understanding of the extent of arbitrage opportunities between Canadian cryptocurrency exchanges would allow the use of generally accepted financial principles when dealing with cryptocurrencies.

It is the responsibility of professional investors and scholars to create the knowledge necessary to protect average and inexperienced investors. Bruzgė and Šapkauskienė (2022b) noted that a more in-depth understanding of arbitrage opportunities would allow investors a better understanding of the interrelationships between cryptocurrency markets and how this can be employed to create optimal financial portfolios. The increased understanding of cryptocurrency and cryptocurrency exchanges would have the positive social impact of helping to preserve average and inexperienced investors' savings for retirement and their children's education by reducing unnecessary or unwanted risk. This demonstrates the positive social change significance of this study.

Summary and Transition

Cryptocurrency’s rise from a conceptual possibility for blockchain technology in 2008 to a key financial asset by the mid to late 2010s has been unprecedented. In comparison to traditional financial assets, cryptocurrency is still in its infancy stage (Bruzgė & Šapkauskienė, 2022b). Despite the relative newness of cryptocurrency, its effect on the financial markets cannot be denied. This has been seen in the drastic increase in users, number of cryptocurrencies, and cryptocurrency’s market capitalization growth since its introduction in 2009.

Cryptocurrency’s growth has been meteoric. In 15 years, the market capitalization of all cryptocurrencies has gone from $0 in 2009 to $841 billion USD in 2022, and grew 556% from 2018-2022 (de Best, 2022). Not only is cryptocurrency trading the fastest growing market in the world (Delfabbro et al., 2021), but, along with the introduction of the personal computer and the internet, cryptocurrency is seen as one of the most disruptive innovations of the information age (Duczmal & Skomorovski, 2021; Yuan & Wang, 2018). This is a long way from its simple beginnings.

Originally cryptocurrency was created to be a decentralized, peer-to-peer digital payment system. Cryptocurrency has grown into a revolutionized financial asset that has gained considerable interest from scholars, professionals, governments, and the general public (Angerer et al., 2021; Bedi & Nashier, 2020; Bruzgė & Šapkauskienė, 2022b; Jeris et al., 2022; Zhang et al., 2018). While cryptocurrency is being accepted as a new form of payment system and financial asset, there still remains "skepticism and a lack of understanding of their nature" (Charfeddine et al., 2020, p. 198). The uncertainty surrounding cryptocurrency has to do with its inconsistency with traditional financial performance indicators and a general lack of knowledge of cryptocurrency as a financial asset.

One topic of incomplete knowledge for cryptocurrencies is the existence of arbitrage opportunities between cryptocurrency markets. Recent studies have focused on arbitrage opportunities for cryptocurrency as a financial asset (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Krückeberg & Scholz, 2020; Makarov & Schoar, 2020; Shynkevich, 2021). To advance the knowledge for scholars, practitioners, governments, and the general public, this quantitative study addressed the extent that arbitrage opportunities exist between Canadian cryptocurrency exchanges, using LOP as its theoretical framework, and evaluated the extent of the relationship between arbitrage opportunities and volatility and liquidity.

The literature review conducted for this study concurred with Charfeddine's et al. (2020) noted findings that there is lack of consistency within the knowledge of cryptocurrency. A lot of recent studies have been conducted on cryptocurrency, not only on arbitrage, but also on cryptocurrency as a financial asset (Corbet et al., 2019), cryptocurrency's relationship with other financial assets (Nedved & Kristoufek, 2023), enhancing portfolio performance (Inci & Lagasse, 2019), governmental and financial regulations (Borri & Shakhnov, 2020; Lee & Oh, 2022), and cybercriminality (Dawson, 2020; Foley et al., 2019). Much of the recent research has resulted in mixed results, demonstrating the gaps within the literature and the need for further research into cryptocurrency. Chapter 2 of this study will review in detail the noted literature review and highlight the current gaps in literature and the relevance to this study.

Chapter 2: Literature Review

The social problem prompting this study was that average and inexperienced investors may be accepting unsuitable risks by adding cryptocurrencies to their financial portfolios due to expectations involving improved performance. The purpose of this study was to increase knowledge of cryptocurrencies as a financial asset by addressing the question of arbitrage opportunities for cryptocurrencies as a financial asset within the Canadian market. Arbitrage opportunities are a violation of the LOP, which is a fundamental and unifying economic and financial principle for understanding workings of financial markets and their valuations.

I conducted a systemic review of over 150 articles focused on cryptocurrencies as a financial asset found four trends and seven key topics of interest. This chapter starts with a review of search strategies used for collecting literature for this study, followed by a literature review of the theoretical foundation, a literature review of the noted four trends and seven key topics of interests, and information regarding how I addressed the gap in literature.

The introduction of Blockchain technology in 2008 enabled the creation of the world's first decentralized, peer-to-peer digital currency, which was called Bitcoin, in 2009. Since then, Bitcoin's success has been a catalyst for the creation of almost 10,000 other decentralized digital currencies, known collectively as cryptocurrency, with a market capitalization of almost $1 trillion USD in 2022 (de Best, 2022). The rise of cryptocurrency has been meteoric, to the point where it is seen as one of the key innovations of the information age (Duczmal & Skomorovski, 2021; Yuan & Wang, 2018). Regardless of the status of cryptocurrency, it is still a relatively new financial asset and should be consistently studied to maintain knowledge as it transitions into a more mature financial asset.

Cryptocurrency is 15 years old. For some investors, cryptocurrency has been around for their entire investing careers. Conversely, cryptocurrency and cryptocurrency markets are still regarded as immature financial assets that are lacking generally-accepted financial principles (Celeste et al., 2020; Kang et al., 2022). This hinders professional investors and scholars from helping average and inexperienced investors because they cannot rely on generally accepted financial principles to guide their understanding of investment strategies and risk management. To be better prepared to help average and inexperienced investors, professional investors and scholars need to look at current literature to address cryptocurrency as a financial asset.

A review of the academic literature is not needed to confirm the growing popularity of cryptocurrency as a financial asset. Current studies of cryptocurrencies have found them to be disconnected from generally accepted financial principles, and lack generalization of findings (Angerer et al., 2021; Corbet et al., 2019). The review of the academic literature for this study found there is little known about cryptocurrency in comparison to traditional financial assets and financial principles, and collectively there are few conclusive findings. Beyond that, literature demonstrated cryptocurrency is gaining attention from a wide range of groups, and average and inexperienced cryptocurrency investors are unknowingly adding excess risks to their financial portfolios.

Cryptocurrency has seen diverse growth. The current literature has confirmed that cryptocurrency is growing in popularity with scholars, investment communities, regulators, governments, and the general public (Almeida & Gonçalves, 2023; Angerer et al., 2021; Bedi & Nashier, 2020; Bruzgė & Šapkauskienė, 2022b; Jeris et al., 2022; Zhang et al., 2018). This can be a challenge for professional investors and scholars in terms of who is investing in cryptocurrency as a financial asset and what knowledge is needed to best support them.

A challenge to scholars is the rapid growth of cryptocurrency among diverse populations. Both experienced and inexperienced investors are being attracted to investing in cryptocurrency as a financial asset (Delfabbro et al., 2021). The need for new knowledge for both experienced and inexperienced investors can be quite different. In addition. data collected for cryptocurrency studies would have the effect of both parties' diverse influences. Which could lead to mixed results.

Experienced investors need knowledge to help them understand in what capacity cryptocurrency as a financial asset can be used to meet specified and individualized financial portfolio mandates. Experienced investors are finding investing in cryptocurrency as a financial asset challenging due to a disconnect from generally accepted financial principles and a lack of generalization of academic findings (Angerer et al., 2021; Corbet et al., 2019). This means that experienced investors are challenged by the danger of adding cryptocurrency as a financial asset to their traditional investment and risk management strategies. It can also lead to an inability to support average and inexperienced investors' needs for investing guidance.

Average and inexperienced investors are unwittingly in danger of taking on too many risks due to cryptocurrency's high volatility, social media misrepresentations, and lack of generally accepted financial principles to support trading rituals. Recent studies have found that cryptocurrencies are, for the most part, an asset for speculation, and thus may unwittingly expose average and inexperienced financial investors to unwanted risk (Baur, Dimpfl, et al., 2018; Baur, Hong, et al., 2018; Corbet et al., 2018). Typically, average and inexperienced investors have neither risk management resources nor financial stability to expose their investments to high levels of risk. Average and inexperienced investors cannot leverage support of experienced investors due to lack of academic knowledge regarding cryptocurrency as a financial asset. The subsequent sections will detail the noted literature review and the strategy for finding the current academic literature.

Literature Search Strategy

For this study, a literature review strategy was used that followed the process used by Almeida and Gonçalves (2023) in their systemic review of investors' behaviors in the cryptocurrency markets. Articles were chosen that included information about cryptocurrencies as a financial asset and specified knowledge regarding the LOP and definitions. This included quantitative, qualitative, mixed methods, and systemic studies but excluded newspapers, magazines, or conference material. All articles were full text and peer-reviewed. The literature review research protocol can be reviewed in Table 2.

I found literature via the Walden University Library. The Walden University online Library collects data from 173 databases, including ScienceDirect, Emerald

Insight, Business Source Complete, and SAGE Journals. Searches were limited to results that had full text, were from peer-reviewed scholarly journals only, and not published prior to 2009. This was due to cryptocurrency's introduction date. But I focused mainly on sources that were published between 2018 and 2024. The keywords used for the initial search were *cryptocurrency*, *arbitrage*, *blockchain*, *Bitcoin*, *Ethereum*, *investment opportunities*, and *trading strategies*.

From the initial search in the online Walden Library, 49 articles were found. Of these articles, 10 were duplicates or deemed irrelevant to the study. All remaining articles were reviewed and several highly relevant articles were found for this study using this method, including Kabašinskas and Šutienė (2021) and Makarov and Schoar (2020). From there, Google Scholar was used to find and assess all articles that were either cited by relevant articles originally found sources or cited the relevant articles originally found source. I expanded the topic of interest beyond arbitrage to account for other topics such as financial assets, regulations, behaviors of investors, cybercriminality, portfolio diversification, safe haven and hedge properties, and price efficiencies. While the topic of interest expanded based on this strategy, the focus on cryptocurrency remained. Several highly relevant studies were found for this study using this method, including Bruzgė and Šapkauskienė (2022b) and Krückeberg and Scholz (2020). This process was repeated until saturation was met. All articles were vetted to be from peer-reviewed scholarly journals through the Walden University Library's online search tool.

While the literature review research protocol was sufficient in uncovering a complete representation of the current literature for cryptocurrency as a financial asset, additional specialized sources were still required. Further to the initial search, other searches were conducted in the Walden University online Library and Google Scholar for more specific or specialized data, such as theories, definitions, and statistical data. Additional keywords were added to the searches: law of one price; purchasing power parity; and cryptocurrency market data. The criteria for peer-reviewed articles were reduced for material that was deemed to have come from expert sources, such as textbooks, research platforms, and trade papers. All found articles reviewed were entered into a Literature Matrix for reference and recall.

Table 2

Literature Review Research Protocol

Parameters	Specifications
Criteria for considering studies for this review	• Studies that contributed to the knowledge of cryptocurrencies as a financial asset; • Studies that offered specified knowledge, such a Law of One Price (LOP) and definitions; • Quantitative, Qualitative, Mixed Methods, and Systemic Literature Review studies; • Excluded newspapers/magazines and conference material; • Included, for specified knowledge, research platforms and trades papers.
Search strategy for identification of studies	• Studies that contributed to the knowledge of cryptocurrencies as a financial asset; • Studies that offered specified knowledge, such a Law of One Price (LOP) and definitions; • Quantitative, Qualitative, Mixed Methods, and Systemic Literature Review studies; • Excluded newspapers/magazines and conference material; • Included, for specified knowledge, research platforms and trades papers.
Eligibility	Included topics: • Financial Asset • Regulations • Investment behaviors • Illicit activities / cyber criminality / cybercriminality • Portfolio diversification • Safe haven / hedge properties • Efficiency / price discovery • Arbitrage Excluded topic • Blockchain technology related themes; • Mining related themes.
Data Collection	• Full text; • Academic Journals.
Assessment of methodological quality	• Articles only from peer-reviewed scholarly journals.

Theoretical Foundation

The theoretical framework of this study is the LOP. The origins of the LOP are not fully known, but dates back to mid-1700s France. Miljkovic (1999) and Persson (2008) attributed the modern day understanding of the LOP to Giovannini (1988), which defined the LOP as a model that demonstrates that the value of an asset, such as currency, should be the same value regardless of the market, and the value should fluctuate in tangent between markets. When prices are normalized for localized costs, such as duties, fees, transportation, and transaction costs, the LOP established that identical goods must be sold for identical prices regardless of the market.

If the LOP is violated, then market forces would react to the profit-making opportunity by transferring the supply from one market to another market. This will cause a shift in price for both markets based on supply and demand economics: the decreased supply will cause an increase to the price in the original market; the increased supply will cause a decrease to the price in the destination market. This will continue until there is no longer a price incentive to transfer the supply from one market to another. This reaction to the violation of the LOP is known as arbitrage: the practice of moving supply between markets for a profit; buying the assets in one market and simultaneously selling the asset for a profit in another market.

The LOP is a generally accepted financial principle and is popular amongst professional investors and scholars alike. The LOP is considered a fundamental and unifying economic principle for understanding the workings of financial markets and their valuations. The LOP works best for studies focused on highly-traded commodities or currencies (Giovannini, 1988; Miljkovic, 1999; Persson, 2008; Rogoff, 1996). To which, The LOP has been used as the theoretical foundation for several recent studies on cryptocurrency as a financial asset (Kabašinskas & Šutienė, 2021; Kristoufek, 2019; Makarov & Schoar, 2020; Pieters & Vivanco, 2017; Shynkevich, 2021, 2023; Witzel, 2005). It is commonly found the LOP can be violated. Resulting in arbitrage opportunities.

Arbitrage opportunities allow for the LOP violations to get back to market equilibrium. Bayram et al. (2020) noted that markets can be dislodged from their equilibrium when they are disrupted by significant change that make traditional principles less useful, and that the introduction of cryptocurrency to the financial markets is one of those disruptive occurrences. Recent studies have used the LOP as their theoretical framework for studies focused on cryptocurrency (Kristoufek, 2019) and arbitrage in the cryptocurrency markets (Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020; Pieters & Vivanco, 2017; Shynkevich, 2021). This demonstrates the LOP has been able to maintain its status as a foundational economic principle as the financial markets transitioned into the age of cryptocurrencies. Answering the question if the LOP is still a relevant framework for studies focused on arbitrage opportunities for cryptocurrency as a financial asset.

The LOP is a common theoretical framework to understand arbitrage opportunities. Recent cryptocurrency studies that have used the LOP as the theoretical framework have had successful results (Kabašinskas & Šutienė, 2021; Kristoufek, 2019; Makarov & Schoar, 2020; Pieters & Vivanco, 2017; Shynkevich, 2021; Witzel, 2005). Kristoufek's (2019) study used the LOP to construct a theoretical exchange rate between Bitcoin and the U.S. dollar. The study found that the price dynamics between the two currencies are properly valuated using the LOP. This study is only one of several to review arbitrage opportunities for cryptocurrency as a financial asset.

The use of the LOP to help understand arbitrage opportunities is common. Kabašinskas and Šutienė's (2021) study used the LOP to explore arbitrage opportunities across a network of 20 cryptocurrency markets. The study found that an arbitrage strategy between exchanges can be developed to maximize profits. Makarov and Schoar's (2020) study used the LOP to help demonstrate their findings that arbitrage opportunities between cryptocurrency exchanges are more substantial across borders and less substantial between individual cryptocurrencies. Pieters and Vivanco's (2017) study used the LOP framework to successfully demonstrate how regulations of different markets caused pricing inefficiencies for Bitcoin due, in part, to the premiums investors are willing to pay for increased anonymity. Shynkevich's (2021) study used the LOP to demonstrate how cryptocurrencies' deviations from price parity were more substantial from 2016 to 2017, and less substantial afterwards.

The LOP is considered a generally accepted financial principle. While the LOP is frequently violated, it is a key building block of current financial and economic theory (Giovannini, 1988; Miljkovic, 1999), and is still maintained to understand highly traded currencies (Miljkovic, 1999; Rogoff, 1996). The reliance of the LOP as a lens to research currencies, has been able to transition into the digital age. This can be seen in the LOP's successful use in the noted recent studies. The theory demonstrates that if the LOP is respected between cryptocurrency markets within Canada, then no arbitrage opportunities will be found.

In an effort to build off of the success of these noted studies and offer the readers a universal and easy lens with which to understand how markets keep asset prices in balance, the LOP will be used as the theoretical theory for this study. Shynkevich (2021) noted the LOP plays an important role in the financial markets and the understanding of the existence of arbitrage. Studies by Kristoufek (2019) and Makarov and Schoar (2020) noted their selection of the LOP as a framework to help describe their studies and findings due to it being a fundamental economic law. Persson (2008) noted that you cannot comprehend the impact of arbitrage on prices and trade without referring to the LOP. These findings from recent studies justifies the use of the LOP in helping to answer the main research question of this study: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market? This study will now look to the current and relevant scholarly work completed on the topic of cryptocurrency as a financial asset.

Literature Review

Due to its recent surge in both popularity and valuation, cryptocurrency has been broadly studied. In the context of traditional financial assets, cryptocurrency, though in its infancy, has been extensively examined (Bruzgė & Šapkauskienė, 2022b). While these studies have created an extensive body of knowledge there is still a lot that needs to be understood about cryptocurrency. This literature review will demonstrate what is known and what is unknown about cryptocurrency as a financial asset.

Developed from Blockchain technology, which was introduced by Satoshi Nakamoto in 2008, the world’s first cryptocurrency was a peer-to-peer, decentralized digital currency known as Bitcoin. Cryptocurrency’s rapid ascend has made it a hot topic within the global financial markets and beyond. This interest has attracted the attention of professional investors, governments and the media, and has made cryptocurrency an essential topic of interest in several fields of academic research (Almeida & Gonçalves, 2023; Angerer et al., 2021; Bedi & Nashier, 2020; Bruzgė & Šapkauskienė, 2022b; Jeris et al., 2022; Zhang et al., 2018). These recent articles have been reviewed for this study.

A systemic review of over 150 articles focused on cryptocurrencies as a financial asset has found seven key topics of interest: regulations; investing behaviors; cybercriminality; portfolio diversification; safe haven / hedge properties of cryptocurrencies; efficiency / price discovery; arbitrage. A review of these popular topics of interest for cryptocurrency as a financial asset can be found in this chapter. This analysis of the literature will demonstrate gaps within the literature and highlight the ones that will be the focus of this study. In addition, as the data from the literature was reviewed and analyzed, several trends were noticed collectively across the seven key topics of interest. These collective trends were mixed results; a focus on Bitcoin; the lack of focus on the Canadian market; mainly quantitative studies. These collective trends will be reviewed in this section. This review of the collective trends will denote how these trends helped to select the components of this study. The format of this section will first review the four collective trends found in the literature, review the seven key topics of interest found in the literature, and end with a summary of the findings and transition to the next chapter.

Collective Trends

During the comprehensive review of the current literature on cryptocurrency arbitrage, four prominent trends were identified: inconsistent results across similar studies, a predominant focus on Bitcoin, a notable lack of attention to the Canadian market, and a heavy reliance on quantitative methodologies. These trends were paramount in the formation of the research questions for this study, as they reveal the gaps within the academic literature. The following sections will delve into each of these trends, examining their implications and how they influenced the design of the present study.

Mixed Results

Mixed results within the seven key topics of interest were noted when comparing the articles pertaining to regulations, cybercriminality, portfolio diversification, safe haven/hedge properties of cryptocurrencies, efficiency/price discovery, and arbitrage. Only investor behaviors had conclusive results. The mixed results are indicative to the infancy of cryptocurrency as a topic of research and as a financial asset, and is an identifier that the gaps within the literature are significant (Angerer et al., 2021; Corbet et al., 2019). The lack of consistent generalization of the findings in the research of cryptocurrency as a financial asset is justification for further research in these areas. This study is focused on one of these noted topics of mixed results—arbitrage.

Focus on Bitcoin

A majority of the studies were focused only on Bitcoin. During the rise of cryptocurrency from a market capitalization of $0 to 1 trillion USD, the original cryptocurrency, Bitcoin, has remained the dominant cryptocurrency, accounting for 41.4% of the global market share (de Best, 2022). Not only is Bitcoin known as the first decentralized currency, it is also ranked as the top cryptocurrency in terms of trade volume, price, and market capitalization (Leung & Nguyen, 2019). As a result, most of the recent studies reviewed for this study focused solely on Bitcoin and there has been a noted need to increase the knowledge around other cryptocurrencies.

Bitcoin is just one of almost 10,000 different cryptocurrencies. Zhang et al. (2018) noted that a comprehensive understanding of cryptocurrency cannot be established by only studying Bitcoin and that more cryptocurrencies should be studied. In addition, recent studies have concluded the need for future studies that are not focused solely on Bitcoin (Almeida, 2021; Corbet et al., 2019; Leung & Nguyen, 2019). While Bitcoin accounts for over 40% of the total market capitalization of cryptocurrency, it is not the only predictor of the cryptocurrency markets. Based on this trend in the literature, this study will collect data for its analysis on more than just Bitcoin.

Lack of Focus on the Canadian Market

Another misnomer predisposition within the literature is a lack of studies focused on the Canadian cryptocurrency market. A systemic literature review of cryptocurrency studies by Almeida and Gonçalves (2023) noted that the top ten countries studied accounted for 78% of all the articles reviewed. Canada was not one of the top ten countries noted by the authors. This lack of academic representation for Canada in studies focused on cryptocurrency as a financial asset is a gap in the literature. This is because Canada is a leading economic nation and has a high level of cryptocurrency acceptance.

Canada is a member of the International Group of Seven (G7)—an intergovernmental consortium of the world's top seven advanced economies of stable democratic countries. In 2022, Canada had the world's eighth largest Gross Domestic

Product—a commonly accepted measure of a country's productivity and economic health (Wikipedia, 2023a). Finally, Canada is the 10th largest user of Bitcoin by trading volumes and has the second most Bitcoin ATMs in the world (de Best, 2022), demonstrating the high level of cryptocurrency adoption by Canadians. With a population of 40 million people, these facts demonstrate the global financial importance of Canada and its high level of cryptocurrency acceptance.

During the literature review for this study, no articles were uncovered that focused on the Canadian market and only one article noted the Canadian market. This lack of focus in the literature does not properly correspond with Canada's advanced economic standing and high level of cryptocurrency acceptance. This is a gap in the current literature for cryptocurrency as a financial asset. Based on this gap, this study will focus on the Canadian cryptocurrency market.

Mainly Quantitative Studies

The first trend that was noticed was that almost all the papers reviewed were of a quantitative nature. A quantitative methodology bias for cryptocurrency as a financial asset seems natural when you consider the currency characteristics of cryptocurrency and the ease of collecting numeric data about cryptocurrency. This author believes that the key driver of this collective trend is the assumption that most scholars who are studying cryptocurrency would have a financial/accounting background. This author has a financial/accounting background. Individuals with a financial/accounting background have developed analytical skill sets that would make them more inclined to use a quantitative design, this author included.

The lack of studies that use a qualitative methodology represents a gap within the literature. Contrarily, the overwhelming use of quantitative methodologies within the literature demonstrates the alignment and justification of the method to the topic of interest. This study lends itself to build off of other similar studies that successfully used quantitative methodologies when focusing on cryptocurrency as a financial asset, notably Bruzgė and Šapkauskienė (2022a, 2022b) and Makarov and Schoar (2020). This acts as justification for a quantitative method when studying cryptocurrency as a financial asset. A quantitative research design was used for this study. Next will be a review of the noted seven key topics of interest for cryptocurrency as a financial asset that were found when reviewing the academic literature.

Seven Key Topics of Interest

During the comprehensive review of the current literature on cryptocurrency arbitrage, seven prominent topics of interest were identified: regulations; investing behaviors; cybercriminality; portfolio diversification; safe haven/hedge properties of cryptocurrency; efficiency/price discovery; arbitrage. These topics of interest were paramount in the organization of what is known about the topic of interest. This section of the literature review chapter will review each of the seven key topics of interest and comment on how the recognition of the category groupings affected the design of this study.

Regulations

Cryptocurrency was originally created as a peer-to-peer digital currency that would not need the assistance of a trusted third party to complete a transaction or a government's monetary policy to guide the valuation of the currency. This is known as decentralized. A noted attribute of cryptocurrency and its markets is the lack of influence by a government or regulatory body (Liang et al., 2021; Makarov & Schoar, 2020; Yuan & Wang, 2018). Based on the decentralized nature of cryptocurrencies, studies have been conducted to see if regulatory bodies and governments have the ability to regulate or influence cryptocurrency.

Studies have looked at direct attempts to regulate cryptocurrency markets as well as the use of monetary policies to indirectly influence cryptocurrency and cryptocurrency markets (Borri, 2019; Borri & Shakhnov, 2020; Lee & Oh, 2022; Ma et al., 2022). Studies completed on the regulatory perspective of cryptocurrency are "one of the most pertinent" bodies of work for the literature on cryptocurrencies (Bedi & Nashier, 2020, p. 4). The authors' conclusion demonstrates the magnitude of this topic of interest. The findings within the literature for this key topic of interest for cryptocurrency as a financial asset demonstrated mixed results.

There are academic findings to indicate that governmental and regulatory bodies can influence cryptocurrency and cryptocurrency markets. Changes in domestic regulations has not only had an effect on domestic cryptocurrency markets, but there is also a large spillover effect to international markets (Borri & Shakhnov, 2020). Using the regulatory action of illegalizing cryptocurrency transactions within their borders in 2017, Chinese authorities attempted to control cryptocurrency (Borri & Shakhnov, 2020). Not only did the Chinese government substantially reduce cryptocurrencies within their borders, but there was also a spillover effect in Korea, Japan, and the U.S. markets through increased trade (Borri & Shakhnov, 2020). These findings were reiterated by Lee and Oh's (2022) study on the same Chinese policy change. Due to its dramatic effect, this Chinese policy change has been referred to as the “China Shock” by the financial markets. Scholars would use the basis of the China Shock as a foundation for their studies.

The findings by the noted studies on the China Shock were generalized in other studies. Researchers found U.S. monetary changes had an effect on the volatility and price effectiveness of cryptocurrency markets (Corbet et al., 2020). Similarly, researchers have found that price differences between cryptocurrencies across borders were influenced by differences in monetary and cryptocurrency policies among different governments (Borri, 2019; Borri & Shakhnov, 2020; Makarov & Schoar, 2020). Finally, studies demonstrated that the effects of governmental monetary policies have a natural link to the valuation of cryptocurrencies and cryptocurrency markets (Bahmani-Oskooee et al., 2020; Kang et al., 2022). These studies concluded that governmental policy changes, such as interest rate changes, would have an unavoidable effect on cryptocurrency and cryptocurrency markets. While these noted studies demonstrated that cryptocurrency and cryptocurrency markets can be regulated, there have been other studies that have upheld the decentralized premise of cryptocurrency.

In contrast to the noted studies, there are academic findings to indicate that governmental and regulatory bodies cannot influence cryptocurrencies or cryptocurrency markets. Ma et al. (2022) studied the impact of U.S. monetary policy shocks on the price of Bitcoin. The authors found that while there was an effect to Bitcoin on the day of monetary policy shocks, the magnitude of these were different in bull markets than compared to bear markets. The authors concluded that unlike traditional financial assets (gold or stocks), Bitcoin valuation is a product of uncontrollable speculative trading and not driven by monetary policy change.

Other studies concur with these findings. Studies by Pyo and Lee (2020) and Vidal-Tomás and Ibañez (2018) concluded that the decentralized nature of Bitcoin and the lack of a global control mechanism for cryptocurrency or cryptocurrency markets means that Bitcoin would not be affected by regulatory or monetary policy changes. These studies findings adhere to the accepted belief that cryptocurrency and cryptocurrency markets cannot be regulated.

Even the generally accepted assertion that the lack of regulations within the cryptocurrency markets is an advantage to cryptocurrency over fiat currencies, has been challenged. Several recent studies noted lack of regulations as an advantage of cryptocurrency as a financial asset (Liang et al., 2021; Makarov & Schoar, 2020; Yuan & Wang, 2018). Backing the belief that investors who are disenchanted with the control and prejudice of fiat currency are using cryptocurrency. But there are contrary conclusions to the benefit of cryptocurrency being unregulated.

There have been other recent studies that do not find lack of regulations to an advantage of cryptocurrency as a financial asset. Pieters and Vivanco (2017) found that noninstitutional investors were willing to pay a premium to invest in markets that had higher anonymity and lower potential of governmental influence, causing the detrimental effects of price inefficiencies and inviting illicit activities. Xiong et al. (2020) noted that it was the lack of regulations within the cryptocurrency markets that was having the detrimental effect of attracting irrational investors. These findings indicate that the lack of regulatory control within the cryptocurrency markets may be seen as an advantage, but in reality, it is driving inefficiencies and irrational behaviors within and between markets. Inefficiencies and irrational investors' behaviors are considered a disadvantage within financial markets.

The findings of the noted studies collectively demonstrated the lack of consistency and generalization of findings. These studies have simultaneously demonstrated the ability and inability of governments and regulatory bodies to directly (cryptocurrency regulations) or inadvertently (monetary policies) influence cryptocurrency and its markets. The results of these findings demonstrate that studies pertaining to regulation of cryptocurrency as a financial asset have fostered mixed results. The mixed results found in the academic literature for regulations and cryptocurrency is an additional demonstration of the significant gaps in the literature for cryptocurrency as a financial asset, signifying the need for future research on this topic of interest. The next section will review the academic literature found for investing behaviors for cryptocurrency as a financial asset.

Investing Behaviors

Investors in cryptocurrency have a distinct culture that is different than the culture of investors in traditional financial assets. In 2008 Satoshi Nakamoto, the creator of Blockchain technology, envisioned a decentralized, digital currency that would allow for peer-to-peer transactions without the need of a trusted third party (bank) or a regulatory body (government) to help value the transaction (Nakamoto, 2008). The vision led to the introduction of the world's first cryptocurrency, Bitcoin, less than a year later. This narrative embedded into the culture of cryptocurrency a sense of DIY (do it yourself) mentality.

Unlike more traditional financial assets, investments in cryptocurrency are not mainly driven by professional investors. Evidence has shown that investing in cryptocurrency attracts not only professional investors, but also non-professional investors (Delfabbro et al., 2021). A review of the literature focused on cryptocurrency as a financial asset found substantial literature examining investor behaviors. While the problem being investigated differs amongst the studies, an overall trend in the literature was that investors were inexperienced (Delfabbro et al., 2021), irrational (Ballis & Drakos, 2020; Gemayel & Preda, 2021; Kaiser & Stöckl, 2020), risktakers (Pelster et al., 2019), who lack self-control (Tjondro et al., 2023). Notably, investment decision-making was mainly based on social influences and sentiment (Almeida, 2021; Bianchi, 2020; Burggraf et al., 2020; Gupta et al., 2020; Mai et al., 2018). A rational investor does not base their decision-making on social influences or sentiment, but on adherence to key economic and financial measurements and principles. Next the academic literature looked into what may be influencing the difference in investing behaviors.

Cryptocurrency markets have dynamic and complex perception influencers. Bianchi (2020) found that prices and trading activities for cryptocurrencies were driven by popularity, emotions, and sentiment. These perception influencers are not considered trusted indicators or information for decision-making based on key financial principles.

Considering what is driving a cryptocurrency investor's perception, the danger is that the average and inexperienced investor is at least partially receiving their information on cryptocurrency from social media.

Not all social media sources are a trustworthy source for information. Mai et al. (2018) noted that social media is not a legitimate source for information on cryptocurrency as a financial asset. Recent studies into social media postings and their effect on cryptocurrency pricing and trading volumes found that not only were cryptocurrencies influenced by social media postings, but positive news had a larger effect than negative news, regardless of the source of the information or the intention of the source (Ante, 2023; Baur & Dimpfl, 2018). These findings demonstrated an irrational investing behavior by cryptocurrency investors. Beyond basing financial decision-making on misinformation, other irrational investing behaviors are demonstrated by cryptocurrency investors.

A common characteristic of social media is the practice of collecting common ideologies and sensemaking, while discouraging individual analysis. This type of characteristic is known as herding. The reliance of cryptocurrency investors on social media for at least part of their information used for financial decision-making has manifested into herding behaviors (Bouri, Gupta, et al., 2019; Raimundo Júnior et al., 2022; Rubbaniy et al., 2021; Xiong et al., 2020). It is dangerous to base your financial decision-making on herd mentality because it removes individual agendas, such as personal risk-to-reward tolerances. Reliance on social media for information and herding behaviors are demonstrations of the irrational investment behaviors within the cryptocurrency markets.

Being an inexperienced investor does not have to mean that you are an irrational investor. Several studies have noted that individual cryptocurrency investors are irrational (Ballis & Drakos, 2020; Kaiser & Stöckl, 2020; Tjondro et al., 2023). A recent study by Gemayel and Preda (2021) focused on learning abilities of cryptocurrency traders. The study concluded that not only were cryptocurrency investors irrational, but also lacked the ability to learn from their experiences and continued to demonstrate irrational investment behaviors over time. All investors start off as inexperienced. Inexperienced investors can either develop knowledge or hire the knowledge to become an experienced investor. The fact that collectively cryptocurrency investors seem unable or unwilling to do this demonstrates other influencers are affecting their decision-making.

Cryptocurrency investors are unlike other investors that invest in traditional financial assets. Several studies have linked the behaviors of cryptocurrency investors to that of addicted online gamblers (Delfabbro et al., 2021; Mills & Nower, 2019) and risktakers (Pelster et al., 2019). This introduces a mental capacity issue for cryptocurrency investors that is not as influential for investors of more traditional financial assets. This is because rational investors' decision-making is based on adherence to generally accepted financial principles rather than a personal attitude or emotion towards the situation.

Rather than basing decision-making on generally accepted financial principles, cryptocurrency investors have demonstrated a reliance on personal attitudes and emotions, which makes them irrational investors. One of the main reasons that cryptocurrency investors are seen as irrational is the significant impact socially-influenced sentiment has on their decision-making (Almeida, 2021; Gupta et al., 2020). Studies by Burggraf et al. (2020) and Mai et al. (2018) examined the predictive powers social influences and investor sentiment had on cryptocurrencies. It was found that social influences (Mai et al., 2018) and investor sentiment (Burggraf et al., 2020) had stronger predictive powers than the use of tested financial strategies. A study by Tjondro et al. (2023) found that cryptocurrency investors simply lack self-control when it came to their cryptocurrency investment behaviors. These behaviors further demonstrate the irrational investor characteristics of a cryptocurrency investor. It also highlights a social problem that is growing in the financial community.

The magnitude of irrational investment behaviors within the cryptocurrency markets grows as cryptocurrency gains in popularity. Cryptocurrency is one of the fastest growing markets in the world (Delfabbro et al., 2021), and is growing in all facets—market size, options (types and markets), and number of users (de Best, 2022). The social problem that arises from this knowledge of cryptocurrency investor behavior is that as cryptocurrency continues to grow, so will general public interest and media attention. The findings of this literature review of cryptocurrency investing behaviors has shown that the general public might not be fully aware of the risks they are accepting or how to properly protect themselves from harm due to the behaviors they are displaying and not learning from (Delfabbro et al., 2021; Gemayel & Preda, 2021). These concerns are at the heart of the social problem of this study.

This section has reviewed the literature focused on the investing behavior of investors in cryptocurrency as a financial asset. The findings demonstrated that cryptocurrency investing is attracting both experienced and inexperienced investors. The findings associated with inexperienced investors in cryptocurrency were inclusive and generalized. Inexperienced investors in cryptocurrency are irrational and are causing a social issue that needs to be addressed. Findings in the academic literature that may be able to help experienced investors when dealing with inexperienced investors will be reviewed in subsequent sections. These key topics of interest are portfolio diversification; safe haven/hedge properties of cryptocurrencies; efficiency/price discovery; and arbitrage. Another social issue surrounding cryptocurrency is its connection to illicit activities and terrorist funding. The next section will focus on that key topic of interest.

Cybercriminality

Cybercriminality is a term used to summarize the illicit activities that are facilitated or financed via the dark web or criminal virtual networks. Speaking at a Senate financial committee, the Secretary of the Treasury for the United States, Janet Yellen, noted that cryptocurrency is mainly used for illicit financing (Lennon, 2021). While Treasury Secretary Yellen can be seen as an expert on the global financial environment, a review of the academic literature needs to be conducted for this key topic of interest. This section will focus on studies that reviewed cryptocurrency and cybercriminality.

The general assumption is that cryptocurrency is not just used to finance illicit activities, but facilitates it as well. A study by Albrecht et al. (2019) noted that cryptocurrencies are favored by the dark web and virtual criminal networks. This is based on cryptocurrency's digital characteristics and anonymous attributes. The next part of this section will look at current studies that concur with the noted lowly opinion of cryptocurrency.

Cryptocurrency has been found to be a conduit and even an instigator of illicit activities. Trautman (2014) examined how crimes could be financed by digital payment systems. The author found that cryptocurrency was used to finance numerous types of crimes, including procurement of illegal substances, child exploitation, and assassinations. Studies by Alnabulsi and Islam (2018), Dawson (2020), and Gandal et al. (2018) all generalized Trautman's findings and noted the anonymity of cryptocurrencies as an amplifier of cybercriminality. Studies by Didenko and Buckley (2018) and Foley et al. (2019) concluded that anonymous cryptocurrencies are being used to finance illicit activities. While these studies are conclusive that cryptocurrency is the preferred payment mechanism for illicit activities, they are inconclusive as to if cryptocurrency is fostering an increase in illicit activities. The next part of this section will look at current studies that attempted to increase the knowledge of cryptocurrency's relationship to the level of illicit activities occurrences.

Enabling illicit activities is not the same as fostering growth of illicit activities. Corbet et al. (2019) found that most recent studies concluded a simple migration of payment preferences to cryptocurrency, but did not demonstrate evidence on cryptocurrency fostering growth of illicit activities. The lack of conducive findings to support or refute the professional opinion of cryptocurrency's role in cybercriminality demonstrates a gap in the literature. While the question of cryptocurrency's influence over cybercriminality, beyond a preferred payment method, remains a gap in the literature, one of the noted reasons for cryptocurrency popularity with buyer and sellers of cybercriminality, anonymity, has started to be disproven.

A key assumption of the findings that cryptocurrency is the preferred payment method for cybercriminality is based on cryptocurrency's attribute of anonymity. Recent studies have found that cryptocurrency transactions are not as anonymous as touted (Biryukov & Tikhomirov, 2019; Yin et al., 2019). While the technology that backs cryptocurrency, blockchain, does not tie any identification to the transaction, this does not mean that cryptocurrency transactions are untraceable. Recent studies have been able to de-anonymize cryptocurrency transactions by using highly sophisticated processes, involving thinking machines (Yin et al., 2019), as well as simplistic and inexpensive, yet as effective, network analysis (Biryukov & Tikhomirov, 2019) to successfully demonstrate the link between transactions. While these studies do not dismiss the growing use of cryptocurrency for cybercriminality, they do undermine the role cryptocurrency plays as an influencer of cybercriminality, due to the fact that cryptocurrency transactions are not as anonymous as thought.

The role of cryptocurrency in cybercriminality has been well studied. The role of cryptocurrency in the migration of illicit activity from the streets to online is universally accepted. The assumption that cryptocurrency is a conduit of growth in illicit activities is inconclusive, with further research required. The mixed results found in the academic literature for cybercriminality and cryptocurrency is an additional demonstration of the significant gaps in the literature for cryptocurrency as a financial asset, signifying the need for future research on this topic of interest. The next section will review the academic literature found for the portfolio selection strategies of cryptocurrency as a financial asset.

Portfolio Selection Strategies

Financial assets have certain characteristics that professional investors rely upon to help them reduce risk through portfolio selection strategies. Cryptocurrency is seen as a financial asset (Baur, Hong, et al., 2018). In conjunction with cryptocurrency’s meteoric rise in both popularity and market capitalization, cryptocurrency has had a large and diverse body of literature based on its characteristics as a financial asset for portfolio selection strategies (Bedi & Nashier, 2020; Corbet et al., 2019). This academic literature has centered around cryptocurrency and portfolio selection strategies of diversification, safe haven / hedging properties, and pricing efficiencies. The following three sections will review the literature based on these portfolio selection strategies. Similar to other sections, the trend of these bodies of literature offered mixed results.

Portfolio Diversification Properties for Cryptocurrency

In accordance with modern portfolio theory, a diversification strategy reduces risk by collectively holding assets that are negatively correlated, meaning that the volatility and valuation of two different assets have opposite reactions under similar market scenarios (Markowitz, 1952). Recent studies on the diversification capabilities of cryptocurrency as a financial asset have had mixed results. The next part of this section will focus on the academic literature that found cryptocurrency to be useful for portfolio diversification.

The academic community has studied the portfolio diversification properties for cryptocurrency. A study by Baur, Dimpfl, et al. (2018) analyzed the relationship between Bitcoin and other traditional financial assets. The study found that Bitcoin was negatively correlated with the other financial assets, signifying its diversification potential. Other recent studies have reiterated and confirmed these findings (Charfeddine et al., 2020; Mensi et al., 2019). Rehman and Vinh Vo (2020) also reiterated these findings, noting that cryptocurrencies have diversification opportunities specifically for precious metal investors. These noted studies all found cryptocurrency to have diversification properties. The next part of this section will focus on the academic literature that did not find cryptocurrency to have diversification properties.

Continued review of the academic literature on the portfolio diversification properties of cryptocurrency uncovers a lack of generalization of the already noted studies' findings. In contrast to the already noted studies, a study by Khaki et al. (2023) noted that while cryptocurrency did have diversifier benefits, it was only in a few scenarios and therefore not a material tool for a portfolio diversification. Similarly, a study by Beneki et al. (2019) noted that while cryptocurrency had diversifying properties, these properties have been significantly reduced in recent years due to a delay in trade responses and large changes to the time-varying correlation between cryptocurrency and other financial assets. Studies by Baur, Hong, et al. (2018) and Bedi and Nashier (2020) concluded that cryptocurrency has no diversification benefits. These studies concluded that due to the high volatility and speculative nature of cryptocurrency, cryptocurrency is ineffective as a diversifier. These noted studies all found cryptocurrency to have limited or no diversification properties.

This section has reviewed the recent academic literature for the portfolio diversification properties of cryptocurrency. The collective findings within the literature demonstrated mixed results. The mixed results for portfolio diversification properties of cryptocurrency reveal a gap within the literature. This signifies the need for future research for this topic of interest. The next section will review the academic literature found for safe haven / hedge properties of cryptocurrency as a financial asset.

Safe Haven and Hedge Properties of Cryptocurrencies

Financial assets with safe haven or hedge properties are characteristically similar to assets within a diversification strategy. A safe haven is a financial asset that is negatively correlated to just one other financial asset or the portfolio on average only during times of market turmoil, while a hedge is a financial asset that is negatively correlated to just one other financial asset or the portfolio on average (Markowitz, 1952). The academic literature on cryptocurrency as a financial asset with safe haven properties has been inconclusive. The next part of this section will focus on the academic literature that found cryptocurrency to be useful as safe havens/hedges.

The academic community has studied the safe haven properties for cryptocurrency. Alexander and Imeraj (2021), who examined variance risk premium for Bitcoin, found that Bitcoin has a near zero correlation with the variance risk premium to other assets, which supports Bitcoin as having safe haven properties. Selmi et al. (2018) and S. J. Shahzad et al. (2020) agreed with the notion of Bitcoin as a safe haven. Selmi et al. (2018) concluded that Bitcoin was a safe haven for extreme oil price movements. Shahzad et al. (2020) concluded that Bitcoin was a safe haven against extreme stock market conditions. In one of the few studies to examine cryptocurrencies beyond just Bitcoin, Bouri et al. (2020) found that different cryptocurrencies offered safe haven options. The authors found that Bitcoin, Ripple, and Steller were safe havens for all U.S. equities, while Litcoin and Monero were safe havens for U.S. market-wide equity indexes. These noted studies all found cryptocurrency to have safe haven properties. The next part of this section will focus on the academic literature that disconfirmed cryptocurrency to have safe haven properties.

Continued review of the academic literature on the safe haven properties of cryptocurrency uncovers a lack of generalization for the previously noted studies' findings. Conlon and McGee (2020) studied if adding Bitcoin to your portfolio would reduce the risk of downside exposure. The authors concluded that Bitcoin could not be considered a safe haven due to its high volatility and illiquidity. Nedved and Kristoufek (2023) concurred that Bitcoin did not have safe haven properties as its price movement was aligned to that of the stock market. Finally, Charfeddine et al. (2020) concluded that cryptocurrency was a poor tool to use as a safe haven instrument. The academic literature within this section found that cryptocurrency does not have safe haven properties and is in contrast to other findings within the academic literature. A portfolio selection strategy very similar to a safe haven is a hedge. The next section will review the academic literature for the hedge properties of cryptocurrency as a financial asset.

Another portfolio selection strategy reviewed in the academic literature is the hedge properties of cryptocurrency as a financial asset. Unlike the literature pertaining to diversification and safe haven properties of cryptocurrency, the literature favors that Bitcoin acts as a hedge against global uncertainty (Baur, Dimpfl, et al., 2018; Bedi & Nashier, 2020; Borri, 2019; Chemkha et al., 2021). This would demonstrate the maturity of cryptocurrency and its general adherence to generally accepted financial principles. Conversely, not all the literature reviewed generalized the noted findings.

A few studies found in the academic literature did conclude that cryptocurrency does not have hedge properties. Bakry et al. (2021) concluded that Bitcoin was a better financial asset for diversification than it was a safe haven or hedge. In addition, Conlon and McGee (2020) denoted that cryptocurrencies should not be considered beyond a speculation role within a portfolio, including a hedge, due to the high volatility and illiquidity of cryptocurrency. While these studies do not signify inclusiveness amongst the collective literature, they do cast doubt on cryptocurrency's hedge properties and its general adherence to generally accepted financial principles.

This section has reviewed the recent academic literature for the safe haven / hedge properties of cryptocurrency. The collective findings within the literature demonstrate mixed results. The mixed results for safe haven / hedge properties of cryptocurrency reveal a gap within the literature. This signifies the need for future research for this key topic of interest. The next section will review the academic literature found for price efficiency / price discovery properties of cryptocurrency as a financial asset.

Price Efficiency/Price Discovery Properties of Cryptocurrency

As noted in the previous section, cryptocurrency is regarded as a financial asset. Mature financial assets have certain characteristics that professional investors have come to rely upon to help them reduce risk. The academic literature considered cryptocurrency to be both mature (Dyhrberg et al., 2018) and immature (Celeste et al., 2020; Kang et al., 2022). Gregoriou (2019) simplifies the debate over the maturity of cryptocurrency by denoting that cryptocurrency must be seen as an immature financial asset due to the abnormal returns obtained by investors. A portfolio selection strategy is to evaluate only mature financial assets. One of the key characteristics of a mature financial asset is price efficiency.

Price efficiency, also known as price discovery, refers to the Efficient Market hypothesis, a financial principle that assumes that market prices for a financial asset openly reflects all available information (Kang et al., 2022). The academic literature on the price efficiency of cryptocurrency as a financial asset has collectively been inconclusive. The next part of this section will focus on the academic literature that found cryptocurrency to have price efficiency properties.

One characteristic of price efficiency is the liquidity of the financial asset. A study by Brauneis and Mestel (2018) examined Bitcoin’s price efficiency based on its liquidity. Simply defined, liquidity is how quickly a financial asset can be turned into cash—the more quickly, the more liquid. Brauneis and Mestel (2018) concluded that cryptocurrency’s price efficiency was influenced by its liquidity. Based on economic theory, the more liquid a financial asset is, the greater price efficiency it has. This is because there are less barriers to stop available information from timely and reliably affecting the market price of a financial asset. As liquidity increases, cryptocurrency becomes more price efficient.

The liquidity of a financial asset can be influenced by several factors. A study by Makarov and Schoar (2019) demonstrated the generalization of the previous authors' findings by concluding that the price efficiency of cryptocurrency is influenced by liquidity of the financial assets between borders. Future studies by Brauneis and Mestel would revisit their study and add to the existing knowledge. Brauneis et al. (2022) found that cryptocurrency was a liquid asset, but the liquidity decreased with higher volatility. This means, in market turmoil, cryptocurrency would turn from a price efficient to a price inefficient financial asset. Other recent studies' results confirmed these findings (Bianchi, 2020; Bouri, Gil-Alana, et al., 2019; Shahzad et al., 2021). These noted studies all found cryptocurrency to have price efficiency properties. The next section will focus on the academic literature that did not find cryptocurrency to have price efficiency properties.

Not all of the academic literature agrees with the noted findings liquidity is an influencer of price efficiency. Krückeberg and Scholz (2020) examined arbitrage opportunities within Bitcoin markets. The authors demonstrated an inverse relationship between price efficiency and liquidity—meaning the more liquid the financial asset, the more inefficient the financial asset became. Due to the contrary findings to an expected financial asset relationship, the authors' findings cast doubt on the price efficiency and maturity of cryptocurrency as a financial asset. The next section will review another expectation for price efficiency – that financial assets can become more mature over time.

Some studies have noted that while cryptocurrency had demonstrated price inefficiency in the past, cryptocurrency has become more efficient over time. Vidal-Tomás and Ibañez (2018) noted that cryptocurrency is inefficient, but it is becoming more efficient over time. Celeste et al. (2020) and Kang et al. (2022) generalized the noted findings by denoting that cryptocurrency has a low and growing level of efficiency. These studies all noted that while cryptocurrency is inefficient, it is becoming more efficient over time, as it is becoming more mature. These studies are more middle ground, rather than decisive on cryptocurrency's price efficiency properties. There are studies that found cryptocurrency to be definitively price inefficient.

Cryptocurrency has price inefficient qualities. As noted, Krückeberg and Scholz (2020) found cryptocurrency to be price inefficient in liquid situations. Ahmed (2022) noted that research pertaining to cryptocurrency's price efficiency has been inconsistent. These findings refute priorly noted findings for cryptocurrency's price efficiency properties and bring into question the maturity of cryptocurrency as a financial asset. Demonstrating the collective mixed results found in the current literature for the price efficiency properties of cryptocurrency as a financial asset.

This section has reviewed the recent academic literature for the price efficiencies / price discovery properties of cryptocurrency. The collective findings within the literature demonstrate mixed results. The mixed results for price efficiency / price discovery properties of cryptocurrency reveal a gap within the literature. This signifies the need for future research for this topic of interest. The next section will review the academic literature found for the last of the key topics of interest, arbitrage opportunities for cryptocurrency as a financial asset.

Arbitrage

Cryptocurrency has gone from obscurity to a global phenomenon in just a few years. Cryptocurrency's meteoric rise has gained a lot of attention academically and professionally (Almeida & Gonçalves, 2023; Angerer et al., 2021; Bedi & Nashier, 2020; Bruzgė & Šapkauskienė, 2022b; Jeris et al., 2022; Zhang et al., 2018). Some of these recent studies have focused on the maturity of cryptocurrency as a financial asset (Bruzgė & Šapkauskienė, 2022b; Celeste et al., 2020; Dyhrberg et al., 2018; Kang et al., 2022). These studies examine if cryptocurrency follows the economic and generally accepted financial principles that are expected of a mature financial asset. One of these financial principles is the LOP and arbitrage opportunities. The academic literature for arbitrage opportunities for cryptocurrency as a financial asset will be reviewed in this section.

One of these key economic and financial measurements for mature financial assets is LOP (Giovannini, 1988; Kabašinskas & Šutienė, 2021; Kristoufek, 2019; Makarov & Schoar, 2020; Miljkovic, 1999; Persson, 2008; Pieters & Vivanco, 2017; Shynkevich, 2021; Witzel, 2005). LOP ascertains that identical goods must be sold for identical prices regardless of the market. If there is any price difference between markets, then the markets' price variance would be quickly corrected through arbitrage. Arbitrage is the practice of moving supply between markets for a profit: buying the asset in one market and simultaneously selling the asset for a profit in another market. Transferring the supply from one market to another market will cause a shift in price for both markets based on supply and demand economics: the decreased supply will cause an increase to the price in the original market; the increased supply will cause a decrease to the price in the destination market. This will continue until there is no longer a price incentive to transfer the supply from one market to another market.

The review of the academic literature found significant knowledge that arbitrage opportunities do exist for cryptocurrencies. A famous example of the existence of arbitrage opportunities for cryptocurrency as a financial asset is the ‘Kimchi premium’. The Kimchi premium, named after the South Korean traditional pickled dish, is the notably high price for cryptocurrency in South Korea than in comparison to U.S. prices, due to higher demand with a lower supply (Lee & Oh, 2022). This premium is a direct reflection of Chinese policy change that banned all cryptocurrency transactions in 2017 (Lee & Oh, 2022). Known as the ‘China Shock’, this Chinese regulatory change had a large international spillover into the South Korean cryptocurrency markets, causing substantial arbitrage opportunities (Borri & Shakhnov, 2020). The presence of one cross-border driven arbitrage opportunity brings into question if there are other such opportunities.

While academic literature can agree that arbitrage opportunities do exist for cryptocurrency as a financial asset, the conclusiveness stops there. From there, the academic literature on arbitrage opportunities for cryptocurrency as a financial asset branches off into several potential influences of the arbitrage opportunities. These influences are: lack of regulations; local costs; price inefficiency; illiquidity; cryptocurrency immaturity as a financial asset; technological limitations. This section will now review the academic literature for each of these influences and comment on how the collective findings influenced the research questions for this study.

Lack of Regulations

As a decentralized currency, cryptocurrency is not regulated by a governing body and is, therefore, borderless. Recent studies have noted that an advantage for cryptocurrency is that it is not governed by a regulatory body or government (Inci & Lagasse, 2019; Kabašinskas & Šutienė, 2021; Liang et al., 2021; Pieters & Vivanco, 2017). Originally, the advantage of cryptocurrency being decentralized was focused on the lowering of transaction costs and curtailing potential abuses by regulatory bodies and governments. Inadvertently, the lack of regulations may be influencing arbitrage opportunities for cryptocurrency as a financial asset. A review of the academic literature for this topic of interest found the results to be inconclusive.

The presence of cross-border arbitrage opportunities between cryptocurrency markets has been well documented. A study by Makarov and Schoar (2020) analyzed the trading and efficiencies of cryptocurrency markets. The study found that arbitrage opportunities were larger and lasted longer across borders. These findings contrast with traditional financial assets, such as gold, that demonstrate price parity across borders. Based on these findings, research should be conducted to understand what is influencing cross-border arbitrage opportunities for cryptocurrency, unlike other financial assets.

Arbitrage opportunities for cryptocurrency as a financial asset are occurring across borders in contrast to traditional forms of money. Makarov and Schoar (2020) concluded that traditional financial assets had either one global regulatory body or similarly governed local regulatory bodies that maintained the efficiency of the financial assets, resulting in no arbitrage opportunities. Cryptocurrencies and cryptocurrency markets do not have such a driving force, to help manage the price efficiency of cryptocurrency, resulting in arbitrage opportunities (Makarov & Schoar, 2020). This finding clearly denotes the lack of regulations as an influencer of arbitrage for cryptocurrency as a financial asset. With this knowledge, a question persists pertaining to the validity of the assumption that the decentralized nature of cryptocurrency means that regulatory bodies and governments are unable to regulate cryptocurrency.

With cryptocurrency being decentralized, it is widely accepted that cryptocurrency cannot be regulated by a governing body or government. Several recent studies, reviewed in the Regulations section of this Chapter, demonstrated the effect governments could have on cryptocurrency markets: either directly through policy aimed specifically at cryptocurrency (Borri & Shakhnov, 2020; Lee & Oh, 2022; Makarov & Schoar, 2019, 2020) or indirectly through monetary policy changes (Bahmani-Oskooee et al., 2020; Borri, 2019; Corbet et al., 2020; Kang et al., 2022). The Regulations section noted the findings were of mixed results. The findings demonstrate an uncertainty within the academic literature as to if cryptocurrency is being regulated or not and to the influence lack of regulations for cryptocurrency could have on the noted cross border arbitrage opportunities. Next, this section will look at the affect local costs may have on arbitrage opportunities for cryptocurrency as a financial asset.

Local Costs

With the inconclusiveness of the influence that the lack of regulations has on arbitrage opportunities for cryptocurrency as a financial asset, other factors, such as local costs, have been studied. Beyond the previously noted studies, other recent studies that have globally reviewed the arbitrage opportunities between cryptocurrency markets have noted that they found notable cryptocurrency arbitrage opportunities (Bruzgė & Šapkauskienė, 2022a; Kabašinskas & Šutienė, 2021; Pieters & Vivanco, 2017). A common link to these studies is that they used the LOP framework. A criteria of LOP is that all local costs—regulatory costs, such as taxes, transaction costs, such as fees or transportation costs, and time lags—should be removed or disregarded from the local price (Giovannini, 1988). Cryptocurrencies are more expensive in South Korea simply because of a spillover effect on local costs in China, that has caused a liquidity issue in South Korea (Borri & Shakhnov, 2020) and therefore should not be seen as an arbitrage opportunity. This is because there are no profit-taking opportunities available for South Korean cryptocurrency investors when the local costs are accounted for. Studies must be conscious that while arbitrage opportunities look to be available for cryptocurrency, they are in fact simply the market efficiently incorporating the local costs into the local valuation and are not arbitrage opportunities because investors cannot take advantage of the price disparity.

Other studies have noted similar effects of local costs being erroneously mistaken as arbitrage opportunities based on price disparity. Makarov and Schoar (2020) noted this in their study. The authors concluded that local costs were the main factors contributing to market segmentation being confused for arbitrage opportunities. Based on the LOC criteria, the effect of local costs needs to be removed from any market price comparison for arbitrage opportunities to be commented on. With the local costs accounted for, the question remains if arbitrage opportunities exist for cryptocurrency as a financial asset.

One way to remove the local costs from a study focused on arbitrage opportunities is to disregard prices all together. Referring specifically to this concern, a study by Duan et al. (2021) used information efficiency and geographical networking, rather than a price model, to examine arbitrage opportunities between different cryptocurrency markets across borders. In confirmation of the previously noted studies that concluded that local costs were the influence of cross border price imparity, Duan et al. (2021) found that Bitcoin markets displayed no arbitrage opportunities due to the efficient manner in which data was reflected with in the markets in a manner consistent with the Effective Market Hypothesis. In contrast to the previously noted studies that concluded there were substantial arbitrage opportunities for cryptocurrency as a financial asset, this demonstrates how local costs can be mistaken for arbitrage opportunities when not accounted for. While the combination of these studies may seem to have filled in the gap on the knowledge of arbitrage in the cryptocurrency markets, a further review of the literature found that the gap persisted.

Mixed results demonstrate a lack of understanding around if arbitrage opportunities for cryptocurrency as a financial asset persists in the academic literature. Fischer's et al. (2019) study on cryptocurrency statistical arbitrage found that an arbitrage trading strategy outperformed more traditional trading strategies, such as the buy and hold strategy. The authors' findings indicate there must be something more than local costs causing arbitrage opportunities. With the academic literature offering inconclusive findings as to the role that local costs for plays in arbitrage opportunities for cryptocurrency as a financial asset, the literature moved on to internal factors for cryptocurrency, such as price inefficiencies and illiquidity, to explain the phenomenon.

Price Inefficiency and Illiquidity

The academic literature on arbitrage opportunities for cryptocurrency due to price inefficiencies and illiquidity of the financial asset has been extensive, but inconclusive. As noted in the Price Efficiency section, which is simply the inverse to price inefficiency, there were several studies that demonstrated that price inefficiencies were the cause of cryptocurrency arbitrage opportunities based on the Effective Market Hypothesis (Celeste et al., 2020; Kang et al., 2022) and illiquidity issues (Brauneis & Mestel, 2018; Krückeberg & Scholz, 2020). This highlights that the information for cryptocurrency is not equally transferring into the price of the financial asset between cryptocurrency markets. To address price inefficiencies influences, the academic literature on the speed in which cryptocurrency and cryptocurrency markets process information needs to be reviewed.

Academic literature has looked at the speed at which cryptocurrency and cryptocurrency markets process information. The slower the information is processed into the cryptocurrency pricing and between markets the greater the price inefficiency. Wątorek et al. (2021) examined the price inefficiency properties of cryptocurrency to understand the influences of external information, such as exchange rate changes, had on the cryptocurrency markets. The authors found that slow information-flows frequently resulted in arbitrage opportunities for cryptocurrency and cryptocurrency markets. Similar to the findings in the Price Efficiency section, price inefficiency of cryptocurrency as a financial asset can cause arbitrage opportunities. Another influence of how a financial asset processes information is the assets liquidity.

An illiquid financial asset cannot process information as quickly as a liquid financial asset due to the lack of buyers or sellers to absorb the information into the market price. Studies by Brauneis et al. (2022) and Bruzgė and Šapkauskienė (2022a) noted that slow flow of information resulted in arbitrage opportunities for cryptocurrency, but only in illiquid situations. Recent studies concluded that illiquidity of cryptocurrency can cause arbitrage opportunities (Brauneis & Mestel, 2018; Brauneis et al., 2022; Dubey, 2022; Makarov & Schoar, 2019). The studies demonstrate that the reduced speed in which information is absorbed by cryptocurrency and between cryptocurrency markets, due to insufficient transaction volumes, causes price inefficiencies and enables arbitrage opportunities. These findings seem to explain how the China Shock caused the Kimchi Premium.

A further review of the literature finds not all studies agree with the noted authors' findings. Recent studies found arbitrage opportunities for cryptocurrency, but only in liquid situations (Karaömer, 2022; Krückeberg & Scholz, 2020; Nakagawa & Sakemoto, 2022). These findings were generalized by Kristoufek and Bouri (2023), who concluded that arbitrage opportunities increased when markets were liquid and there was high price volatility. The mixed results found in the academic literature for the influence of price inefficiency and illiquidity has on arbitrage opportunities may be the result of conflicting pull of the professional to the speculator investor has on the deemed maturity of cryptocurrency as a financial asset.

Cryptocurrency Immaturity as a Financial Asset

The level of maturity of cryptocurrency as a financial asset has been extensively reviewed in academic literature. The results on cryptocurrency's maturity as a financial asset previously noted in this literature review have been mixed. With some of the recent studies concluding cryptocurrency to be a mature financial asset (Brauneis & Mestel, 2018; Brauneis et al., 2022; Dyhrberg et al., 2018), while other recent studies concluding cryptocurrency to be an immature financial asset (Celeste et al., 2020; Gregoriou, 2019; Kang et al., 2022). This contrast of conclusion of findings may be the result of the timeline of when the data was collected for the studies.

When the data was collected for studies on arbitrage opportunities for cryptocurrency as a financial asset may be causing the mixed results collectively found in the literature. Studies by Duan et al. (2021), Shynkevich (2021), and Vidal-Tomás and Ibañez (2018) all concluded that as cryptocurrencies increased in popularity arbitrage opportunities were reduced. The assumption here is that as the influence of professional investors eclipses the influence of speculator investors on cryptocurrency, cryptocurrency became a more mature financial asset. This results in few, and eventually no, arbitrage opportunities for cryptocurrency as a financial asset.

As cryptocurrency grows in popularity, the influence of professional investors will eventually gain critical mass over the influence of the speculator investor. The result of such a switch in behavior of a financial asset would be the adherence to generally accepted financial principles, such as the LOP and the void of arbitrage opportunities. In conjunction with this assumption, Shynkevich (2021) concluded that arbitrage opportunities all but disappeared after 2018. 2018 is a pivotable year for cryptocurrency, as the currency substantially grew in users, volume , and market capitalization – the market capitalization grew over 4900% in 2018 alone (de Best, 2022). The findings that in recent years cryptocurrency has become a more mature financial asset and as a result has experienced a decline in arbitrage opportunities may partially explain the mixed results in academic literature. Meaning, studies that include data prior to 2018 may find an increased likelihood of arbitrage opportunities than studies that were focused on data after 2018.

Increased popularity is more than just an increase in users, but also an increase in frequency of transactions. Krückeberg and Scholz (2020) noted that since 2018 arbitrage opportunities have gone up. Kristoufek and Bouri (2023) noted that it was increased congestion of the cryptocurrency markets that was causing cryptocurrency’s high price volatility and arbitrage opportunities. As the markets for cryptocurrency become more liquid, based on increased number of users and transactions, the disconnect between cryptocurrency across cryptocurrency markets become more obvious.

This section has reviewed the academic literature for the maturity of cryptocurrency as a financial asset and it effect on the arbitrage opportunities for cryptocurrency as a financial asset. Within the literature, the findings have been inconclusive and resulted in mixed results. The academic literature finds cryptocurrency to be both mature with no arbitrage opportunities and immature with arbitrage opportunities. These mixed results demonstrate a gap within the literature, especially around if the increased liquidity of cryptocurrency after 2018 has made cryptocurrency a mature financial asset. Based on these mixed results, the influence of the capabilities of the information systems used by cryptocurrency markets should be considered.

Technological Limitations

This section has already demonstrated the mixed results as to the influence of increased frequency (liquidity) on arbitrage opportunities for cryptocurrency as a financial asset. What was not noted in the review was the effect and limitations imposed by the technology used to collect the data for the noted studies. A study by Foley et al. (2023) took a different approach to understanding this phenomenon. This study reviewed how the data for arbitrage opportunities for cryptocurrency as a financial asset was collected. It was concluded that studies that found arbitrage opportunities were not based on the data, but how the data was collected. A key requirement for the validity and repeatability of data collected is the accuracy of the data to represent what has happened. This finding brings into question whether there is another influencer of the data that may have not been considered and maybe causing the mixed results.

The mixed results found in the academic literature focused on arbitrage opportunities for cryptocurrency as a financial asset may have been influenced by technical issues rather than the lack of generalizability of the findings across studies. Foley et al. (2023) noted that studies on arbitrage of cryptocurrency as a financial asset are increasingly using ticker tape data for their quantitative analysis. Using algorithmic analytics, the authors found that as cryptocurrency markets grew in both number of users and number of transactions, the technology used to capture the data across different markets (time stamps) had become stretched and insufficient to offer reliable data. This means that the noted arbitrage opportunities were not the result of inefficiencies within or across the cryptocurrency markets, but a reflection of the insufficient quality of the data collected for these types of microstructure research. A simple way to get around this concern is to use the end-of-day price data, also known as closing price; but this would be limited to only one moment in time, rather than giving a picture of the entire day. For this study, daily closing price was selected.

Literature Review Summary

The literature review of this study has covered in detail the academic literature for cryptocurrency as a financial asset. The main topic of this study is arbitrage opportunities for cryptocurrency as a financial asset. The academic literature has proven that arbitrage opportunities do exist between cryptocurrency markets. Within these findings the review has uncovered several mixed results as to the influence of this phenomenon: does arbitrage still exist when governmental/regulatory and transaction costs are normalized; does arbitrage exist today; is arbitrage a symptom of a markets liquidity (or lack thereof); is arbitrage a result of insufficient quality of the data collected to study the phenomenon? These mixed results represent gaps within the academic literature and have influenced the scope of this study.

The scope of this study has been devised to address the gaps found within the literature. To address the government/regulatory question that arbitrage opportunities are the reflection of governmental/regulatory costs, this study will only focus on the Canadian market. This will ensure the same government/regulatory costs across the data. The Canadian market were selected due to the lack of literature focused on Canada and its cryptocurrency exchanges, even though Canada is considered a global economic leader and has a high level of cryptocurrency acceptance. Furthermore, transaction costs will be normalized across the data. This will be done by removing the transaction costs, such as transaction fees, from the market price.

To address the maturity of the cryptocurrency question, that arbitrage opportunities have disappeared in recent years due to cryptocurrency becoming more efficient, only current data from 2023-2024 will be used. To address the liquidity question, does the frequency of transactions cause arbitrage opportunities, data for volume as well as price will be reviewed to see if an influencer relationship exists. Finally, to address the technology question, that arbitrage opportunities do not actually exist and that they only appear to exist when examining the data due to insufficient technology to properly capture ticker level data, only end-of-the-day prices, daily closing prices, will be used.

The literature review noted several gaps within the academic literature for cryptocurrency as a financial asset. The scope of this study was on the existence of arbitrage opportunities of cryptocurrency as a financial asset within the Canadian Market. The gaps within the literature uncovered specifically for this topic of interest have been used in the scope of this study. This study will add to the existing knowledge by answering the noted gaps in the literature.

Summary and Conclusions

As cryptocurrency has grown in popularity, so has the interest of scholars. I analyzed academic studies focused on cryptocurrency as a financial asset. To do this, a literature review research protocol was created to locate credible, recent, and relevant works. A systemic review of over 150 articles focused on cryptocurrencies as a financial asset, found four collective trends and seven key topics of interest. Analysis of these trends and topics was the foundation of this study.

The four collective trends were mixed results for similar studies, focus on Bitcoin, lack of focus on the Canadian market, and the studies were almost completely of quantitative design. The seven key topics of interest were regulations, investing behaviors, cybercriminality, portfolio diversification, safe haven and hedge properties, efficiency and price discovery, and arbitrage. Table 3 summarizes the main conclusions of what is known and what is unknown for each key topic of interest. The trends and key topics of interest were principal in the creation of the research questions for this study.

Table 3

Main Points of What is Known and What is Unknown for Each Key Topic of Interest

Key Topics of Interest	Main Known	Main Unknown
1) Regulations	Unlike other financial assets, there is a lack of formal regulations or a regulatory body for cryptocurrency, and this is viewed as an attribute for cryptocurrency as a financial asset.	Collectively there are mixed results as to if cryptocurrency can be directly or indirectly influenced by regulations.
2) Investing Behaviors	Cryptocurrency investing attracts professional and non-professional investors. Cryptocurrency	As cryptocurrency becomes a more mature financial asset, and investing in cryptocurrency becomes more popular, cryptocurrency

		investing is dominated by irrational investing behaviors.	investing should not be dominated by irrational behaviors.
3)	Cybercriminality	Cryptocurrency is a preferred method of payment for illicit activities.	If illicit activities have increased because of the introduction of cryptocurrency.
4)	Portfolio Diversification	Professional investors are using cryptocurrency in a portfolio diversification investment strategy.	Collectively there are mixed results as to if cryptocurrency can be successfully used in a portfolio diversification investment strategy.
5)	Safe Haven / Hedge Properties	Professional investors are using cryptocurrency in a safe haven investment strategy.	Collectively there are mixed results as to if cryptocurrency can be successfully used in a safe haven investment strategy.
6)	Efficiency / Price Discovery	Overtime, cryptocurrency is demonstrating a greater level of price efficiency.	Collectively there are mixed results as to if cryptocurrency openly reflects all available information in its price.
7)	Arbitrage	Arbitrage opportunities do exist for cryptocurrency as a financial asset.	The influence that lack of regulations, local costs, price inefficiency and illiquidity, immaturity as a financial asset, and technological limitations play on arbitrage opportunities for cryptocurrency as a financial asset.

Particular to the research questions of this study was I reviewed arbitrage opportunities for cryptocurrency as a financial asset. Literature demonstrated that arbitrage opportunities do exist for cryptocurrency as a financial asset, but there are gaps in literature regarding the influence of arbitrage opportunities. The research questions and scope of this study adds to the knowledge of this topic of interest by addressing gaps in the literature pertaining to the data collection and how it influences arbitrage opportunities between the cryptocurrency markets. The social problem that prompted this study is that average and inexperienced investors may be accepting unsuitable risks by adding cryptocurrencies to their financial portfolios due to the expectations of improved performance based on past performance, social disinformation, and speculatory investing behaviors.

The purpose of this study was to increase knowledge of cryptocurrencies as a financial asset by addressing if there were arbitrage opportunities for cryptocurrency as a financial asset within the Canadian market. Answering the research questions of this study, not only helped to increase the academic knowledge for this topic of interest, but it also helped professionals, governments, and regulatory bodies better understand how to protect average and inexperienced investors via reducing the risk of investing in cryptocurrency, while still allowing for benefits as a part of a financial portfolio for average and inexperienced investors. To understand how the data for this study was collected, analyzed, and deciphered, Chapter 3 will review the methodology and justify its selection.

Chapter 3: Research Method

The purpose of this quantitative study was to test the LOP on cryptocurrency and cryptocurrency exchanges in Canada. The LOP means identical goods must be sold for identical prices at different locations. Findings of the study helped to support addressing the social problem that prompted this study, which was a lack of conclusive knowledge to help support average and inexperienced investors who may be accepting unmanageable risks by adding cryptocurrencies to their financial portfolios due to expectations of improved performance. To do this, a nonexperimental cross-sectional research design was used.

This chapter includes information about the research methodology and how it supported the study. I define the research design and rationale for its use. Next, I address data analysis plan and threats to validity. The chapter ends with a summary and transition to Chapter 4.

The research method of a study is the components involved in the actual execution of the study. The research method is the configuration of the study to address the research problem (Burkholder et al., 2020). This chapter involves addressing methods to complete this study and how I determined reliability of research in order to accept or reject hypotheses of this study. Chapter 3 includes information about the population, sampling, data collection, data analysis, and threats to validity. These components align to the purpose of the study to create the research methodology of the study.

Research Design and Rationale

The research design for this study was the quantitative method. This involves collection and analysis of numerical data to explain, predict, and understand a phenomenon (Frankfort-Nachmias et al., 2020). This section includes a review of the design and rationale for its selection. It will accomplish this by demonstrating the alignment of the design to the research question, reviewing the variables that were studied, highlight any time or resource constraints, and demonstrating the consistency of the design choice needed to advance knowledge of the topic of interest.

I used a quantitative research design. This method should be used when researchers are attempting to predict relationships between two or more variables (Burkholder et al., 2020). A review of the research questions of this study establishes the alignment of the research design selection to the study. The research questions for this study are:

RQ1: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market?

RQ2: To what extent does validity and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges?

Based on the research questions, the goal of the study was to gain an understanding of the likelihood of the phenomenon occurrence based on the relationship between factors. The prediction of the phenomenon occurrence is known as a hypothesis.

Each research question has a hypothesis and null hypothesis. A hypothesis is a statement that predicts the relationship between two or more factors (Frankfort-Nachmias et al., 2020). The hypothesis helps to transition the Research Questions into a specific, testable expected outcome. The hypotheses for each research question are:

$H_0$1: Daily closing prices by exchange does not cause arbitrage opportunities in the Canadian cryptocurrency market.

H_a1: Daily closing prices by exchange does cause arbitrage opportunities in the Canadian cryptocurrency market.

$H_0$2: Volatility and liquidity do not influence arbitrage opportunities between Canadian cryptocurrency exchanges.

H_a2: Volatility and liquidity do influence arbitrage opportunities between Canadian cryptocurrency exchanges.

The hypothesis details the relationship between different factors. These factors are known as variables.

The relationship between two or more variables was what was being tested to gain an understanding of the topic of interest. For RQ1, the dependent variable was daily arbitrage opportunity. This is a dichotomous variable and involved using a nominal level of measurement. A recent study by Bruzgė and Šapkauskienė (2022b) successfully used a dichotomous dependent variable in their study of arbitrage opportunity for cryptocurrency as a financial asset. The independent variable was daily closing prices for different exchanges, which involved using a nominal level of measurement.

For RQ2, the dependent variable was daily arbitrage opportunity. This involved using a nominal level of measurement. The independent variables were daily volatility and liquidity of cryptocurrency. These are both ratio levels of measurement. Table 4 summarizes the dependent and independent variables for both research questions.

Table 4

Summary of Research Questions and Variables

Research Questions (RQ)	Direct Variable	Indirect Variable(s)
RQ1: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market?	Daily arbitrage opportunity – this is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement.	Daily closing prices for same cryptocurrency between two different exchanges – this variable is a nominal level of measurement.
RQ2: To what extent does validity and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges?	Daily arbitrage opportunity – this is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement.	Volatility (based on β) and liquidity (based on the bid-ask spread) by cryptocurrency – these are discrete variables and both ratio level of measurement.

Based on the results from the initial research question's test, when arbitrage opportunities are found, a second hypothesis for volatility and liquidity will be added to test if there is a relationship between the occurrence of arbitrage opportunities and volatility and liquidity between Canadian cryptocurrency exchanges. If volatility and liquidity did not have an influence on the existence of arbitrage opportunities, then the null hypothesis would be accepted. If volatility and liquidity did have an influence on the existence of arbitrage opportunities, the null hypothesis would be rejected. To understand limitations to the dependent and independent variables being tested to answer the research question, constraints involving the design choice need to be addressed.

There were no constraints on time or resources based on the selection of this research design. Data required for this study were free and readily available to the general public. The financial theory and Excel / IBM SPSS knowledge and permission required to analyze the data is possessed by the author who has two accounting designations and access to the noted software. Therefore, the feasibility and permission required to collect and analyze the data was solely linked with the decision to complete the study or not. Therefore, the decision to do the study was based on the consistency of the research design needed to advance the knowledge for the topic of interest.

As noted in Chapter 2, almost all the papers reviewed for this study had a quantitative research design. Recent studies have shown that the topic of interest can be successfully researched using a quantitative method (Bruzgė & Šapkauskienė, 2022b, 2022a; Duan et al., 2021; Foley et al., 2023; Kabašinskas & Šutienė, 2021; Kristoufek & Bouri, 2023; Leung & Nguyen, 2019; Makarov & Schoar, 2020; Shynkevich, 2021; Wątorek et al., 2021; Zaher et al., 2020). The overwhelming use of quantitative research design within the literature demonstrates the alignment and justification of the method to the topic of interest and its advancement of knowledge.

Methodology

To understand how the research design was implemented, the methodology of the study must be defined. To have a clear understanding how a study plans on answering a research question, there must be a clear understanding of how the components of the study will be applied to support the research design (Burkholder et al., 2020). To define the methodology of the study, the details of the research design plan needs to be reviewed. This section will do this by detailing the target population, sampling procedures, data collection, and archival data.

Population

Defining the population helps to set the scope of the study. A population represents the total of individuals, objects, or events for the topic of interest (Frankfort-Nachmias et al., 2020). For this study, the scope was limited to the events of arbitrage for cryptocurrency as a financial asset. To help promote the advancement of knowledge by this study, the scope of the population needs to be further refined.

The review of the literature in Chapter 2 noted a collective trend of a lack of representation of Canada within the academic work for arbitrage opportunities for cryptocurrency as a financial asset. Canada is a leading economy with a high level of cryptocurrency acceptance (Blair, 2022), and by 2023 Canada is projected to be the fourth largest cryptocurrency market in the world based on revenues (*Cryptocurrencies - Canada | Statista Market Forecast*, n.d.). To help fill this gap in the literature and further refine the population of this study, this study will focus on arbitrage opportunities for cryptocurrency as a financial asset in the Canadian market. The Canadian cryptocurrency market is of substantial size to help advance the knowledge of this topic of interest.

Like most of the world, cryptocurrency is not considered legal tender in Canada; however, it is not illegal to use cryptocurrency in Canada. The approximate 9% of the Canadian population that owns cryptocurrency has access to the almost $1 US trillion market that consist of over 200 cryptocurrency exchanges and the almost 10,000 different cryptocurrencies (Laycock, 2022). While a study focused on the Canadian cryptocurrency market would add to the existing knowledge, further refinement of the population was required to make the study manageable while still ensuring its validity. This kind of subset of the population is known as a sample.

Sampling and Sampling Procedures

To realistically and successfully study arbitrage opportunities for cryptocurrency as a financial asset in Canada, a sample of the market must be looked at. A sample is a subset of the population used to make inferences of the total population (Frankfort-Nachmias et al., 2020). To help guide the selection of the sample, Chapter 2 noted gaps in the literature, mainly the literature was focused on Bitcoin, if technical issues are influencing arbitrage findings, and if cryptocurrency is a mature financial asset. This section will not review each of these noted gaps and how they influenced the scope of the sample population.

A noted collective trend found in the academic literature review was that the majority of studies were focused solely on Bitcoin. Recent studies have noted that Bitcoin is not the sole predictor of cryptocurrency and there is a need to increase the knowledge around other cryptocurrencies (Almeida, 2021; Corbet et al., 2019; Leung & Nguyen, 2019). With approximately 10,000 cryptocurrencies, a creditable criterion to select the sample population is required. The criterion of the most popular cryptocurrencies in Canada was used. This sample population criterion follows the sample process used by recent studies that looked at arbitrage opportunities for more than one cryptocurrency (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021). The top four popular cryptocurrencies in Canada with at least 1% of the market, which account for 64% of the overall market holdings, are Bitcoin, Ethereum, Dogecoin, and Cardano (de Best, 2022;

Laycock, 2022). Internationally, each of these cryptocurrencies are seen as a leading cryptocurrency (Demmler, 2023). Only data for these cryptocurrencies were collected for our sample.

With over 200 cryptocurrency exchanges from which to collect data, a credible set of criteria to select the sample population was required. The LOC principle notes that local costs need to be accounted for and must be considered in the sample selection. Embedded into the market prices for cryptocurrency are regulatory costs and transactional costs. To ensure that the exchanges selected had the same regulatory and transactional costs, three selection criteria were made: the exchange must support the four noted cryptocurrencies; prices are quoted in Canadian dollars and paid out in Canadian dollars (to remove foreign exchange costs); and the exchange had to be approved by Canada's largest security committee—the Ontario Security Committee.

The noted criteria will help to ensure that, along with consistent regulatory costs, only legitimate and leading exchanges were selected for data collection. These sample population criteria follow the sample process used by recent studies that looked at arbitrage opportunities for more than one cryptocurrency (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021). Based on these criteria, there were six exchanges selected: Bitbuy Canada; Bitvo; Coinsquare; Netcoins; Newton; Wealthsimple. These exchanges accounted for 15% of the Canadian cryptocurrency market revenues in 2022 (Cryptocurrencies - Canada | Statista Market Forecast, n.d.). To note, Binance, the world's largest cryptocurrency exchange, announced in May 2023 they would be immediately leaving the Canadian market due to regulatory issues, such as its inability to gain approval from the Ontario Security Committee (Durrani, 2023). This will have an effect of increasing the market share of the noted exchanges.

With the selection of the sample population's cryptocurrencies and cryptocurrency exchanges, the next requirement is to define the specifics of the data to be collected. The data specifics for this study would be quantitative information to be collected and the time period. The specific details of the data collected for the sample population were based on gaps in the academic literature found in Chapter 2. The particulars of these gaps will be reviewed next.

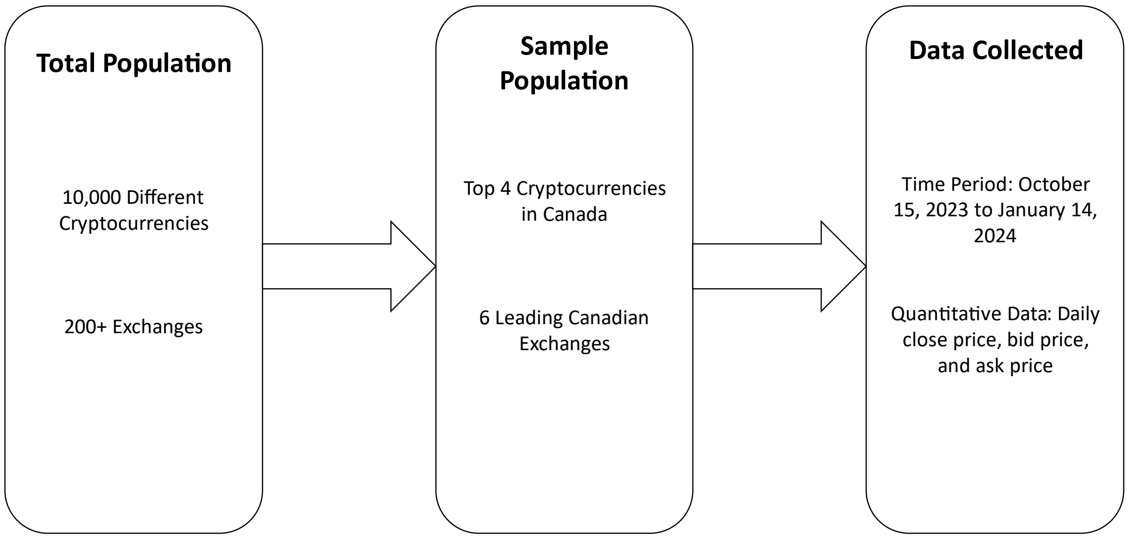
The quantitative data to be collected for the sample population were closing price, bid price, and ask price. These selections were based on findings from Chapter 2. A study by Foley et al. (2023) found that most studies on arbitrage opportunities for cryptocurrency as a financial asset relied on ticker tape data that was flawed due to system limitations. The use of end of day prices, also known as closing prices, would circumvent this concern. Hansen et al. (2024) successfully used daily closing prices in their study on cryptocurrency and how volatility and liquidity can be used to determine arbitrage opportunities. In addition to the closing price, the data on daily bid and ask prices per cryptocurrency will also be collected. These three pieces of information (closing, bid, and asking prices) will allow the study to create measures for volatility and liquidity. Recent studies have collectively demonstrated mixed results as to the influence volatility and liquidity may have on arbitrage opportunities for cryptocurrencies as a financial asset.

The data collected for this study will be limited from 2023-2024. This is due to a gap in the literature based on the maturity of cryptocurrency as a financial asset. Shynkevich (2021) concluded that arbitrage opportunities all but disappeared after 2018 due to its transition into a mature asset. While other recent studies disagree with this conclusion (Kristoufek & Bouri, 2023; Krückeberg & Scholz, 2020), this study used 3 months of current data, from October 15, 2023 to January 14, 2024, to gain new knowledge for this gap within the literature. This criterion also addressed Delfabbro's et al. (2021) concern that growth in cryptocurrencies is happening so rapidly that any data cited as recently as 3 months ago can be considered outdated. The data to be collected, daily closing, bid, and ask prices, were decided upon to address these noted gaps in the academic literature.

The sample of a study is the subset of the total population being studied. The sample for this study was for Bitcoin, Ethereum, Dogecoin, and Cardano, which accounts for 64% of the Canadian market holdings. This information was collected from the six exchanges, Bitbuy Canada, Bitvo, Coinsquare, Netcoins, Newton, and Wealthsimple, which accounted for 15% of the number of transactions. In tangent, these sample data collection criteria capture 10% of the total population. With Canadian cryptocurrency revenues of US$ 2.03bn from 2019 to 2022, the sample population would have a dollar value of US$ 0.2bn (Cryptocurrencies - Canada | Statista Market Forecast, n.d.). This data were collected over the time period of October 15, 2023 to January 14, 2024, and included the daily closing, bid, and ask prices. The breakdown from the total population being studied to the sample population and the data collected can be found in Figure 2.

Figure 2

Sample Population and Data Collection Breakdown



The first quantitative test on the sample population was descriptive statistics. Determining a good sample size for descriptive statistics depends on several factors, including the desired level of precision, the variability of the population, and the level of confidence you want to achieve in your estimates. Based on the Central Limit Theorem, a common rule of thumb is to aim for a sample size of at least 50 cases for descriptive statistics (Frankfort-Nachmias et al., 2020). Based on the Central Limit Theorem, the noted sample size of 10% of an over US$ 2.03bn population is a sufficiently large sample size. This demonstrates that the distribution of the sample's mean will approximate a normal distribution.

The second quantitative test on the sample population was a binary logistic regression test. In binary logistic regression, the effective size of a sample population can be measured using the events per variable (EPV) rule (Warner, 2012). The EPV rule suggests having at least ten events (positive outcomes) per independent variable in the logistic regression model. This guideline helps ensure sufficient statistical power and stability of the estimated coefficients (Warner, 2012). Based on the EPV, the noted sample size of 10% of an over US$ 2.03bn population is a sufficiently large sample size to ensure the predictive accuracy of a binary logistic regression test.

In quantitative research, the ability of a sample population to address the research questions is based on how the data is collected. Only data that is appropriate and collected properly can be used to empirically analyze and interpret a phenomenon (Burkholder et al., 2020). The next section will review how the data was collected for this study. This will be done by reviewing what information was collected, the purpose of the information, the timing of the information, and how the information was gathered. The following section will cover these details.

Data Collection

An empirical study is only as good as the data it uses. For a quantitative study to be successful in predicting a phenomenon, the data collected must be appropriate for the problem and accessible to the researcher (Burkholder et al., 2020). This section will review how the data for this study was collected. To understand the data that needs to be collected, the research questions need to be reviewed.

Following recent studies on arbitrage opportunities for cryptocurrency as a financial asset, descriptive statistics was used to tabulate the probability and subsequent magnitude of arbitrage opportunities for cryptocurrency as a financial asset (Bruzgė &

Šapkauskienė, 2022b; Makarov & Schoar, 2020). This information was used to answer the first research question: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market? If it is determined that arbitrage opportunities do exist between Canadian cryptocurrency exchanges, then a binary logistic regression analysis would be performed to assess the influence of both measures for volatility and liquidity had on the existence of arbitrage opportunities. This information was used to answer the second research question: To what extent does volatility and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges? Based on the noted research questions, archival data was collected.

Archival Data

Due to the scope of this study, the characteristics of the data required are of a historical nature. Historical data is past data that has been collected and stored for future reference and analysis (Burkholder et al., 2020). Historical data is also known as archival data. Archival data is valuable for economic modeling as it allows researchers to examine past trends and behaviors of the economy. Particular to this study, the archival data was able to demonstrate if arbitrage opportunities existed for cryptocurrency between certain Canadian exchanges from October 15, 2023 to January 14, 2024, and if the volatility and/or liquidity of the particular cryptocurrency were influencers of the arbitrage opportunity.

The use of archival data for research in the cryptocurrency field is a common practice. Recent studies have successfully used archival data as the main source of data to examine arbitrage opportunities for cryptocurrency as a financial asset (Bruzgė & Šapkauskienė, 2022a, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020). This study design for the use of archival data was built off these noted studies. The use of archival data as the source of data for this quantitative study was also selected due to the ease of collecting this data.

The data required for this study was easy to collect. For most cryptocurrency exchanges, the required archival data for this study is readily available on the exchange's website. This data was daily closing, bid, and ask prices by cryptocurrency by exchange. If the required data was not easily collected from an exchange's website, then a letter of request was sent to the exchange. This letter of request can be found in Appendix A. Due to the open availability of this data on exchanges' websites and the fact that there are complete datasets for this information for larger markets (for an example, go to www.kaggle.com/kaushiksuresh147/top-10-cryptocurrencies-historical-dataset for several freely-available historical datasets of cryptocurrencies), there was little apprehension over exchanges' willingness to offer their archival data due to confidentiality concerns or corporate policies.

While the data for this study is readily available, it still requires analysis. Quantitative data requires organization and analyzation to alter it from a simple dataset into knowledge about a larger population (Warner, 2012). To determine if arbitrage opportunities exist and, if so, measure the influence that volatility and liquidity have on the existence of arbitrage opportunities for cryptocurrency as a financial asset, statistical tools, statistical knowledge, and financial knowledge are required. These requirements embody the plan for data analysis and will be reviewed in the next section.

Data Analysis Plan

A data analysis plan is a crucial component of any study. Providing a comprehensive data analysis plan can demonstrate its alignment to the rest of the study, explain the purpose of the study, and lay the foundation for the interpretation of the findings of the study (Frankfort-Nachmias et al., 2020). The data analysis plan becomes the conduit between the data collected and the research questions of a study. To do this, this section will review the software to be used, data preparation, and the details and rationale on how the research questions was answered.

Software

The main software used in this study was IBM's Statistical Package for the Social Sciences (SPSS). SPSS is a software program widely used in social sciences and data analysis. It provides a comprehensive range of statistical procedures and data management tools. SPSS was initially developed by Norman H. Nie, C. Hadlai "Tex" Hull, and Dale H. Bent at Stanford University in the late 1960s (Wikipedia, 2023b). The first version of SPSS was released in 1968 (Wikipedia, 2023b). Over the years, SPSS underwent several updates and enhancements to become one of the most popular statistical software packages. In 2009, SPSS was acquired by IBM Corporation, and it is now known as IBM SPSS Statistics (Wikipedia, 2023b).

SPSS was selected for this study because it is a versatile software package that offers a wide range of features and capabilities for data analysis, including descriptive statistics, inferential statistics, can assist in analyzing the reliability and validity measures, data can be updated from Microsoft Excel, and allows for data manipulation. All these features were required for organization and analysis of the data collected for this study. In addition, the author of this study has the statistical training to decipher SPSS outputs, has been trained in using SPSS, and has a current license to use SPSS through Walden University.

As noted, SPSS is a popular tool in the social sciences field. SPSS's reliability and validity as an instrument for statistical analysis has been well documented (Field, 2018; Frankfort-Nachmias et al., 2020; Wagner III, 2019; Warner, 2012). These endorsements of SPSS are based on its consistency and precision as a statistical tool. The reliability of a statistical tool is a crucial aspect of a quantitative research methodology, but the statistical tool is only as good as the data that is used. How the collected data was prepared to be used in the study will be reviewed next.

Data Preparation

The purpose of preparing or cleaning the data in a quantitative study is to ensure that the collected data is accurate, consistent, and reliable for analysis. Data cleaning involves identifying and correcting errors, inconsistencies, missing values, outliers, and other issues that may compromise the quality and integrity of the data (Frankfort-Nachmias et al., 2020). The following data preparation plan leverages workings from similar recent studies on arbitrage opportunities for cryptocurrency as a financial asset (Bruzgė & Šapkauskienė, 2022a; Krückeberg & Scholz, 2020; Makarov & Schoar, 2019). Because the data is of historical nature and was expected to be from a system data dump (no manual entry), it is assumed that the data was accurate, and all data points will be accepted. In addition, there were approximately 20,000 data points, assuming one data point contains the daily prices (closing, bid, and ask) for a particular cryptocurrency from a particular exchange. This means that individual outliers will statistically have insufficient effect on the overall dataset.

Consistency is crucial in quantitative research to ensure that data points are recorded uniformly. The data for this study was cleaned to ensure consistency. Since the data was collected from several different exchanges, the collective data will lack uniformity if not cleaned for consistency. Consistency cleaning involves identifying and resolving inconsistencies in data entry, formatting, or labeling. The goal is to ensure that each dataset matches the other datasets, so they can be combined into the one large dataset needed to answer the research questions of the study.

Research Questions and Data Analysis

The purpose of this quantitative study was to test the theory of the LOP on cryptocurrency and cryptocurrency exchanges in Canada. LOP models that identical goods must be sold for identical prices at different locations. LOP compares the market value of cryptocurrencies across different markets to see if there are arbitrage opportunities. If there are arbitrage opportunities, then LOP has been violated. To prove the existence of arbitrage opportunities for cryptocurrency as a financial asset between Canadian cryptocurrency exchanges, two research questions were created. This section will review each of the research questions, the dependent and independent variables, and how the data was analyzed. Table 4, located at the end of this section, summarizes this information.

RQ1 of the study is: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market? For this research question the null hypothesis and hypothesis are:

$H_0$1: Daily closing prices by exchange does not cause arbitrage opportunities in the Canadian cryptocurrency market.

H_a1: Daily closing prices by exchange does cause arbitrage opportunities in the Canadian cryptocurrency market.

The dependent variable of the hypothesis was daily arbitrage opportunity. This is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement. The independent variable of the hypothesis was the daily closing prices of cryptocurrency by the different Canadian cryptocurrency exchanges. This is a discrete variable and is a ratio level of measurement. To test if daily arbitrage opportunities do exist (dependent variable), the daily closing price of a cryptocurrency from one exchange will be compared to another exchange (independent variable). If the prices are the same, then the dependent variable will equal No. If the prices are different, then the dependent variable will equal Yes.

The dependent variable, arbitrage opportunity (Y/N) is a constructed variable. It is constructed based on the comparison of the independent variable and daily closing price for a particular cryptocurrency by cryptocurrency exchange. For this study, there are four different cryptocurrencies (Bitcoin, Ethereum, Cardano, and Dogecoin) and six different exchanges (Bitbuy Canada, Bitvo, Coinsquare, Netcoins, Newton, and Wealthsimple). An example of this: day closing price for cryptocurrency A in Exchange A will be subtracted to the day closing price for cryptocurrency A in Exchanges B to F. Therefore, for one day there are five different constructed variables for each of the cryptocurrencies. If the constructed variable has a value equal to or greater than $0.001, then it will be considered an arbitrage opportunity (Y). If the constructed variable has a value less than $0.001, including a negative number (eliminating the double counting of arbitrage opportunities between different datasets), then it will not be considered an arbitrage opportunity (N). An individual dataset will be created for each exchange. These datasets will be created in Microsoft Excel and then placed into SPSS.

Within SPSS, descriptive statistical analysis will be performed. The analysis will demonstrate the existence (possibility) of arbitrage opportunities, the frequency (probability) of arbitrage opportunities, and the size (mean, medium, and mode) of the arbitrage opportunities. This data analysis plan followed the work completed by Bruzgė and Šapkauskienė (2022b), in which the researchers used descriptive statistics to demonstrate the existence and magnitude of arbitrage opportunities for investors for exchanges based in the U.K., the U.S., and European countries. For their study, Bruzgė and Šapkauskienė (2022b) set a minimum amount of arbitrage at $0.001. This means that a difference between two exchanges of less than $0.001 was not considered an arbitrage opportunity. This study set the same limitation on its criteria for what was considered an arbitrage opportunity.

If the null hypothesis of RQ1 is accepted, then the study will be concluded. If the null hypothesis of RQ1 is rejected, then the study will commence with the review of RQ2.

RQ2 of this study is: To what extent does volatility and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges? For this research question the null hypothesis and hypothesis are:

$H_0$2: Volatility and liquidity do not influence arbitrage opportunities between Canadian cryptocurrency exchanges.

H_a2: Volatility and liquidity do influence arbitrage opportunities between Canadian cryptocurrency exchanges.

The dependent variable of the hypothesis was daily arbitrage opportunity, the same dependent variable used in RQ1. This is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement. The independent variables were volatility and liquidity. There is no individual measurement for either volatility or liquidity. Volatility and liquidity are conceptual measurements of risk in comparison to something considered stable. To understand the influence volatility and liquidity have on arbitrage opportunities for cryptocurrency as a financial asset in the Canadian market, the two independent variables had to be constructed. While constructed, these independent variables are based on fundamental financial principles and are universally accepted key performance measures for financial assets. The construct of the independent variables for volatility and liquidity will now be reviewed.

The first independent variable was volatility. As noted in Chapter 2, there are mixed results as to the influence volatility has on arbitrage opportunities for cryptocurrency as a financial asset. Recent studies by Brauneis et al. (2022) and Kristoufek and Bouri (2023) concluded that increased volatility of a cryptocurrency can cause arbitrage opportunities. In contrast, recent studies by Celeste et al. (2020) and Kang et al. (2022) concluded that it was not increased volatility, but the immaturity of cryptocurrency that causes arbitrage opportunities.

The inference of the stability of daily pricing of a financial asset is known as price volatility (volatility). Volatility is the amount of risk associated to a financial asset based on fluctuations to its market price (Ross et al., 2022). When a financial asset is determined to have high price volatility, its price can change dramatically in a short period of time. When a financial asset is determined to have low price volatility, it tends to maintain its price over time. To understand how volatility is a measure of the riskiness of a financial asset, there needs to be an understanding of how the total risk of a financial asset is measured and how it influences volatility.

The total risk is based on the systematic risk plus the unsystematic risk of a financial asset. Systematic risk is risk that is global or inherent to financial markets (Ross et al., 2022). Unsystematic risk is risk that is unique to an individual or small group of financial assets, such as a company or an industry (Ross et al., 2022). Understanding this breakdown of risk is important to understand if a particular type of risk is manageable. While systematic risk is inherent to all financial assets, unsystematic risk can essentially be eliminated through the principle of diversification.

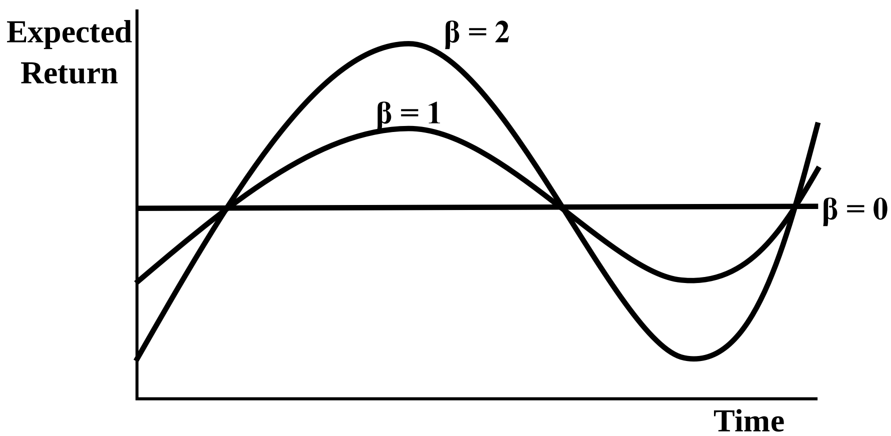
In the context of investing, the principle of diversification is a risk management strategy that involves the spreading of assets across different asset classes within a financial portfolio. The principle of diversification is a fundamental investment strategy that reduces risk by holding several different assets that are negatively correlated to each other, meaning that the volatility and valuation of two different assets have opposite reactions under similar market scenarios (Markowitz, 1952). This strategy results in the elimination of unsystematic risk within a properly diversified financial portfolio. Therefore, only systematic risk remains in a properly diversified financial portfolio. This leads to another fundamental principle of investing in financial assets: the systematic risk principle.

Financial investments should only be rewarded based on the risk taken—the higher the risk, the greater the reward. The systematic risk principle states that the reward of a financial asset depends only on the systematic risk of the financial asset (Ross et al., 2022). This means investors are only rewarded based on the inherent overall market risk, and any specific risks to a financial asset are disregarded. The challenge to investors becomes how do they isolate and measure the systematic risk of a financial asset.

One way to determine the systemic risk of a financial asset is to measure its beta coefficient (β). The β is a measure of the systematic risk or volatility of a particular financial asset in relation to the overall market (Ross et al., 2022). The β assesses the sensitivity of a financial asset's returns to changes in the overall market. The β does this by comparing the price volatility of an individual financial asset to the price volatility of a benchmark index. By definition, a financial asset with a β of 0 would be considered risk-free. As the β of a financial asset increases, so does the perceived risk associated with the financial asset: a financial asset with a β of 0.5 has half as much systematic risk of an average asset; a financial asset with a β of 1 has the same systematic risk of an average asset; a financial asset with a β of 2 has twice as much systematic risk of an average asset; a financial asset with a β of -1 implies that the security tends to move in the opposite direction of the market. Figure 3 demonstrates volatility of a financial asset through different β values.

Figure 3

Increased Volatility of Expected Returns of Different Betas (β)



For the Canadian market, the main benchmark index to set the β value to is the Standards and Poor/Toronto Stock Exchange Composite Index (S&P/TSX). The S&P/TSX is an equities benchmark that tracks the daily price changes of 250 of Canada's largest public companies on the Toronto Stock Exchange. The S&P/TSX is considered a barometer of the Canadian financial markets. Therefore, the daily movement/volatility of the S&P/TSX would have a β of 1. For the methodology, to understand the volatility of a particular cryptocurrency, its daily price change will be compared to the daily price change of the S&P/TSX Index. This will be based on comparison to prior day's closing prices and current day's closing prices for both the S&P/TSX and the particular cryptocurrency. On occasions where the percentage change of a particular cryptocurrency is higher than the percentage change of the S&P/TSX, the particular cryptocurrency will have a β greater than 1. Inversely, on occasions where the percentage change of a particular cryptocurrency is lower than the percentage change of the S&P/TSX, the particular cryptocurrency will have a β less than 1. Finally, on occasions where the percentage change of a particular cryptocurrency is opposite the percentage change of the S&P/TSX, the particular cryptocurrency will have a negative β. β is considered a ratio level of measurement. The daily β value by cryptocurrency will be placed into SPSS for a binary logistic regression test, as one of the two independent variables to predict their influence on the dependent variable. The second independent variable for the dependent variable was based on the liquidity of the cryptocurrency.

The second independent variable was liquidity. As noted in Chapter 2, there are collectively mixed results as to the influence liquidity has on arbitrage opportunities for cryptocurrency as a financial asset. Recent studies by Brauneis et al. (2022), Brauneis and Mestel (2018), and Makarov and Schoar (2020) concluded that decreased liquidity (illiquidity) of a cryptocurrency can cause arbitrage opportunities. In contrast, recent studies by Kristoufek and Bouri (2023) and Krückeberg and Scholz (2020) concluded that increased liquidity of a cryptocurrency can cause arbitrage opportunities for cryptocurrencies. For the market price of a financial asset to openly reflect all available information, the financial asset must have the ability to readily be turned into cash. This is known as the liquidity of a financial asset. Simply put, the liquidity of a financial asset is based on how quickly it can be bought or sold (Brauneis & Mestel, 2018). Financial assets with high liquidity will have sufficient outstanding units and adequate supply and demand to facilitate new information as it enters the market through the buying and selling of the asset. The challenge becomes how to measure if the outstanding units are sufficient to allow for this flow of information.

One measurement used to gauge the liquidity of a financial asset is the difference between what buyers are willing to purchase a financial asset for in comparison to what sellers are willing to offer a financial asset for. This is known as the bid-ask spread. The bid-ask spread is a key concept in financial markets and represents the difference between the highest price that a buyer is willing to pay for a security (the bid price) and the lowest price that a seller is willing to accept (the ask price) at a given point in time (Ross et al., 2022). A transaction occurs when the bid and an ask prices match.

The smaller the spread between the buyer and seller the higher the liquidity. A narrow bid-ask spread indicates the ease in which buyers and sellers can react to new information based on the higher frequency of transactions (Ross et al., 2022). This means that buyers and sellers of a financial asset with a narrow bid-ask spread are more likely to find an agreeable price, either by consensus or new buyers or sellers entering the market. It is universally perceived that financial assets with higher liquidity are safer to invest in. The challenge becomes having a measure that will gauge if the bid-ask spread is indicative of a liquid or illiquid financial asset.

While it is universally accepted that the narrower the bid-ask spread is, the greater the liquidity of a financial asset, the bid-ask spread of a particular financial asset needs to be compared to some form of standard to indicate if the spread implies a liquid or illiquid financial asset. Recent studies have used the bid-ask spread as an indicator of a cryptocurrency's liquidity (Krückeberg & Scholz, 2020; Makarov & Schoar, 2020). These studies converted the value of the spread into a percentage for comparability purposes. Krückeberg and Scholz (2020) defined the bid-ask percentage as the total of the ask price minus the bid price and then divided by the ask price ((ask-bid)/ask). Makarov and Schoar (2020) noted that an average bid-ask percentage was 10 basis points. A basis point (bps) is a unit of measurement commonly used in finance and represents one-hundredth of a percentage point—0.01% or 0.0001. This study used the same liquidity range used by Makarov and Schoar to indicate if a bid-ask percentage indicates if a cryptocurrency is to be considered liquid (0-3 bps), average (4-16 bps), or illiquid (17+ bps). Liquidity is considered a ratio level of measurement. The daily liquidity value by cryptocurrency was placed into SPSS for a binary logistic regression test as the second of the two independent variables to predict their influence on the dependable variable.

To quantify the relationship between the dependent variable and independent variables, a binary logistic regression test was selected. Binary logistic regression is a statistical analysis technique used to predict the probability of an event occurring when the outcome variable is tested against two predictor variables (Warner, 2012). A binary logistic regression analysis models the relationship between two independent variables (predictor variables) to a dependent variable (outcome variable). The Nagelkerke R-squared will be used to calculate the strength of this relationship. The Nagelkerke R-squared is a measure of the goodness-of-fit in logistic regression models (Warner, 2012). It is an extension of the traditional R-squared used in linear regression, adapted for binary logistic regression (Warner, 2012). To ensure that a binary logistic regression analysis was an appropriate test for this study, the assumptions of the test and its alignment to the rest of the study needs to be reviewed.

Checking and confirming the assumptions of a statistical test is a fundamental component of the quantitative analysis process. Ignoring the assumptions placed on a dataset for a particular statistical measure is not only irresponsible, but can lead to the determination of an incorrect conclusion and brings into question the integrity of the research (Kotronoulas et al., 2023). Checking and confirming the assumptions for a statistical test will help to ensure the validity, reliability, and generalizability for the findings of a study. This section will now review the assumptions on the dataset for a binary logistic regression statistical test.

This study will employ the use of a binary logistic regression model to analyze the data collected for RQ2. Based on Warner (2012), a binary logistic regression model can be used to analyze data for studies where the dependant variable is dichotomous. For the dataset to be considered appropriate for a logistic regression several assumptions need to be met dependant variable must be dichotomous, large sample size, no multicollinearity, independence of observations, linear relationship, and no perfect separation. As noted in the previous paragraphs, the raw data collected was transformed to help meet generally accepted financial principles. The data used for the dependant variable, daily closing price, was transformed from a continuous variable to a dichotomous variable for arbitrage (0 = no arbitrage; 1 = arbitrage). The data used for the independent variable, daily closing price, was transformed from a continuous variable to a dichotomous variable for volatility (0 = involatile; 1 = volatile). The data used for the independent variable, daily closing bid and ask prices, was transformed from a continuous variable to a categorical variable for liquidity (0 = illiquidity; 1 = average; 2 = liquid). These transformed data points were used in the binary logistic regression model of this study.

The assumptions for a binary logistic regression model were vetted for both the raw and transformed dataset, were applicable, to ensure that the datasets were acceptable. Both datasets maintained the transformed dichotomous dependant variable and only the raw and transformed data used for volatility and liquidity independent variables were dual tested for adherence to the assumptions. Both evaluations of the noted assumptions found the datasets to be appropriate for the use of a binary regression model. The subsequent paragraphs will define the noted assumptions and summarize the statistical tests and performance by each dataset. The checking of the assumptions will be completed in Chapter 4.

The use of a binary logistic regression analysis is appropriate for this study, not only because the datasets adhere to the aforementioned assumptions, but Warner (2012) noted that binary logistic regression is useful for studies where researchers are examining the contribution of independent variables on the dependent variable and assess the significance and magnitude of each independent variable. This matches the purpose of this study. Also, Tjondro et al. (2023) successfully used a binary logistic regression analysis in their study on cryptocurrency. A summary of the noted research questions, the dependent and independent variables, and the data analysis plan of this study can be found in Table 5

Table 5

Summary of Research Questions, Variables, and Data Analysis Plan

Research Questions (RQ)	Variables	Data Analysis
RQ1: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market?	Dependent Variable: Does Arbitrage Opportunities exist daily for a particular cryptocurrency between one exchange to another that is greater than $0.001 (dichotomous: Yes or No) Independent Variable: Daily closing price by cryptocurrency by exchange	Descriptive Statistics: To demonstrate it arbitrage opportunities exist (possibility), what is the likelihood of an arbitrage opportunity occurrence (probability), and what is the magnitude of the occurrence (mean, mode, medium).
RQ2: To what extent does validity and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges?	Dependent Variable: Does Arbitrage Opportunities exist daily for a particular cryptocurrency between one exchange to another that is greater than $0.001 (dichotomous: Yes or No) Independent Variables: Volatility (based on the β of the daily price change of an individual cryptocurrency in comparison the daily price change of the TSX) and Liquidity (based on the daily size of the bid to ask spread)	Inferential Statistics: Binary Logistic Regression – demonstrate the overall predictability relationship between the dependent variable and the independent variables. Nagelkerke R^2 will be used to determine the overall predictability level.

I used descriptive statistics and a binary logistic regression test to answer the research questions. Data collected on four leading cryptocurrencies from six leading Canadian cryptocurrency exchanges were placed into SPSS for descriptive and inferential statistical analysis. To do this, the data collected was constructed into a dichotomous dependent variable and two independent variables. To demonstrate that the data analysis of the findings and the construct of the variables were done without bias and were not threats to the validity of this study will be reviewed next.

Threats to Validity

Threats to the validity of a study can be instigated by several different factors. Burkholder et al. (2020) defines the validity of a study as its ability to reflect a phenomenon without being influenced by coincidental relationships, research biases, or limitations of the study. Threats to the validity of a study would interfere with the ability of the study to accurately represent the topic of interest. To understand the potential threats to the validity of this study, this section will review the external, internal, and construct threats to validity and how they were addressed.

External Validity

External validity refers to a study's ability to represent the population for the topic of interest. Warner (2012) defines external validity as a study's ability to generalize its findings beyond its current context. It is a study's ability to generalize its findings to a broader population or under a different setting. Threats to the external validity of a study can be the study's design, sampling techniques, and data collection methods. This section will review key threats to external validity of a quantitative study and how they were addressed within this study.

Based on the design of the study and an overview of threats to external validity by Burkholder et al. (2020), three main threats to external validity were noted:

1) Sampling Bias: When the sample used in the study is not representative of the target population.

2) Selection Bias: When participants or subjects are not randomly selected.
3) Measurement Bias: When the measurement instruments used in the study do not accurately capture the intended constructs or introduce systematic errors.

Addressing the sampling bias, there are over 10,000 different cryptocurrencies in the world (Laycock, 2022). As such, a creditable criterion to select the sample population was used rather than random selection. The criterion of the most popular cryptocurrencies in Canada was used. This sample population criterion follows the sample process used by recent studies that looked at arbitrage opportunities for more than one cryptocurrency (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021). The top four popular cryptocurrencies in Canada, which account for 64% of the Canadian market holdings, are Bitcoin, Ethereum, Dogecoin, and Cardano (de Best, 2022; Laycock, 2022). Only data for these cryptocurrencies were collected for the sample population.

Addressing the selection bias, there are over 200 different exchanges in the world (Laycock, 2022). With 200+ cryptocurrency exchanges to collect data from, a credible set of criteria to select the sample population was used, rather than random selection. The LOC principle notes that local costs need to be accounted for and must be considered in the sample selection. Embedded into the market prices for cryptocurrency are regulatory costs and transactional costs. To ensure that the exchanges selected had the same regulatory and transactional costs, three selection criteria where made: the exchange must support the four noted cryptocurrencies; prices are quoted in Canadian dollars and paid out in Canadian dollars (to remove foreign exchange costs); and the exchange had to be approved by Canada’s largest security committee—the Ontario Security Committee.

These criteria would help to ensure that only legitimate and leading exchanges were selected for data collection. This sample population criteria follows the sample process used by recent studies that looked at arbitrage opportunities for more than one cryptocurrency (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021). Based on these criteria, there were only six exchanges: Bitbuy Canada; Bitvo; Coinsquare, Netcoins, Newton, Wealthsimple. These exchanges accounted for 15% of the Canadian cryptocurrency market revenues in 2022 (Cryptocurrencies - Canada | Statista Market Forecast, n.d.). To note, Binance—the world's largest cryptocurrency exchange—announced in May 2023 that they would be immediately leaving the Canadian market due to regulatory issues, such as its inability to gain approval from the Ontario Security Committee (Durrani, 2023).

Addressing the measurement bias, the foundation of the data analysis plan is based on the construction of three variables. The dependent variable is based on the comparison of the daily closing prices of a cryptocurrency by different exchanges. The independent variable of volatility is based on the construction of a β for a cryptocurrency in comparison to the S&P/TSX. The independent variable of liquidity is based on the cryptocurrency's bid-ask spread in comparison to set expectations. Consideration to each of these measurements need to be given to ensure that biases do not threaten the external validity of the study.

For the construct of the dependent variable threat to external validity, a clearly defined and operationalized variable was created. Clearly defining and operationalizing the variables of interest is essential to ensure consistent and reliable measurement

(Warner, 2012). The math behind the construct of the dependent variable for this study was simplistic but distinctly defined, and followed the work of another recent study of the same topic of interest (Bruzgė & Šapkauskienė, 2022b). These precautions reduced the likelihood of subjective interpretations by different researchers or participants, minimizing measurement bias threat to external validity.

For the construct of the independent variables threat to external validity, the use of validated and reliable measurements was used. Warner (2012) noted it is crucial to select measurement instruments that have been rigorously tested and validated for the constructs being studied. The Data Analysis Plan section clearly validated the reasoning for the selection of these constructed measurements and demonstrates them to be tested and fundamental financial principles. By using established and reliable measures, researchers can enhance the accuracy and validity of the collected data, minimizing measurement bias threats to external validity.

This section has reviewed the threats to the external validity of this study. It provided an overview of factors that may limit the generalizability and applicability of research findings to populations, settings, or conditions beyond the specific study context. For each of these factors, strategies were discussed that were used to mitigate these threats. This review of threats to the validity for this study will now focus on internal validity.

Internal Validity

Internal validity refers to a study's ability to assess relationships within the study. Warner (2012) defines internal validity as the degree to which a research study provides accurate and reliable conclusions about cause-and-effect relationships between variables. This means that researchers must acknowledge potential threats that could introduce bias or alternative explanations within their analysis. This section will review key threats to internal validity of a quantitative study and how they were addressed within this study.

As the data collected for this study is archival, many of the traditional threats to internal validity are eliminated, such as testing effect, attrition, and experimental effect. Based on the design of the study and an overview of threats to internal validity by Burkholder et al. (2020), three main threats to internal validity were noted:

1) Selection Bias: When the process of selecting participants or assigning them to different groups is not random or unbiased, leading to systematic differences between groups.
2) History: When external events or circumstances occur during the study period and could impact the dependent variable autonomously of the independent variable.
3) Maturation: Changes or developments that naturally and autonomously occur over time to the topic being studied.

To address the selection bias, it was noted in the External Validity section that the cryptocurrencies and exchanges used for this study were not randomly selected. While random selection would have eliminated potential selection bias, it would have had detrimental effects to the overall reliability of the study. Currently there are approximately 10,000 different cryptocurrencies and over 200 different cryptocurrency exchanges (Laycock, 2022). While this pool of participants may seem perfect for random selection, the truth of the matter is that a slim minority of these participants represent the vast majority of the market.

Of the approximate 10,000 different cryptocurrencies, the top two cryptocurrencies account for 61% of the total market capitalization for cryptocurrency (Statista, 2023). Further to this point, the top eight cryptocurrencies account for 86% of the total market capitalization of cryptocurrencies, and all remaining cryptocurrencies each account for less than 1% of total market capitalization for cryptocurrencies. To treat all cryptocurrencies as the same would overestimate the influence most cryptocurrencies have on the total population. Therefore, a creditable criterion to select the sample population was used rather than random selection. The criterion of the most popular cryptocurrencies in Canda was used. This sample population criterion follows the sample process used by recent studies that looked at arbitrage opportunities for more than one cryptocurrency (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021).

Similarly, of the over 200 different cryptocurrency exchanges, many of them were not prevalent in the Canadian market. A credible set of criteria to select the sample population was used, rather than random selection. The LOC principle notes that local costs need to be accounted for and must be considered in the sample selection. Embedded into the market prices for cryptocurrency are regulatory costs and transactional costs. To ensure that the exchanges selected had the same regulatory and transactional costs, three selection criteria where made: the exchange must support the four noted cryptocurrencies; prices are quoted in Canadian dollars and paid out in Canadian dollars (to remove foreign exchange costs); and the exchange had to be approved by Canada’s largest security committee, the Ontario Security Committee. These criteria help to ensure that only legitimate and leading exchanges were selected for data collection.

Finally, to ensure that personal selection bias did not affect the criteria used, this researcher is removed from all participants in this study. It is noted that this researcher does not own any cryptocurrencies, and any accounts that were created for any cryptocurrency exchange were done solely for research purposes and no transactions were ever performed. This effort was made to ensure that there was no selection bias pertaining to this researcher.

History threats must also be addressed. For financial assets, it is accepted that external events or circumstances occur and will impact the asset and many of its measurements. These risks are known as systematic (global) risk. Inversely, unsystematic risk is a risk associated to the individual financial asset or a small group of similar financial assets. History threats associated to the unsystematic risk is the nature of valuations for financial assets (Ross et al., 2022). Beyond accepting the fact that external events will affect the valuations of financial assets but will not be rewarded, two further measures were put into place to mitigate this threat. First, the consideration of volatility, using a β comparison between the cryptocurrency and the S&P/TSX, naturally counteracts systematic risk, because it is global risk. Second, data will be collected over a 3-month time period, from October 15, 2023 to January 14, 2024.

To address maturation threats, this study acknowledges the cryptocurrency markets in Canda and around the world are ever-changing. In fact, Delfabbro et al. (2021) noted that growth in cryptocurrencies is happening so rapidly that any data cited as recently as 3 months ago can be considered outdated. Efforts to mitigate this have been made from using recent data, and to an extensive literature review of studies on cryptocurrencies and arbitrage opportunities for cryptocurrency as a financial asset. However, this is a clear threat to the internal validity of this study and was noted as a limitation to the study and a call for future research.

This section has reviewed the threats to the internal validity of this study. It provided an overview of factors that may limit the confidence in the causal relationships between variables demonstrated within the study. For each of these factors, strategies were discussed that were used to mitigate these threats. This review of threats, to the validity for this study, will now focus on construct validity.

Construct Validity

Construct validity assesses the ability of statistical conclusions to adequately provide meaningful and accurate information. Warner (2012) defines construct validity as the extent to which a measurement instrument or operationalization accurately measures the underlying theoretical construct it intends to assess. It is concerned with the degree to which the scores obtained from a measurement instrument reflect the theoretical concept being studied. This section will review key threats to internal validity of a quantitative study and how they were addressed within this study.

Based on the design of the study and an overview of threats to external validity by Burkholder et al. (2020), two main threats to external validity were noted:

1) Inadequate Operationalization: If the operationalization of the construct does not fully capture its conceptual meaning or fails to include all relevant dimensions or indicators.
2) Construct Confounding: Construct confounding occurs when the measurement instrument or operationalization includes elements that are not part of the intended construct.

To address inadequate operationalization, inadequate operationalization of a quantitative study can be mitigated through use of established and validated measurements (Warner, 2012). The Data Analysis Plan section clearly validated the reasoning for the selection of these constructed measurements and demonstrated them to be tested and fundamental financial principles. In addition, this author has two accounting designations and has the financial market work experience to properly develop and analyze the study's constructs. Furthermore, each design construct was reviewed by two financial peers of the author to ensure the validity and limit the selection bias. By using established and reliable measures, researchers can enhance the accuracy and validity of their study's constructs, minimizing the inadequate operationalization threat to the construct validity of the study.

To address construct confounding, construct confounding of a quantitative study can be mitigated through having multiple sources of data (Warner, 2012). This study collected data from six different exchanges. This will limit the impact of any unintended elements from one dataset will have on the completed dataset. Furthermore, each dataset was reviewed and only specifically required information will be transferred to the complete dataset. Doing so minimized the construct confounding threat to the construct validity of the study.

This section has reviewed the threats to the construct validity of this study. It provided an overview of factors that made the evidence to support the accuracy and meaningfulness of the measurement instrument in capturing the intended construct. For each of these factors, strategies were discussed that were used to mitigate these threats. This review of threats, to the validity for this study, will now focus on ethical procedures.

Ethical Procedures

Due to the scope of this study, the characteristics of the data required were of a historical or archival nature. This study did not need nor require an interaction or data from human participants. Therefore, review of the ethical procedures of this study focuses on the treatment of data collected. This section will demonstrate the simplicity and openness of the data collected and how this data was stored during and after the study.

The use of archival data for research in the cryptocurrency field is a common practice. Recent studies have successfully used archival data as the main source of data to examine arbitrage opportunities for cryptocurrency as a financial asset (Bruzgė & Šapkauskienė, 2022a, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020). This study design for the use of archival data was built off these noted studies. The use of archival data as the source of data for this quantitative study was also selected due to the ease of collecting and the openness of the data.

The data required for this study was easy to collect. For most cryptocurrency exchanges, the required archival data for this study is readily available on the exchange's website. This data was daily closing, bid, and ask prices by cryptocurrency by exchange. If the required data was not easily collected from an exchange's website, then a letter of request was sent to the exchange. This letter of request can be found in Appendix A. Due to the open availability of this data on exchanges' websites and the fact that there are complete datasets for this information for larger markets, there was little apprehension over exchanges' willingness to offer their archival data due to confidentiality concerns or corporate policies. Furthermore, due to the openness of the data required for studying arbitrage opportunities for cryptocurrency as a financial asset, several recent studies have made their data available to the general public (Bruzgė & Šapkauskienė, 2022a; Makarov & Schoar, 2019).

Regardless of the openness of the required data, the data collected for this study was meticulously cared for, to ensure the responsible and respectful use of the data. This was done by ensuring data privacy and confidentiality, and data security.

1) Data Privacy and Confidentiality: Protect the privacy and confidentiality of individuals who assisted in the data collection, beyond the researcher.
2) Data Security: Ensure the security and integrity of the archival data. Take necessary precautions to protect the data from unauthorized access, loss, or alteration.

To ensure data privacy and confidentiality, removal or anonymize any identifying information, such as names, addresses, or any other personally identifiable information, to ensure that individuals’ identities cannot be disclosed or compromised. To ensure data security, the data was only stored, after it was collected, in SPSS for the duration of the study and then it was stored in two separate external hard drives in two separate locations. Only authorized individuals involved in the research have access to either SPSS or the noted external hard drives.

The ethical procedures section of a study outlines the guidelines and considerations researchers follow to ensure the responsible and respectful use of data. The fact that this study only used archival data that is readily available on the internet and had limited to no interactions with human participants reduces the focus on stanch ethical practices. In this section, several key ethical procedures were discussed on how the archival data would be private and secured. By following these ethical procedures, the researcher plans to uphold the ethical standards expected of this level of research.

Summary

Chapter 3 includes an outline of the research method for this study. Burkholder et al. (2020) succinctly defined the research method as the sum of the components required in the execution of a study. For this chapter, I addressed the research design and rationale, population, sampling and sampling procedures, data collection, data analysis plan, and threats to validity. Together, these individual components demonstrated the design of the method and convey to the readers of this study how the research was executed. The outcome of this execution will be discussed in Chapter 4. To understand how the outcome of this study was presented and discussed, the subsequent chapter will review, in detail, the findings of this study.

Chapter 4: Results

The purpose of this quantitative study was to test the LOP on cryptocurrency and the cryptocurrency market in Canada. My intent was to compare the market price of cryptocurrencies between different Canadian cryptocurrency exchanges. This has added to the existing body of knowledge regarding cryptocurrency as a financial asset. To fully realize the purpose and intent of the study, the study must answer its research questions and the hypotheses.

To address the research problem, I tested if arbitrage opportunities existed between Canadian cryptocurrency exchanges. To address this topic, the following research questions and hypotheses were used:

RQ1: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market?

$H_0 1$: Daily closing prices by exchange does not cause arbitrage opportunities in the Canadian cryptocurrency market.

$H_a 1$: Daily closing prices by exchange does cause arbitrage opportunities in the Canadian cryptocurrency market.

The dependent variable was daily arbitrage opportunity. This is a dichotomous variable and involved using a nominal level of measurement. The independent variable was daily market values of different Canadian cryptocurrency exchanges. This is a discrete variable and involved using a ratio level of measurement.

If it is concluded that arbitrage opportunities do exist between Canadian cryptocurrency exchanges, then a second research question and hypothesis will be tested.

RQ2: To what extent does volatility and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges?

$H_0$2: Volatility and liquidity do not influence arbitrage opportunities between Canadian cryptocurrency exchanges.

H_a2: Volatility and liquidity do influence arbitrage opportunities between Canadian cryptocurrency exchanges.

The dependent variable of the hypothesis was daily arbitrage opportunity. This is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement. The independent variables for RQ2 were volatility (based on β measurements) and liquidity (based on bid-ask spread measurements) by cryptocurrency for different Canadian cryptocurrency market. These are discrete variables and involved using ratio levels of measurement. To fully understand results of the study, data collection must be reviewed.

As noted, the purpose of this chapter is to present the results of the study. Warner (2012) noted that for a quantitative study, the Results chapter is dedicated to describing the process of organizing the data collected for statistical analysis, what tools were used to analyze the data, and the finding of the analysis. In order to present the results of the study, this chapter has been organized into three sections: Data Collection; Data Presentation; Study Results. The Data Collection section will review how data were obtained in comparison to the original data collection plan. The Data Presentation section will review descriptive characteristics of data, how data were organized, and tools I used.

This is followed by a review of statistical analysis, interpretations, and findings of the study by research question.

Data Collection

This study involved using the quantitative method. For a quantitative study to be successful in terms of predicting a phenomenon, data must be appropriate for the problem and accessible to researchers (Burkholder et al., 2020). To demonstrate reliability and appropriateness of data for the study, I detail how data were obtained and if there were any deviations from the original data collection plan. To detail how data were collected, I describe the nature of data, time period in which data were collected, and primary and secondary datasets and related data collection processes, discrepancies, and verification practices.

Archival Data

Due to the scope of this study, the characteristics of the data required are of a historical nature. Historical data—also known as Archival data is past data that are collected and stored for future reference and analysis (Burkholder et al., 2020). Archival data is valuable for economic modeling in order to examine past trends and behaviors involving the economy. I used two different datasets. The primary dataset was collected for particular cryptocurrencies from particular cryptocurrency exchanges to support evaluation of RQ1 and RQ2. The second secondary dataset was collected from the TSX to support evaluation of RQ2.

Data for this study were archival in nature. Benefits of using archival data were cost efficiency, time effectiveness, and improved validation and replication. In addition, ethical concerns regarding confidentiality and research bias were reduced because I did not collect new data. With the understanding of using archival nature data, the next step in understanding data collection for this study as to define the time period for data collection.

Time Period

I used archival data for data collection. Archival data demonstrated if arbitrage opportunities existed for cryptocurrency between certain Canadian exchanges between October 15, 2023 and January 14, 2024 (the focus of RQ1), and whether volatility and/or liquidity of particular cryptocurrency were influencers of the arbitrage opportunity (the focus of RQ2). I used 3 months of current archival data to address concerns in the literature review. I found a gap in literature involving maturity of cryptocurrency as a financial asset. Shynkevich (2021) concluded arbitrage opportunities all but disappeared after 2018 due to cryptocurrency’s transition into a mature asset. While other recent studies disagree with this conclusion (Kristoufek & Bouri, 2023; Krückeberg & Scholz, 2020), this study used 3 months of current archival data, from October 15, 2023 to January 14, 2024, to circumvent this inconsistency within the literature. This decision also addressed Delfabbro's et al. (2021) concern that growth in cryptocurrencies is happening so rapidly that any data cited as recently as several months ago can be considered outdated.

Archival data for research in the cryptocurrency field is a common practice. Recent studies have successfully used archival data as the main source of data to examine arbitrage opportunities for cryptocurrency as a financial asset—most notably Bruzgė and

Šapkauskienė (2022a, 2022b), Kabašinskas and Šutienė (2021), and Makarov and Schoar (2020). Archival data as the primary data source was deliberately chosen in order to expedite data collection and avoid potential negative social impacts associated with other data collection processes. With approximately 94% of the Canadian populace and 62.5% of the global population possessing internet accessibility (Petrosyan, 2024), the requisite information was freely accessible from exchange websites for the general public. This approach ensured data accessibility without imposing adverse consequences on the target population.

This study used archival data from October 15, 2023 to January 14, 2024. During this time period, there were two separate datasets collected – a primary dataset and a secondary dataset. To further understand the data collected for this study, this section will next describe the primary dataset. This description will cover the data collection process, review of any data collection discrepancies to the original data collection plan, and verification of the data collected for the primary dataset.

Primary Dataset

As noted in Chapter 3, the expectation was that the primary dataset required for this study would be easy to collect. The data required for this study came from a secondary source. For most cryptocurrency exchanges, the required archival data for this study was readily available on the exchange’s website. This data was the daily closing, bid, and ask prices. These pieces of data are readily available across exchanges. For this study, the noted data was collected for the four leading cryptocurrencies in Canada (Bitcoin, Ethereum, Cardona, and Dogecoin), from six leading Canadian cryptocurrency exchanges (Bitbuy Canada, Bitvo, Coinsquare, Netcoins, Newton, and Wealthsimple). This section will now review the data collection process discrepancies and verification for the primary dataset.

Data Collection Process

Archival data for daily closing, bid, and ask prices was collected for four leading cryptocurrencies, from six leading Canadian cryptocurrency exchanges. For most of the data collected, the process matched the data collection plan noted in Chapter 3. This included normalization of the data for any fee differences between the different cryptocurrency markets. A sample of the data collected can be found in Figure 4. There were two additional challenges that needed to be addressed during the execution of the data collection plan. These two challenges were the need to collect the data in a repeatable and effective manner, and the need to eliminate data due to lack of reliability and changes to the market. These two challenges will be reviewed in the proceeding section.

Figure 4

Sample of Data for Ethereum

Date	Bitbuy/Bitvo			Coinsquare			Netcoins			Newton		
	CP	BP	AP	CP	BP	AP	CP	BP	AP	CP	BP	AP
2023-10-16	2,125.44	2,155.26	2,178.42	2,167.43	2,206.44	2,125.64	2,165.43	2,137.13	2,192.49	2,163.19	2,138.40	2,187.97
2023-10-17	2,153.42	2,128.29	2,151.46	2,138.69	2,098.20	2,178.40	2,140.00	2,111.74	2,166.09	2,137.99	2,113.50	2,162.47
2023-10-18	2,167.70	2,116.68	2,139.37	2,127.89	2,087.90	2,167.51	2,128.44	2,100.98	2,155.04	2,127.75	2,103.58	2,151.91
2023-10-19	2,158.52	2,161.17	2,184.41	2,172.04	2,131.22	2,212.23	2,171.30	2,169.80	2,171.30	2,171.39	2,146.47	2,196.30
2023-10-20	2,179.36	2,157.57	2,201.15	2,195.14	2,152.75	2,235.52	2,194.25	2,193.34	2,194.25	2,194.38	2,169.41	2,219.35

Note. CP = Closing Price; BP = Bid Price; AP = Ask Price

Data Collection Discrepancies

As noted, while the data collection process mainly matched the data collection plan noted in Chapter 3, there were some discrepancies. One challenge during the execution of the data collection process was focused on the repeatability and the effective manner in which the data was gathered. This challenge pertained to the fact that cryptocurrency exchanges run continuously, 24 hours a day, 7 days a week, including statutory holidays. This continuous flow is unlike traditional financial markets, which typically run from 9:30 AM to 4:30 PM, Monday to Friday, and close for weekends and statutory holidays. Further to this challenge, most of the targeted exchanges kept detailed archival information on the bid or ask prices. These challenges caused an obstacle with designating the daily end of day data and recording the bid and ask prices. The original plan was to collect all of the archival data direct from the exchanges' websites or request the data if information was missing on the websites. Upon review of the websites and the information available, it was decided that an automatic tool would be created to daily collect data directly from the websites. This method of data collecting is referred to as scraping data or pulling data, and will be referred to as a *pull* in this study.

A tool was created to automatically pull the required data from the exchanges' websites at the designated for end of the day. This tool was created in Microsoft Excel. The tool automatically pull the required data from the exchanges' websites at the same time every day: 11:59.59 PM. The use of a select time at the end of the day to collect data from a continuous flow of cryptocurrency follows the cryptocurrency study by Bianchi et al. (2022). This was done by creating a query within Excel (Visual Basic) and using

Excel’s Power Query feature and schedule refresher. Power Query is an add-in in Excel and is often used to import data into an Excel spreadsheet. By setting a schedule refresher, the spreadsheet can be programmed to automatically pull data from a website at a specific time every day, even if the Excel workbook is closed.

While the data collection tool was successfully created, verification of the data collected was necessary. Warner (2012) noted that it is a quantitative researcher’s responsibility to implement measures to identify and remedy such inconsistencies during the data collection process. A notable challenge typically encountered during the transition from the planning to the execution phase of data collection pertains to the susceptibility of data inconsistencies, which may compromise the integrity of the dataset. These inconsistencies manifest in the form of errors, missing values, and outliers, thereby posing a potential threat to the overall validity and reliability of the collected data.

To verify the data and protect against any system failures or internet disruptions, the same data was also collected manually at 11:59.59 PM. The manual pull was slower—taking approximately two minutes to collect the data, and was open to human error, such as forgetting to start on time. The manual data pull was expedited by opening the websites beforehand on a mobile device and taking pictures of the data to save copying time. All pictures were saved on the mobile device and backed up on a server. This process offered a layer of increased repeatability by allowing any questionable inputs to be reviewed and verified at a later data. Even though the manual pull was slower and open to human error, it was found to be fairly accurate and reliable in comparison to the automatic data pull. This was attributed to the efficiency of the manual data pull and the low level of transactions at the particular time of the day.

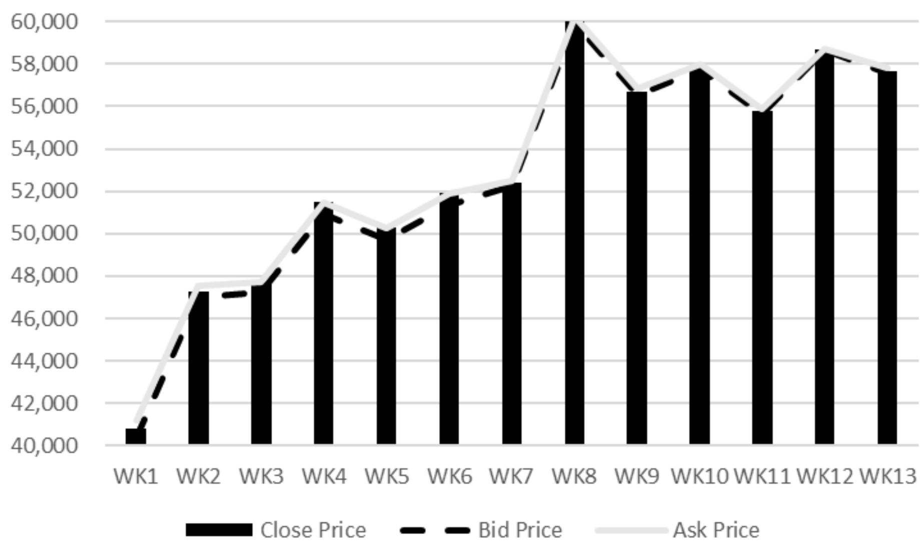
This dual system of data collection, with the manual pull backing up the automatic pull, resulted in a successful data pull for all exchanges for the October 15, 2023 to January 14, 2024 timeline. For the closing price, the data collected was further verified by comparing it to the price noted in the exchanges archival data. This dual system and the controls put into place allowed for reliable data to be collected for every one of the noted cryptocurrencies, from each of the noted exchanges, except for Wealthsimple. Wealthsimple's data from neither the automatic nor the manual data pulls could be consistently verified with the archival data on the exchange's website. Due to this abnormal level of inconsistency, Wealthsimple's data was removed from the data set used for the study's analysis. With the challenge over the manner in which the data was collected and verified addressed, focus can be turned to the need to eliminate data due to challenges within the Canadian cryptocurrency market.

While the actual data collection process mainly matched the planned data collection process, there was a need to address some challenges. Another challenge during the data collection was market related. The cryptocurrency markets are everchanging (Delfabbro et al., 2021). On November 15, 2023, following its market consolidation strategy, Bitbuy announced that it had purchased its competitor Bitvo (Smith, 2023). Both Bitbuy and Bitvo were a part of the data collection plan for this study. On December 1, 2023, Bitbuy migrated all of Bitvo's customers to its exchange platform and shutdown the Bitvo exchange platform (Smith, 2023). This meant that as of

December 1, 2023, Bitvo's dataset match Bitbuy's dataset, because it became the exact same data. This caused an external validity issue within the data being collected; Bitbuy and Bitvo ceased to have the possibility of an arbitrage opportunity because the exchanges were now using the same information from December 1, 2023 to January 14, 2023 (50% of the data set). To eliminate this external validity effect, it was decided that Bitbuy and Bitvo datasets would be combined into Bitbuy/Bitvo and the data from the first half of the data collected would be from Bitbuy, since it is the substantially the larger of the two exchanges. Figure 5 show the weekly distribution of the dataset for Bitcoin from Bitbuy/Bitvo.

Figure 5

Weekly Histogram for Bitcoin Data from Bitbuy/Bitvo in $CND



The main result of the remedies to the two noted discrepancies to the original data collection plan, that was outlined in Chapter 3, reduced the number of exchanges within the study from six to four. Warner (2012) noted that while remedies to correct problems within the data collection process may have the desired effect to the reliability of the data collected the researchers must also consider the effect the remedies may have on the effect size of the sample population and its ability to represent the target population. While the remedies reduced the number of exchanges by a third, the effect on the sample population's ability to represent the target population was minimal. The next section will review the verification of the dataset's ability to represent the overall population.

Data Collection Verification

The primary dataset for this study was derived from archival data that was collected on four different cryptocurrencies, from six different exchanges, from the time-period of October 15, 2023 to January 14, 2024. While the data is readily available on the cryptocurrency exchange's websites, collecting the data was not as easy as originally expected. To compensate for the noted discrepancies, remedies were selected to ensure the data was collected in a timely and reliable fashion. The altered collection process may have opened the dataset to inconsistent within the data. Concerns based on the noted remedies were based on the fact that the altered collection process reduced the number of exchanges to collect data from.

The remedies introduced reduced the number of exchanges focused on in this study were based on the need for verifiable and reliable data, and changes to the Canadian cryptocurrency market landscape. The first remedy was based on the need to ensure verifiable and reliable data. As noted in the Data Collection section of this Chapter, data points automatically collected were compared to both manually collected data points and the archival data on the exchanges' websites. All data points were found to be verifiable and reliable, except the ones from Wealthsimple. These data points were found to be unverifiable. Therefore, the decision was made to removed Wealthsimple from the study. While ensuring the validity of the data, this remedy had the negative effect of reducing the number of exchanges in which data was being collected from. Another remedy that reduced the number of exchanges in which data was collected was based on changes to the Canadian cryptocurrency market landscape.

The Canadian cryptocurrency market drastically changed in 2023 when three main market changers were announced. In April 2023, WonderFi (BitBuy's parent company) merged with Coinsquare and Coinsmart. While each exchange kept its original internet platform, the merger created Canada's largest regulated cryptocurrency exchange, with 1.65 million registered users (Crawley, 2023). Binance—the world's largest cryptocurrency exchange and Canada's largest exchange—announced in May 2023 that they would be immediately leaving the Canadian market due to regulatory issues, such as its inability to gain approval from the Ontario Security Committee (Durrani, 2023). Finally, in November 2023, Bitbuy announced that it had purchased its competitor Bitvo. Bitbuy and Bitvo were both a part of the data collection plan for this study. On December 1, 2023, Bitbuy migrated all of Bitvo's customers to its exchange platform and shutdown the Bitvo exchange platform. This remedy, while uncontrollable, had a negative effect to this study of reducing the number of exchanges to collect data from. Favorably, based on all of these noted changes, it is estimated that Bitbuy now accounts for 50% of the cryptocurrency transactions in Canada (Smith, 2023).

Based on the noted recent changes to the Canadian cryptocurrency market, while the number of exchanges to collect data from was reduced from six to four, the effect to the effect size of the sample population would not be as drastic. The sample population collected from the four exchanges within this study would account for, to be conservative, 50% of the overall population. This was far more than the 10% originally expected in the data collection plan from Chapter 3. Based on both the Central Limit Theorem and the EPV rule, the sample size of this study is considered to have an effect size strong enough to reliably represent the total population. To uphold the reliability and validity of quantitative research, researchers must ascertain if the chosen sample size effectively mirrors the characteristics of the entire population by being of sufficient size (Frankfort-Nachmias et al., 2020). This section will now review these tests to ensure sample size is of sufficient size to be representative of the total population based on both the Central Limit Theorem and the EVA rule.

The first quantitative test on the sample population was descriptive statistics. Determining a good sample size for descriptive statistics depends on several factors, including the desired level of precision, the variability of the population, and the level of confidence you want to achieve in your estimates. Based on the Central Limit Theorem, a common rule of thumb is to aim for a sample size of at least 30 cases for descriptive statistics (Frankfort-Nachmias et al., 2020). Based on the Central Limit Theorem, the noted sample size of 50% of an over US$ 2.03bn population is a sufficiently large sample size. This demonstrates that the distribution of the samples' mean will approximate a normal distribution.

The second quantitative test on the sample population will be a binary logistic regression test. In binary logistic regression, the effective size of a sample population can be measured using the EPV rule (Warner, 2012). The EPV rule suggests having at least ten events (positive outcomes) per independent variable in the binary logistic regression model. This guideline helps ensure sufficient statistical power and stability of the estimated coefficients (Warner, 2012). Based on the EPV, the noted sample size of 50% of an over US$ 2.03bn population is a sufficiently large sample size to ensure the predictive accuracy of the binary logistic regression test.

Summary

During the execution of this study, the data collection plan outlined in Chapter 3 was basically followed for the primary dataset. There were two challenges that needed to be addressed. The remedies implemented to address the challenges altered the way the archived data was pulled from the cryptocurrency exchanges' websites, and changed the number of cryptocurrency exchanges used in the analysis of this study. These changes did not reduce the verification or repeatability of the data collected. This section denoted the effect of the variances between the planned to actual data collection process for the primary dataset. The next section will focus on the articulation of the same understanding for the secondary dataset.

Secondary Dataset

As noted in Chapter 3, the expectation was that the secondary dataset required for this study would be easy to collect. During the data collection process, it was confirmed that the secondary dataset was as readily available and collectable as anticipated during the planning process. Required to support RQ2, the secondary dataset was required to gauge the volatility of the different cryptocurrencies. One way to determine the volatility of a financial asset is to assess its systemic risk. Systemic risk of a financial asset can be measure by its β. The β is a measure of the systematic risk or volatility of a particular financial asset in relation to the overall market (Ross et al., 2022). For the Canadian market, the main benchmark index to set the β value to is the S&P/TSX. The S&P/TSX is an equities benchmark that tracks the daily price changes of 250 of Canada's largest public companies on the Toronto Stock Exchange. The S&P/TSX is considered a barometer of the Canadian financial markets. Therefore, the daily movement/volatility of the S&P/TSX would have a β of 1. To further understand the data collected for this study, this section will next describe the secondary dataset. This description will cover the data collection process, review of any data collection discrepancies to the original data collection plan, and verification of the data collected for the secondary dataset.

Data Collection Process

To collect the data necessary to transform the S&P/TSX performance into a β, daily closing price of the S&P/TSX composite index (the collective valuations of the 250 publicly traded companies) was required. This second set of archival data is readily available from several different qualified and recognized websites. Yahoo-Finance Canada (Yahoo) was selected: https://ca.finance.yahoo.com. Yahoo is a well-respected and reliable website for TSX data and information. Furthermore, this author has been using Yahoo for professional archival data collection for over 20 years.

To pull the required data from Yahoo's website, several parameter inputs are necessary: Asset Selection: S&P/TSX Composite Index (^GSPTSE); Data Type: Historical Data; Time Period Range: Start: October 15, 2023 – End: Jan 14, 2024; Show: Historical Prices; Frequency: Daily. A sample of the data pulled from Yahoo can be found in Figure 6.

Figure 6

Data for the S&P/TSX Composite Index

Date	Open	High	Low	Close	Adj Close	Volume
2023-10-16	19,498.10	19,643.10	19,426.90	19,620.80	19,620.80	192,172,100
2023-10-17	19,561.60	19,768.60	19,552.20	19,692.80	19,692.80	195,977,300
2023-10-18	19,670.10	19,670.10	19,434.30	19,450.70	19,450.70	189,308,900
2023-10-19	19,448.60	19,505.20	19,327.10	19,348.80	19,348.80	193,909,500
2023-10-20	19,309.50	19,309.50	19,115.60	19,115.60	19,115.60	200,966,000

Note. The Close column represents the closing price that will be used in the calculation of the β value.

Data Collection Discrepancies

As noted, the data collection process for the secondary dataset matched the planned data collection plan outlined in Chapter 3. While this was true, there was still a challenge that needed to be reviewed. The data from the secondary dataset was meant to support the primary dataset. With that said, the parameters of the two datasets did not match. This section will review this discrepancy and the remedy implemented.

A difference between the data collected for the primary dataset and the secondary dataset was that the cryptocurrency exchange used in the primary dataset, runs continuously, 24 hours a day, 7 days a week, including statutory holidays. This continuous flow is unlike traditional financial markets, like the S&P/TSX, used in the secondary dataset, which typically run from 9:30 AM to 4:30 PM, Monday to Friday, closing for weekends and statutory holidays. To remedy this disconnect in the datasets it was decided to remove the data collected for weekends (Saturdays and Sundays) and any statutory holidays from the primary dataset. This was decided based on the fact that the traditional markets are closed on weekends and statutory holidays, making data collection impossible.

The main result of the remedy to the discrepancy was the reduction of data points to the primary dataset. This was necessary to match the parameters between both the primary and secondary datasets. Warner (2012) noted that while remedies to correct problems within the data collection process may have the desired effect to the reliability of the data collected the researchers must also consider the effect the remedies may have on the effect size of the sample population and its ability to represent the target population. While the remedies reduced the number of data points, the effect to the sample population's ability to represent the target population was minimal. The next section will review the verification of the dataset's ability to represent the overall population.

Data Collection Verification

The secondary dataset for this study was made from archival data collected from the S&P/TSX for the time period of October 15, 2023 to January 14, 2024. This data was readily available and there were no discrepancies when the actual dataset was compared to the data collection plan from Chapter 3. With that said, to make the parameters of the primary dataset compatible with the parameters of the secondary dataset, changes were made to the data points in the primary dataset.

The changes made to the primary dataset was the removal of weekends and statutory holidays from the primary dataset to match the secondary dataset resulted in a reduction of data points collected. The time period of October 15, 2023 to January 14, 2024 consists of 92 days of data collection. During this time period, 27 days were weekends (13 Saturdays and 14 Sundays) and 3 days were statutory holidays in Canada (December 25, 2023, December 26, 2023, and January 1, 2024). Removal of these days from the dataset reduced the number of days of data collection to 62 days. The Central Limit Theorem, which is a fundamental concept in statistics, denotes that a sample size greater than 30 inputs is large enough to offer a normally distributed representation of the population being tested (Frankfort-Nachmias et al., 2020). While the numbers of days removed from the data collected accounts for almost a third of the data, the Central Limit Theorem demonstrates that the dataset is large enough to offer a proper representation of the phenomenon.

Moreover, the exclusion of the aforementioned data from the primary dataset contributed to enhancing the representativeness of the primary dataset concerning the attributes of traditional financial assets. This adjustment is significant, considering that traditional financial markets observe closures during weekends and statutory holidays. Despite these closures, the influence of new information on market supply and demand dynamics persists. Notably, on the subsequent business day following weekends or statutory holidays, there is an observable release of pent-up effects of new information into the financial markets. By eliminating the data collected during weekends and statutory holidays from the primary dataset, a similar effect is induced, aligning the dataset more closely with the ongoing dynamics observed in traditional financial markets.

Summary

This study was based on a quantitative method. Social scientists use of statistical analysis to summarize and communicate on a phenomenon is only possible if the numeric data is representative of the information being reviewed (Frankfort-Nachmias et al., 2020). This section demonstrated the reliability and appropriateness of the data collected for this study. This was done by reviewing how the data was obtained and any discrepancies to the original data collection plan, and the effect remedies for the discrepancies had on the validity of the data for the two datasets collected for this study. To ensure the data collected was properly organized to facilitate interpretation and validity of the findings, the Chapter will next focus on the presentation of the data.

Data Transformation to Align with Methodology

Effective data presentation is a fundamental component of quantitative research. How numeric data is organized and summarized is key to a researchers ability to make sense of the data (Frankfort-Nachmias et al., 2020). The goal of the data presentation for this study was to organize and summarize the data to facilitate decision making and for clarity of interpretations to answer the research questions. This section will do this by first reviewing the descriptive data of the primary dataset, reviewing how the primary and secondary datasets were organized into financial measure, and how these financial measurements were placed into SPSS for the binary logistic regression model.

Descriptive Data

Descriptive data refers to the type of data that describes and summarizes the information within the dataset. Descriptive data is a fundamental aspect of data analysis (Warner, 2012). Each cryptocurrency had 62 days of data collected: three different data points (daily closing, bid, and ask prices) from four different cryptocurrency exchanges. In total, there were 744 data points successfully collected for each cryptocurrency or 2,976 data points collected in total. To better understand the data collected and its representation of the overall population, four descriptive data measurements were reviewed for each cryptocurrency's closing price: mean, median, range, and standard deviation. The central tendency measurement the mean, also known as the average, is the sum of all the closing prices by cryptocurrency added together and divided by the total number of values in the dataset (62). The central tendency measurement the median is the middle value in the dataset when all the closing prices by cryptocurrency are put in numerical order. The dispersion measurement of the range is the denotation of the minimum and maximum value of all the closing prices by cryptocurrency. The dispersion measurement of the standard deviation is a measurement of the level of variation of dispersion there is between the closing prices by cryptocurrency. The output of the Descriptive Data can be found in Figure 7**.**

Figure 7

Descriptive Output for Data

Measure	Bitbuy/Bitvo	Coinsquare	Netcoins	Newton
		Bitcoin		
Mean	52,648.15	52,625.91	52,627.15	52,618.55
Median	51,650.77	51,404.57	51,463.83	51,483.14
Range	38,446.31 - 62,429.00	38,547.78 - 62,450.09	38,395.61 - 62,422.71	38,425.96 - 62,401.04
Std Dev	6,083.04	6,085.78	6,077.37	6,078.60
		Ethereum		
Mean	2,819.68	2,821.74	2,822.09	2,821.48
Median	2,840.17	2,835.53	2,836.40	2,835.83
Range	2,125.44 - 3,575.26	2,127.89 - 3,599.60	2,128.44 - 3,598.82	2,127.75 - 3,578.59
Std Dev	322.61	323.51	323.27	322.62
		Cardano		
Mean	0.58833	0.58917	0.58986	0.58982
Median	0.52162	0.52365	0.52442	0.52407
Range	0.3358 - 0.885	0.3309 - 0.8828	0.33098 - 0.89303	0.33101 - 0.89357
Std Dev	0.16972	0.16867	0.16900	0.16928
		Dogecoin		
Mean	0.10899	0.10916	0.10924	0.10920
Median	0.10858	0.10800	0.10780	0.10781
Range	0.0803 - 0.1404	0.0799 - 0.1405	0.079996 - 0.140248	0.079981 - 0.140207
Std Dev	0.01473	0.01471	0.01471	0.01470

From the central tendency measurements, the mean and median, the differences of similar data are highlighted. The results demonstrate that while the closing prices for each cryptocurrency were collected from four different sources (exchanges), the data is similar. The similarity of the different central tendency measurements by cryptocurrency across different exchanges demonstrates that consumers for each exchange are using similar sources and timing of market information to make their investment decisions. Having different exchanges with similar data demonstrates a consistent level of information efficiency across the exchanges and mitigates the possibility of unknown factors causing a Type II error of occurring within the analysis of the RQ1.

The dispersion measures, the range and standard deviation, quantify the spread of the variability of the data within the dataset and provide insight into how the data points are distributed around the central tendency values. The wide range and high standard deviations of the data demonstrates the volatility of cryptocurrencies. This is further reiterated when you compare the results to a traditional financial asset. As noted, the TSX is recognized as a trusted measure of financial assets' performance in Canada. When comparing the TSX range to the Ethereum range for the same time period, one can quantify the volatility of cryptocurrency.

Within the October 15, 2023 to January 14, 2024 time period, the TSX had a range of 18,737.40 – 21,074.90, representing a 12.5% change in closing price from lowest to highest point. For the same time period, Ethereum-Bitbuy/Bitvo had a range of 2,125.44 – 3,575.26, representing a 68.2% change in closing price from lowest to highest point. The high volatility of cryptocurrency demonstrates the immaturity of cryptocurrency as a financial asset. Recent studies by Celeste et al. (2020), and Kang et al. (2022) all found the immaturity of cryptocurrency as a financial asset was a influence on arbitrage opportunities. With the descriptive data haven given an overview of the data collected, this section will next review how the data was organized.

Data Organization

The data collected for the primary and secondary datasets were daily closing, bid, and ask prices. While these data points were specially collected to answer the research questions, the current configuration of the data points were not sufficient. The data points needed to be organized to unlock the findings or to be converted into the financial measure selected to answer the research questions. This section will now review how the primary and secondary datasets were organized to accurately interpret the existence of arbitrage opportunities, and the financial measurements for β and the bid-ask spread.

Arbitrage Opportunity

The purpose of this study was to test LOP to see if arbitrage opportunities existed in the Canadian cryptocurrency markets. For this study, the process used to identify an arbitrage opportunity followed a methodology akin to the successful cryptocurrency arbitrage studies conducted by Bruzgė and Šapkauskienė (2022b) and Kabašinskas and Šutienė (2021). Aligned with these studies, the daily closing prices obtained from exchanges were interpreted as potential buying and selling opportunities. An arbitrage opportunity materializes only when a buyer can concurrently purchase a cryptocurrency on one exchange and sell it on another exchange to generate a profit.

To depict this buy-sell relationship within the data collected for this study, we calculated the net value by subtracting the closing price from the buying exchange from the closing price from the selling exchange (Selling Closing Price – Buying Closing Price). Following the structure used by Bruzgė and Šapkauskienė (2022b, 2022a) in their study of arbitrage opportunities, an arbitrage opportunity was recognized if the resulting amount from the transaction equaled or exceeded $0.01 for Bitcoin or Ethereum, $0.00001 for Cardano, or $0.000001 for Dogecoin. Conversely, if the transaction amount fell below these specified thresholds, it was marked as 0, signifying the absence of an arbitrage opportunity. A sample of this data can be found in Figure 8.

Figure 8

Summary of Arbitrage Opportunities for Bitcoin

Date	Buying Exchange	Selling Exchange 1	Selling Exchange 2	Selling Exchange 3	Arbitrage Opportunity		
	Bitbuy/Bitvo CP	Coinsquare CP	Netcoins CP	Newton CP	BS1	BS2	BS3
2023-10-16	38,446.31	38,547.78	38,395.61	38,425.96	101.47	-	-
2023-10-17	38,595.00	38,899.46	38,917.97	38,870.45	304.46	322.97	275.45
2023-10-18	38,513.26	38,791.61	38,824.45	38,791.03	278.35	311.19	277.77
2023-10-19	39,858.03	40,038.31	40,081.98	40,057.14	180.28	223.95	199.11
2023-10-20	40,811.95	40,671.39	40,657.87	40,644.98	-	-	-

Note. CP = Closing Price; BS = Buy-Sell Combination

The constructed data point, Arbitrage Opportunities, clearly shows when and where an arbitrage opportunity exists. This data point was used to interpret the data to answer RQ1. Next, this section will review how the pate point β was constructed and its purpose to the study.

Beta (β)

To support RQ2, an additional measurement was required to gauge the volatility of the different cryptocurrencies. One way to determine the systemic risk of a financial asset is to measure its β. β is a measure of the systematic risk or volatility of a particular financial asset in relation to the overall market (Ross et al., 2022). For the Canadian market, the main benchmark index to set the β value is the S&P/TSX. The S&P/TSX is an equities benchmark that tracks the daily price changes of 250 of Canada's largest public companies on the Toronto Stock Exchange. The S&P/TSX is considered a barometer of the Canadian financial markets. Therefore, the daily movement/volatility of the S&P/TSX would have a β of 1. This would then be compared to the daily closing price change from the prior day of the cryptocurrency by exchange. To construct the β value, the calculation involved is the subtraction of the previous day's closing price from the current day's closing price and dividing this result by the previous day's closing price. The equation for β is:

$$\boldsymbol{\beta} = \frac{(\textit{Current Day's Closing Price} - \textit{Previous Day's Closing Price})}{\textit{Previous Day's Closing Price}}$$

To understand the volatility of a particular cryptocurrency, its daily price change was compared to the daily price change of the S&P/TSX Index. This will be based on comparison to prior day’s closing prices and current day’s closing prices for both the S&P/TSX and the particular cryptocurrency as a percentage. On occasions where the percentage change of a particular cryptocurrency is higher than the percentage change of the S&P/TSX, the particular cryptocurrency will have a β greater than 1. Inversely, on occasions where the percentage change of a particular cryptocurrency is lower than the percentage change of the S&P/TSX, the particular cryptocurrency will have a β less than 1. Finally, on occasions where the percentage change of a particular cryptocurrency is opposite the percentage change of the S&P/TSX, the particular cryptocurrency will have a negative β. A daily price fluctuation 1.5 times or more above 1 is traditionally considered to reflect price volatility. To represent this, a dichotomous categorical variable of yes (represented as 1) or no (represented as 0) to the daily price fluctuation being equal to or greater than 1.5 times the β was constructed. The use of a dichotomous categorical variable as an independent variable in a binary logistic regression is common practice and acceptable (Warner, 2012). A summary of the β test output for Cardano – Bitbuy/Bitvo is located in Figure 9.

Figure 9

Summary of β Data Output for Cardano Bitbuy/Bitvo

Bitcoin	TSX		Bitbuy/Bitvo				
Date	Prior CP	Current CP	Prior CP	Current CP	TSX CP Change (B)	Exchange CP Change (Y)	Volatile (Y >= 1.5B)
2023-10-16	19,462.90	19,620.80	0.34	0.34	0.8113%	0.0000%	No
2023-10-17	19,620.80	19,692.80	0.34	0.34	0.3670%	1.0624%	Yes
2023-10-18	19,692.80	19,450.70	0.34	0.34	1.2294%	1.0739%	No
2023-10-19	19,450.70	19,348.80	0.34	0.34	0.5239%	0.0000%	No
2023-10-20	19,348.80	19,115.60	0.34	0.34	1.2052%	0.0000%	No

Note. CP = Closing Price

The constructed data point, β, clearly shows when and where a cryptocurrency was volatile. This data point was used to interpret the data to partially and answer RQ2. Next, this section will review how the data point bid-ask spread was constructed and its purpose to the study.

Bid-Ask Spread

To support RQ2, an additional measurement was required to gauge the liquidity of the different cryptocurrencies. One way to determine the fluidness of a financial asset is to review its bid-ask spread. The bid-ask spread is a key concept in financial markets and represents the difference between the highest price that a buyer is willing to pay for a security (the bid price) and the lowest price that a seller is willing to accept (the ask price) at a given point in time (Ross et al., 2022). A transaction occurs when a bid price and an ask price match. Krückeberg and Scholz (2020) defined the bid-ask spread as percentage based on the total of the ask price minus the bid price and then divided by the ask price. A bid-ask spread data point was constructed for this study. The equation for the bid-ask spread is:

$$\textbf{Bid-Ask Spread} = \left(\frac{\textit{Ask Price} - \textit{Bid Price}}{\textit{Ask Price}}\right) x\ 100$$

To better assess the impact of the bid-ask spread on liquidity, we referred to other studies that successfully incorporated the bid-ask spread in their analyses of cryptocurrencies. Notably, Makarov and Schoar (2020) noted that an average bid-ask spread percentage was 10 basis points. A basis point (bps) is a unit of measurement commonly used in finance and represents one-hundredth of a percentage point—0.01% or 0.0001. This study used the same liquidity range used by Makarov and Schoar to indicate if a bid-ask spread percentage of a cryptocurrency is to be considered liquid (0-3 bps), average (4-16 bps), or illiquid (17+ bps). As a percentage, Liquidity is considered a ratio level of measurement, but it was turned into an ordinal categorial variable of liquid (represented as 2), average (represented 1), and illiquid (represented as 0). The use of an ordinal categorical variable as an independent variable in a binary logistic regression is common practice and acceptable (Warner, 2012). A summary of the Bid-Ask Spread data output for Bitcoin Bitbuy/Bitvo is located in Figure 10.

Figure 10

Summary of Bid-Ask Spread Data Output for Dogecoin Bitbuy/Bitvo

Date	BP	AP	B-A Spread	B-A %	Liquidity
2023-10-16	37,986.28	38,865.63	879.35	2.26%	Illiquid
2023-10-17	38,428.24	39,312.65	884.41	2.25%	Illiquid
2023-10-18	38,348.38	39,233.68	885.3	2.26%	Illiquid
2023-10-19	39,597.86	40,516.41	918.55	2.27%	Illiquid
2023-10-20	40,179.74	41,110.21	930.47	2.26%	Illiquid

Note. BP = Bid Price; AP = Ask Price; B-A = Bid – Ask Spread

The constructed data point, bid-ask spread, clearly shows when and where a cryptocurrency was considered liquid or illiquid. This data point was used to interpret the data to partially answers RQ2. Next, this section will review how the data was presented to make it fit into the binary logistic regression model in SPSS.

Data Preparation for the Binary Logistic Regression Model

The purpose of this study was to test LOP to see if arbitrage opportunities existed in the Canadian cryptocurrency markets. To support this purpose, two research questions were created. A binary logistic regression model was used to analyze the data collected to answer RQ2. This section will review the tool used for the binary logistic regression model and how the data collected was organized to be placed into the tool.

SPSS was selected to support the binary logistic regression model for the study. This selection was made because SPSS is a versatile software package that offers a wide range of features and capabilities for data analysis including descriptive statistics; inferential statistics; the ability to assist in analyzing the reliability and validity measures; the ability to upload data from Excel; the ability to manipulate data. All these features will be required for organization and analysis of the data collected for this study. In addition, the author of this study has the statistical training to decipher SPSS outputs, has been trained in using SPSS, and has a current license to use SPSS through Walden University.

To prepare the data collected to be used in SPSS, a quantitative dataset was created in Excel. The dataset changed all of the constructed data points for arbitrage, volatility, and liquidity into quantitative data. For arbitrage, Arbitrage was given a value of 1 and No Arbitrage was given a value of 0. For volatility, Volatile was given a value of 1 and Involatile was given a value of 0. For liquidity, Liquidity was given a value of 2, Average was given a value of 1, and Illiquidity was given a value of 0. A quantitative dataset was created for each cryptocurrency.

Arbitrage is a one-way transaction: you can only simultaneously buy in one exchange and sell in another exchange for a profit, and not the other way around. This is due to the fact that the arbitrage opportunity is not between the two exchanges, but rather between the current price of each exchange. Therefore, there are twelve different buy-sell exchange combinations between the four exchanges. A summary of the Buy-Sell exchange combinations is located in Table 6. Since there are 62 days of data collected, each cryptocurrency would have (62 x 12) 744 data points in the quantitative dataset and (744 x 4) 2,976 data points for the complete study. A sample of the quantitative dataset created for the study can be found in Figure 11. These datasets were uploaded from Excel into SPSS.

Table 6

Buying and Selling Exchange Combinations

#	Buying Exchange	Selling Exchange
1	Bitbuy/Bitvo	Coinsquare
2	Bitbuy/Bitvo	Netcoins
3	Bitbuy/Bitvo	Newton
4	Coinsquare	Bitbuy/Bitvo
5	Coinsquare	Netcoins
6	Coinsquare	Newton
7	Netcoins	Bitbuy/Bitvo
8	Netcoins	Coinsquare
9	Netcoins	Newton
10	Newton	Bitbuy/Bitvo
11	Newton	Coinsquare
12	Newton	Netcoins

Figure 11

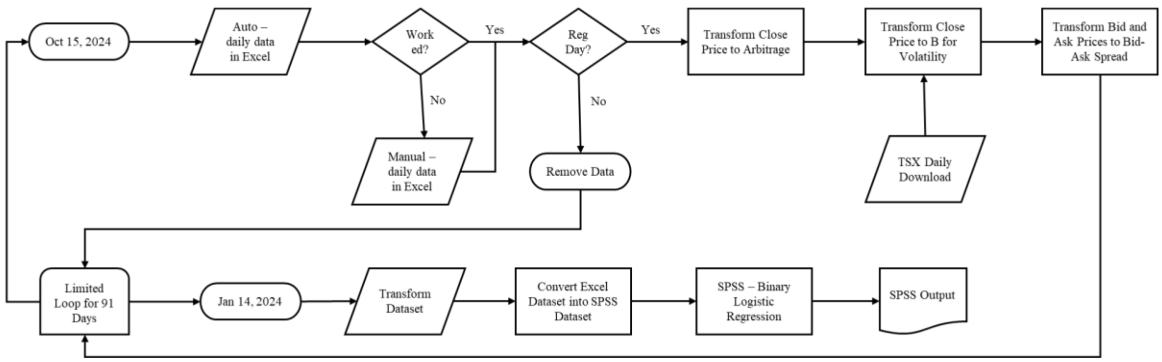
Sample of Cardano Quantitative Dataset for SPSS

Date	Arbitrage	Volatile	Liquidity
2023-10-16	1	0	0
2023-10-17	0	1	0
2023-10-18	0	0	0
2023-10-19	1	0	0
2023-10-20	1	0	0

Once the Excel datasets were uploaded and converted into a SPSS dataset, SPSS used the data to tabulate the binary logistic regression model. Figure 12 is a flowchart of the data collection, cleaning, transformation, and analysis process used for this study. The following criteria were selected for the binary logistic regression model: Dependent Variable was set to Arbitrage column; Independent Variables (covariates) were set to Volatile and Liquidity; both Independent Variables were set to Categorial Covariates; Options selected were Hosmer-Lemeshow goodness-of-fit and confidence interval for the exponentiation of the regression coefficient β (exp(β)) of 95%. The output of the binary logistic regression model will be reviewed in the Study Results section of this Chapter.

Figure 12

Flowchart for Data Collection, Transformation, and Analysis Process



Summary

In this section the data collection process and data presentation for the study was reviewed. Reliable data is essential in quantitative research to successfully predict a phenomenon (Burkholder et al., 2020). The data collection plan that was outlined in Chapter 3 was developed to capture reliable data pertaining to the existence of arbitrage opportunities in the Canadian cryptocurrency market. This section described the nature of the data, the time period in which the data was collected, how the data was collected, how the data was verified, what data was removed from the overall dataset, how the data was representative of the total population being studied, and how the data was used to create the measurements necessary to answer the research questions being evaluated. With the data collected properly verified and organized to answer the research questions of the study, the results of the quantitative tests can be reviewed.

Study Results

The Study Results section is a critical component of a researcher's study. Warner (2012) noted that the aim of the Study Results section is to demonstrate how the data collected was used to answer the research questions of the study. The previous section described how the data collected was presented and organized for statistical analysis. This section will describe the statistical analysis, interpretations of findings from the statistical analysis, and how these findings compare or contrast with prior studies. Since this study has two research questions, this information will be formatted into two sections.

Research Question 1

To address the research problem, this study aims to test if arbitrage opportunities exist between Canadian cryptocurrency exchanges. To address this topic, the following research questions and hypotheses have been created.

RQ1: To what extent do daily closing prices of cryptocurrency by different exchanges cause arbitrage opportunity in the Canadian cryptocurrency market?

$H_0$1: Daily closing prices by exchange does not cause arbitrage opportunities in the Canadian cryptocurrency market.

H_a1: Daily closing prices by exchange does cause arbitrage opportunities in the Canadian cryptocurrency market.

The dependent variable of the hypothesis is daily arbitrage opportunity. This is a dichotomous variable (Yes or No to arbitrage opportunity) and is a nominal level of measurement. The independent variable of the hypothesis is the daily market values of cryptocurrencies by the different Canadian cryptocurrency exchanges. This is a discrete variable and is a ratio level of measurement. To test if daily arbitrage opportunities do exist (dependent variable), the daily price of a cryptocurrency from one market will be compared to another market (independent variable). If the prices are the same, then the dependent variable will equal No. If the prices are different, then the dependent variable will equal Yes.

To answer RQ1, the data collected was tested. This section will now articulate the results and the findings of the test. The goal is to provide a clear account of what was discovered during the research process. To do this, this section will summarize the statistical analysis and the interpretation of the analysis that help to formulate the findings of the study.

Statistical Analysis

The statistical analysis that was completed to answer RQ1 was a basic probability analysis for the occurrence of arbitrage opportunity. This analysis was based on the number of valid days of data collection (62), how many times were arbitrage opportunities found by cryptocurrency, and by buy-sell cryptocurrency exchange combinations. Warner (2012) noted the data assumptions for this type of analysis as random selection, normally distributed, and independent variables. The data collected for this analysis was the internet-based daily closing price by cryptocurrency, by cryptocurrency exchange. To demonstrate the data collected is sufficient for basic probability analysis, these assumptions were tested.

The data collected for this study was tested to ensure that it was both independent and normally distributed. The daily closing price by cryptocurrency by exchange theoretically are independent. This means that each exchange is a separate legal entity and its closing price will only be affected by the internal workings of its own buyer-seller relationship. The fact that each cryptocurrency is affected by the same market information and forces is separate to the theoretical justification that each exchange is considered independent from another exchange. A review of the distribution of the data collected will demonstrate that it is normally distributed. There are two possible outcomes for the arbitrage opportunity test – yes or no. Of the 2,976 data points collected (62 days by four different cryptocurrencies by 12 different buy-sell exchange combinations), 1,477 outcomes were considered arbitrage opportunities and 1,499 were considered non-arbitrage opportunities. This is a near perfect 50/50 outcome and demonstrates the normal distribution of the data collected. This data collection process followed the work by Bruzgė and Šapkauskienė (2022a, 2022b). Bruzgė and Šapkauskienė (2022a, 2022b) and Mancosu and Vegetti (2020) further confirmed the dataset collected meets these assumptions.

Another statistical detail to help ensure the data collected is sufficient for a basic probability analysis is its goodness-of-fit. This was done by checking the Chi-square value of the arbitrage to non-arbitrage relationship. As noted, the data collected had 1,477 arbitrage observations and 1,499 non-arbitrage observations. If the data was perfectly normally distributed and independent, then the arbitrage and non-arbitrage opportunities would be equal at 1,488 observations each. Based on this information, the Chi-square value of the data collected was ($X^2 = (1499-1488)^2/1488 + (1477-1488)^2/1488$) 0.1626. Based on a threshold probability of 5% and a degree of freedom of (n-1) 1, the critical Chi-square value would be 3.84. The fact that the observed Chi-square value is substantially less than the critical Chi-square value demonstrates the goodness-of-fit for the data collected and its ability to predict arbitrage opportunities.

Upon analyzing the data and applying our predefined criteria for identifying arbitrage opportunities, it becomes evident that such opportunities are a consistent daily occurrence across all exchanges. Furthermore, the distribution of arbitrage opportunities, when considered as a percentage frequency, appears remarkably uniform across all platforms. This uniformity implies that no single exchange consistently offers lower or higher prices, highlighting a balanced occurrence of arbitrage opportunities evenly distributed among the exchanges. The output of the probability analysis by cryptocurrency can be found in Figure 13.

Figure 13

Summary of Arbitrage Opportunity by Cryptocurrency and Buy-Sell Cryptocurrency Exchange Combination

Summary of Arbitrage Opportunity Data for Bitcoin

Buy - Sell Exchanges	Valid Days	Arbitrage Frequency	Arbitrage Percentage	Cumulative Exchanges %
Bitbuy/Bitvo - Coinsquare	62	25	40.3%	
Coinsquare - Bitbuy/Bitvo	62	37	59.7%	100.0%
Bitbuy/Bitvo - Netcoins	62	26	41.9%	
Netcoins - Bitbuy/Bitvo	62	36	58.1%	100.0%
Bitbuy/Bitvo - Newton	62	23	37.1%	
Newton - Bitbuy/Bitvo	62	39	62.9%	100.0%
Coinsquare - Netcoins	62	31	50.0%	
Netcoins - Coinsquare	62	31	50.0%	100.0%
Coinsquare - Newton	62	29	46.8%	
Newton - Coinsquare	62	33	53.2%	100.0%
Netcoins - Newton	62	27	43.5%	
Newton - Netcoins	62	35	56.5%	100.0%

Summary of Arbitrage Opportunity Data for Ethereum

Buy - Sell Exchanges	Valid Days	Arbitrage Frequency	Arbitrage Percentage	Cumulative Exchanges %
Bitbuy/Bitvo - Coinsquare	62	37	59.7%	
Coinsquare - Bitbuy/Bitvo	62	25	40.3%	100.0%
Bitbuy/Bitvo - Netcoins	62	30	48.4%	
Netcoins - Bitbuy/Bitvo	62	32	51.6%	100.0%
Bitbuy/Bitvo - Newton	62	28	45.2%	
Newton - Bitbuy/Bitvo	62	34	54.8%	100.0%
Coinsquare - Netcoins	62	34	54.8%	
Netcoins - Coinsquare	62	28	45.2%	100.0%
Coinsquare - Newton	62	23	37.1%	
Newton - Coinsquare	62	39	62.9%	100.0%
Netcoins - Newton	62	26	41.9%	
Newton - Netcoins	62	35	56.5%	98.4%

Summary of Arbitrage Opportunity Data for Cardano

Buy - Sell Exchanges	Valid Days	Arbitrage Frequency	Arbitrage Percentage	Cumulative Exchanges %
Bitbuy/Bitvo - Coinsquare	62	34	54.8%	
Coinsquare - Bitbuy/Bitvo	62	27	43.5%	98.4%
Bitbuy/Bitvo - Netcoins	62	40	64.5%	
Netcoins - Bitbuy/Bitvo	62	22	35.5%	100.0%
Bitbuy/Bitvo - Newton	62	36	58.1%	
Newton - Bitbuy/Bitvo	62	26	41.9%	100.0%
Coinsquare - Netcoins	62	39	62.9%	
Netcoins - Coinsquare	62	23	37.1%	100.0%
Coinsquare - Newton	62	32	51.6%	
Newton - Coinsquare	62	30	48.4%	100.0%
Netcoins - Newton	62	29	46.8%	
Newton - Netcoins	62	33	53.2%	100.0%

Summary of Arbitrage Opportunity Data for Dogecoin				
Buy - Sell Exchanges	**Valid Days**	**Arbitrage Frequency**	**Arbitrage Percentage**	**Cumulative Exchanges %**
Bitbuy/Bitvo - Coinsquare	62	34	54.8%	
Coinsquare - Bitbuy/Bitvo	62	19	30.6%	85.5%
Bitbuy/Bitvo - Netcoins	62	39	62.9%	
Netcoins - Bitbuy/Bitvo	62	23	37.1%	100.0%
Bitbuy/Bitvo - Newton	62	36	58.1%	
Newton - Bitbuy/Bitvo	62	26	41.9%	100.0%
Coinsquare - Netcoins	62	40	64.5%	
Netcoins - Coinsquare	62	22	35.5%	100.0%
Coinsquare - Newton	62	35	56.5%	
Newton - Coinsquare	62	27	43.5%	100.0%
Netcoins - Newton	62	22	35.5%	
Newton - Netcoins	62	40	64.5%	100.0%

Interpretation

There were 1,488 valid events (62 days over four cryptocurrencies by six Buy – Sell Exchanges combinations). Of the valid events, arbitrage opportunities occurred 1,477 times. This translated to an arbitrage opportunity frequency percentage of 99.3%. The substantial occurrence rate demonstrated that arbitrage opportunities are occurring within the Canadian cryptocurrency market. Based on these findings, we would reject the null hypothesis for the RQ1: H_a1: Daily closing prices by exchange does not cause arbitrage opportunities in the Canadian cryptocurrency market. The finding of the study is there are persistent arbitrage opportunities for cryptocurrency as a financial asset in Canada.

The finding of arbitrage opportunities for cryptocurrency as a financial asset in Canada aligns to the current literature. The literature review conducted for this study and detailed in Chapter 2 found significant knowledge on the existence of arbitrage opportunities for cryptocurrency as a financial asset (Borri & Shakhnov, 2020; Brauneis & Mestel, 2018; Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Makarov

& Schoar, 2020; Pieters & Vivanco, 2017). The findings for RQ1 demonstrate the generalization of current knowledge on the existence of arbitrage opportunities for cryptocurrency as a financial asset in the Canadian cryptocurrency market. These findings fill a gap in the current literature, which will be further reviewed in Chapter 5.

Summary

To test if arbitrage opportunities exist between Canadian cryptocurrency exchanges, a probability analysis was performed on the data collected of closing prices by cryptocurrency by cryptocurrency exchange. The finding of this analysis generalized the findings of the current literature to the Canadian cryptocurrency market. The finding was that arbitrage opportunities for cryptocurrency as a financial asset exist in the Canadian market. With the findings of arbitrage opportunities for cryptocurrency as a financial asset in the Canadian market, the study expands to attempt to understand the influencers of the arbitrage opportunities. This knowledge was reviewed to answer Research Questions 2.

Research Question 2

Based on the findings that arbitrage opportunities do exist between Canadian cryptocurrency exchanges; a second research question was tested.

RQ2: To what extent does volatility and liquidity influence arbitrage opportunities between Canadian cryptocurrency exchanges?

$H_0$2: Volatility and liquidity do not influence arbitrage opportunities between Canadian cryptocurrency exchanges.

*H*a2: Volatility and liquidity do influence arbitrage opportunities between Canadian cryptocurrency exchanges.

The dependent variable of RQ2 is daily arbitrage opportunity. This is a dichotomous variable (yes or no to arbitrage opportunity) and is a nominal level of measurement. The independent variables of the hypothesis are the volatility (based on β) and liquidity (based on the bid-ask spread) by cryptocurrency for the different Canadian cryptocurrency exchanges. These are discrete variables and are both ratio level of measurement. Based on the results from the initial research question's test, when arbitrage opportunities are found a second set of variables for volatility and liquidity will be added to the dataset to test if there is a relationship between the volatility and liquidity and the occurrence of arbitrage opportunities. If daily volatility and liquidity does not have an influence on the existence of arbitrage opportunities, then the null hypothesis will be accepted. If daily volatility and liquidity does have an influence on the existence of arbitrage opportunities, then the null hypothesis will be rejected.

To answer the RQ2, the data collected was tested. This section will now articulate the results and the findings of the test. The goal is to provide a clear account of what was discovered during the research process. To do this, this section will summarize the statistical analysis and the interpretation of the analysis that help to formulate the findings of the study.

Statistical Analysis

To answer RQ2, a binary logistic regression model was used. A binary logistic regression model was selected due to the alignment of the statistical measurement to the purpose of the research question. The purpose of the research question was to prove the relationship volatility and liquidity had on arbitrage opportunities for cryptocurrency as a financial asset in Canada. The concept of a binary logistic regression model is to assess the strength of a relationship between one dependent variable and two or more independent variables. The statistical measurement helps in predicting the value of a dependent variable based on the independent variables (Warner, 2012). The statistical measurement demonstrates how much of the result of the dependent variable is being accounted for by the independent variables. This is a method to determine the reason-result relationship between the independent variables and the dependent variable. With the selection of the binary logistic regression model to answer RQ2, the next step is to ensure the data collected meets the assumptions of the statistical measurement.

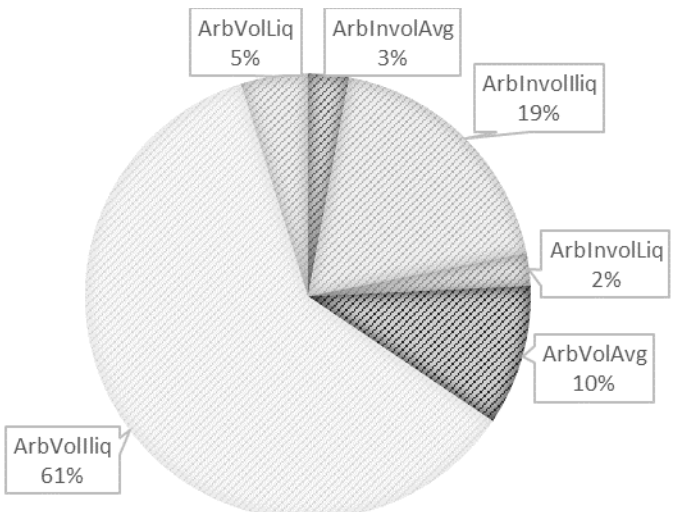
Checking and confirming the assumptions of a statistical test is a fundamental component of the quantitative analysis process. Ignoring the assumptions placed on a dataset for a particular statistical measure is not only irresponsible, but can lead to the determination of an incorrect conclusion and brings into question the integrity of the research (Kotronoulas et al., 2023). Checking and confirming the assumptions for a statistical test will help to ensure the validity, reliability, and generalizability for the findings of a study. This section will now review the assumptions on the dataset for a binary logistic regression statistical test.

This study will employ the use of a binary logistic regression model to analyze the data collected for RQ2. Based on Warner (2012), a binary logistic regression model can be used to analyze data for studies where the dependant variable is dichotomous. For the dataset to be considered appropriate for a logistic regression several assumptions need to be met dependant variable must be dichotomous, large sample size, no multicollinearity, independence of observations, linear relationship, and no perfect separation. As noted in the previous paragraphs, the raw data collected was transformed to help meet generally accepted financial principles. The data used for the dependant variable, daily closing price, was transformed from a continuous variable to a dichotomous variable for arbitrage (0 = no arbitrage; 1 = arbitrage). The data used for the independent variable, daily closing price, was transformed from a continuous variable to a dichotomous variable for volatility (0 = involatile; 1 = volatile). The data used for the independent variable, daily closing bid and ask prices, was transformed from a continuous variable to a categorical variable for liquidity (0 = illiquidity; 1 = average; 2 = liquid). These transformed data points were used in the binary logistic regression model of this study.

There are 12 possible outcomes for the transformed dataset. An arbitrage outcome can have a volatile or involatile outcome combined with an illiquid, average, or liquid outcome (six outcomes). A non-arbitrage outcome can have a volatile or involatile outcome combined with an illiquid, average, or liquid outcome (six outcomes). Figure 14 visualizes the breakdown of the arbitrage outcomes. Figure 15 visualizes the breakdown of the non-arbitrage outcomes. As noted, the arbitrage to non-arbitrage opportunities has a near perfect 50/50 breakdown. In addition, the breakdown of the six different combinations between arbitrage to non-arbitrage outcomes are similar as well – with arbitrage and non-arbitrage outcomes that are combined with volatile and illiquid outcomes accounting for 61% of all data points. This is important to understand because the binary logistic regression model denoted that while arbitrage was significantly influenced by volatility and illiquidity, this influence was immaterial. This may be because cryptocurrency as a financial asset in Canada is simply volatile and illiquid.

Figure 14

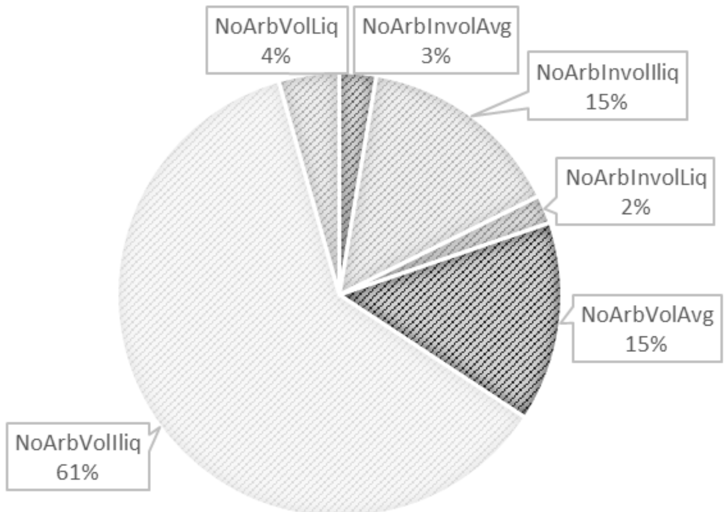
Breakdown of Arbitrage Combinations



Note: ArbVolIliq = Arbitrage+Volatile+Illiquid; ArbVolLiq = Arbitrage+Volatile+liquid; ArbVolAvg = Arbitrage+Volatile+Average; ArbInvolIliq = Arbitrage+Involatile+Illiquid; ArbInvolLiq = Arbitrage+Involatile+liquid; ArbInvolAvg = Arbitrage+Involatile+Average

Figure 15

Breakdown of Non-arbitrage Combinations



Note: NoArbVolIliq = Non-arbitrage+Volatile+Illiquid; NoArbVolLiq = Non-arbitrage+Volatile+liquid; NoArbVolAvg = Non-arbitrage+Volatile+Average; NoArbInvolIliq = Non-arbitrage+Involatile+Illiquid; NoArbInvolLiq = Non-arbitrage+Involatile+liquid; NoArbInvolAvg = Non-arbitrage+Involatile+Average

The assumptions for a binary logistic regression model were vetted for both the raw and transformed dataset, were applicable, to ensure that the datasets were acceptable. Both datasets maintained the transformed dichotomous dependant variable and only the raw and transformed data used for volatility and liquidity independent variables were dual tested for adherence to the assumptions. Both evaluations of the noted assumptions found the datasets to be appropriate for the use of a binary regression model. The subsequent paragraphs will define the noted assumptions and summarize the statistical tests and performance by each dataset. Table 7 summarizes the outcome for each statistical test.

The first two assumptions for a binary logistic regression model are that the dataset must have a dichotomous dependant variable and have a large sample size. Both the raw and transformed datasets used the same dependant variable and data points. The dependant variable is a dichotomous variable – arbitrage (0 = no arbitrage; 1 = arbitrage). Within the datasets, there are 2,976 data points. Based on the Central Limit Theorem, a common rule of thumb is to aim for a sample size of at least 30 cases for descriptive statistics (Frankfort-Nachmias et al., 2020). Therefore, a dataset with 2,976 data points can be considered a large dataset. Based on these points, adherence to the first two assumptions of a binary logistic regression model can be confirmed. Next no multicollinearity assumption will be reviewed.

The third assumption for a binary logistic regression model is no multicollinearity. No multicollinearity refers to the situation where the independent variables are not highly correlated to each other. This is important to confirm because it helps to ensure reliable estimates of the relationship between the dependent and independent variables. Common methods to detect multicollinearity is to review the variance inflation factor (VIF) for continuous data points (raw dataset) and correlation matrix for categorial data points (transformed dataset). A VIF of 1 indicates there is no correlation between the independent variables. This test was completed in SPSS. The raw dataset's VIF was 1.001, indicating that there is almost no correlation between the independent variables and that the dataset is in adherence to the no multicollinearity assumption. Using the Pearson correlation statistic, a score of 0 indicates there is no correlation between the independent variables, while a score above +0.7 or below -0.7

would indicate a violation of the no multicollinearity assumption. This test was completed in SPSS. The transformed dataset's Pearson correlation was -0.37, indicating an immaterial correlation between the independent variables and that the dataset is in adherence to the no multicollinearity assumption. Based on these points, adherence to the third assumptions of a binary logistic regression model can be confirmed. Next independence of observations assumption will be reviewed.

The fourth assumption for a binary logistic regression model is independence of observations. The independence of observations refers to the independence or lack of influence between the independent variables. This is important to confirm to ensure that estimated relationships between the variables are accurate and not biased by a dependence between the independent variables. A common method for checking for independence of observations is the statistical test Durbin-Watson. The Durbin-Watson test detects the presence of autocorrelation in the residuals of a binary logistic regression model. With a range of 0-4, a score of 2 indicates no autocorrelation. The Durbin-Watson test was completed for both the raw and transformed datasets in SPSS. The Durbin-Watson scores for the raw and transformed datasets were 2.007 and 2.005 respectively. These scores indicate no significant positive or negative autocorrelation within the regression model and that independence of observations assumption was upheld. Next the linear relationship assumption will be reviewed.

The fifth assumption for a binary logistic regression model is linear relationship. Linear relationship refers to the relationship between a continuous independent variable and its natural logarithm (logit). This is important to confirm to ensure that the estimated coefficients are not biased in the representation of the relationship of the outcomes. Since the test is only focused on continuous independent variables, the test will only be applied to the raw dataset. This test was preformed in SPSS by creating an interaction term between each independent variable and its logit. If the interaction between the independent variable and its logit are found to be significant ($p <= 0.05$) then the linearity assumption would be violated. The significance between the volatility and liquidity independent variables of the raw data sets and the created logits where both greater than 0.05. These results indicated the adherence to the linear relationship assumption for the raw dataset. Next the no perfect separation assumption will be reviewed.

The final assumption for a binary logistic regression model is no perfect separation. No perfect separation refers to the condition that there should be no situation where a combination of the independent variables can perfectly predict the dependent variable. This is important to ensure so that the binary logistic regression model can provide reliable and generalizable results. A common way to test for perfect separation is to review the classification table of the binary logistic regression model's output and ensure that both of the dichotomous outcomes for the dependent variable are accounted for. This test was completed in SPSS. For both the raw and transformed dataset, both No Arbitrage and Arbitrage outcomes were accounted for. Furthermore, all 2,976 data points were accounted for. This means that for both the raw and transformed datasets, there were no cases of misclassification and that the assumption for perfect separation was adhered to. A summary of the classification tables for both datasets can be found in Table 8.

Table 7

Summary of Results for Assumption Checking

	Datasets	
Assumptions	Raw	Transformed
Dichotomous Dependent Variable	Met	Met
Large Sample Size	Met	Met
No Multicollinearity	VIF = 1.001 Met	Pearson = -0.37 Met
Independence of Observations	Durbin-Watson = 2.007 Met	Durbin-Watson = 2.005 Met
Linear Relationship	Sig > 0.05 Met	Sig > 0.05 Met
Perfect Separation	Met	Met

Table 8

Summary of Classifications Tables for Raw and Transformed Datasets

		Predicted Arbitrage		Total
	Observations	No Arbitrage	Arbitrage	Classified
Raw	No Arbitrage	895	604	
	Arbitrage	806	671	2,976
Transformed	No Arbitrage	1,177	322	
	Arbitrage	1,091	386	2,976

The use of a binary logistic regression analysis is appropriate for this study because it matches the requirement of the test: a dependent variable that is dichotomous and a nominal level of measurement, with two independent variables. In addition, Warner (2012) noted that binary logistic regression is useful for studies where researchers are examining the contribution of independent variables on the dependent variable and assess the significance and magnitude of each independent variable. This matches the purpose of this study. Finally, Tjondro et al. (2023) successfully used a binary logistic regression analysis in their study on cryptocurrency. With the assumptions of the binary logistic regression model confirmed, the next step was to analyze the results of the binary regression model and interpret the results in light of the current literature.

Interpretation

Arbitrage and what influences the opportunity is a result of the maturity of the financial asset. Ahmed (2022) noted that the maturity of cryptocurrency as a financial asset may differ between different cryptocurrencies. This may mean the effect of both volatility and liquidity on arbitrage opportunities would differ for different cryptocurrencies. To capture this characteristic of the financial asset, a binary logistic regression model will first be run for all of the cryptocurrencies together, and then four separate binary logistic regression models will be run for the four individual cryptocurrencies. This will allow for the interpretation of the Canadian market as well as to isolate the characteristics and maturity of each cryptocurrency for interpretation.

All Cryptocurrencies

A binary logistic regression model was completed for all of the cryptocurrencies for this study (Bitcoin, Ethereum, Cardano, and Dogecoin) in SPSS. Data for all of the cryptocurrencies was collected over the time period of October 15th, 2023 to January 14th, 2024. Over this time period, 62 days of data collected was used. Due to the 12 different buy-sell exchange combinations and four different cryptocurrencies, all of the cryptocurrencies' datasets consisted of (62 x 12 x 4) 2,976 data points. All 2,976 data points were included within all of the cryptocurrencies' binary logistic regression models. While the complete SPSS Output Report can be found in Appendix B, several key measurements will be reviewed in this section. These measurements are model statistical significance, goodness-of-fit, and odds ratios.

To fully understand the results of the measurements, it is important to review the baseline of the model before the independent variables are included. This is known as Block 0 or the null model. Referring to the Classification Table, the null model predicted that all outcomes for the dependent variable would be No Arbitrage. The null model correctly predicted the dependent variable 50.4% of the time. This is important to know when interpreting the improved accuracy of predicting the dependent variable when the independent variables are added to the model.

The first key measurement of the binary logistic regression model's output is the statistical significance. Understanding the statistical significance of a binary logistic regression model allows the researcher to know if they can make inferences about the relationship between the dependent and independent variables, and demonstrates the repeatability of the model (Warner, 2012). The threshold for the confidence interval was set at 0.05. Referring to the Block 1: Omnibus Test – the statistical significance of the model is 0.001. The results of the Block 1: Omnibus Test can be found in Table 9. Due to the fact that the result is less than the 0.05 confidence interval threshold, the model is considered to be statistically significant. While the model has been deemed to have significant predictability of the dependent variable, basing an analysis of the results on only one measure is not sufficient for drawing conclusions about the practical and scholarly implication of the findings. The interpretation of the results will continue with the model's goodness-of-fit to be reviewed next.

Table 9

Omnibus Test of Model Coefficients for All Cryptocurrencies

		Chi-square	*df*	Sig.
Step 1	Step	17,561	3	.001
	Block	17,561	3	.001
	Model	17,561	3	.001

To understand how well the model's independent variables explain the variability of the dependent variable, goodness-of-fit tests were reviewed. Warner (2012) noted that goodness-of-fit tests are key for binary logistic regression models, because they ascertain how well the model fits the observed data. This will help to understand magnitude and implications of the model's findings. To gain this understanding, the Nagelkerke R-Squared and Hosmer and Lemeshow tests will be reviewed.

The Nagelkerke R-Square is a measure to ascertain the variation of the dependent variable that was explained by the independent variables. Nagelkerke R-Square is commonly used in binary logistic regression models to demonstrate the models' goodness-of-fit (Warner, 2012). The result of the test was 0.008. This means that less than 1% change in the dependent variable can be accounted to the independent variables. The results of the Nagelkerke's R-Square Test can be found in Table 10. Cohen (1988) said that the effect size of this measure is small to the point of meaninglessness. This means that when the independent variables are added to the model, they are not increasing the predictability of the dependent variable and therefore do not have a good model fit.

Table 10

Nagelkerke R-Square From All Cryptocurrencies Binary Logistic Regression Model

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	4107.889	.006	.008

Note. For the -2 Log likelihood, estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

The next goodness-of-fit test to be reviewed is the Hosmer and Lemeshow Test. The Hosmer and Lemeshow Test ascertains if there is a significant difference between the observed and predicted occurrences within the model (Hosmer et al., 2013). The models Hosmer and Lemeshow Test was 0.798. The results of the Hosmer and Lemeshow Test can be found in Table 11. A significant result less than 0.95 means that the results are insignificant and that the model inadequately fits the data.

Table 11

Hosmer and Lemeshow Test From All Cryptocurrencies Binary Logistic Regression Model

Hosmer and Lemeshow Test			
Step	Chi-square	dt	Sig.
1	1.014	3	.798

The results of both the Nagelkerke R-Square and the Hosmer and Lemeshow Tests demonstrate the insignificant and immaterial goodness-of-fit of the binary logistic regression model for all of the cryptocurrencies. This demonstrates the limited explanatory power of the model and that the observed and predicted models are almost equal. The addition of the volatility and liquidity measure to the model inadequately explains the occurrence of arbitrage opportunities for all of the cryptocurrencies as a financial asset in Canada. The weak predicting influence by the independent variables on the dependent variables can be seen when you compare the null model to the results of this study.

The slight improvement in the model's ability to predict the dependent variable when the independent variables are added to the model can be quantified when the Classification Tables for Block 0 (null model) and Block 1 (current model) were compared. As noted at the beginning of this section, the null model's ability to correctly predict the dependent variable was 50.4%. The addition of the independent variables only slightly increased the model's ability to predict the dependent variable to 52.5%. This slight increase is the quantification of the weak practical significance or goodness-of-fit of the independent variables to the dependent variable. To complete the analysis of the model's results, its odds ratios will be reviewed next.

Within the analysis of the binary logistic regression model, there is a need to comment on the strength and direction of the correlation of the relationship between the dependent and independent variables. In binary logistic regression models, focusing on the model's coefficients, odds ratios, and the measure's significant are used to quantify the relationship between the dependent and independent variables (Hosmer et al., 2013). Reviewing both the coefficients or β and the exponential of Beta measurement—Exp (β) will demonstrate the direction and strength of the relationship between the dependent and independent variables – its odds ratios. This measure must be considered along with a critical tendency measurement, in this case a significance equal to or less than 5%. The results for all of the cryptocurrencies odds ratios can be found in Table 12. For the independent variable volatility, the β of 0.252 indicates that for each one-unit increase in volatility an arbitrage opportunity would become more likely by 0.252. Factored with the Exp(β) of 1.287 would mean that the one-unit increase in volatility would increase the odds of having an arbitrage opportunity by 28.7%. This measurement is considered significant. These odds ratios are considered to be a moderate relationship (Hosmer et al., 2013). For the independent variable liquidity, the β of -.344 indicates that for each one-unit increase in volatility an arbitrage opportunity would become less likely by 0.344. Factored with the Exp(β) of 0.709 would mean that the one-unit increase in volatility would decrease the odds of having an arbitrage opportunity by 29.1%. This measurement is considered significant. These odds ratios are considered to be a moderate relationship (Hosmer et al., 2013). This means that both volatility and illiquidity have a moderate predictive relationship of what may be causing arbitrage opportunities for all of the cryptocurrencies within the Canadian market.

Table 12

Variable in the Equation Test for All Cryptocurrencies

Variables in the Equation									
								95% C.I. for Exp(B)	
		B	S.E.	Wald	df	Sig,	Exp(B)	Lower	Upper
Step 1	Volatile	.252	.089	8.000	1	.005	1.287	1.081	1.533
	Liquidity			8.731	2	.013			
	Liquidity (1)	-.045	.147	.093	1	.760	.956	.717	1.275
	Liquidity (2)	-.344	.170	4.102	1	.043	.709	.508	.989
	Constant	.017	.143	.014	1	.906	1.017		

This analysis has looked at the likelihood of arbitrage opportunities for all of the cryptocurrencies as a financial asset. This analysis has reviewed the measurements of model statistical significance, goodness-of-fit, and odds ratio for all of the cryptocurrencies. The results of the binary logistic regression model have demonstrated that there is significant evidence of a relationship between volatility and illiquidity predicting arbitrage opportunities for all of the cryptocurrencies as a financial asset within the Canadian Market. The results also demonstrate the goodness-of-fit for the relationship is immaterial and the odds ratios are moderate with opposite directional influences.

Individual Cryptocurrencies

A binary logistic regression model was completed for each of the noted cryptocurrencies of this study in SPSS – Bitcoin, Ethereum, Cardano, and Dogecoin. Data for each cryptocurrency was collected over the time period of October 15, 2023 to January 14, 2024. Over this time period, 62 days of data collection was used. Due to the 12 different buy-sell exchange combinations, the dataset consisted of (62 x 12) 744 data points for each cryptocurrency. All 744 data points were included within the binary logistic regression model for each cryptocurrency. The complete SPSS Output Report can be found in Appendix C for Bitcoin, Appendix D for Ethereum, Appendix E for Cardano, and Appendix F for Dogecoin. Several key measurements were reviewed in this section for each cryptocurrency. These measurements are model statistical significance, goodness-of-fit, and odds ratios.

The first key measurement of the binary logistic regression model's output is the statistical significance. Understanding the statistical significance of a binary logistic regression model allows the researcher to know if they can make inferences about the relationship between the dependent and independent variables, and demonstrates the repeatability of the model (Warner, 2012). The threshold for the confidence interval was set at 0.05. Referring to the Block 1: Omnibus Test—the binary logistic models were found to be statistically significance for all the cryptocurrencies, except Bitcoin. While the significance offers key insight as to the predictability of the dependent variable based on the independent variables, basing an analysis of the results on only one measure is not sufficient for drawing conclusions about the practical and scholarly implication of the findings. The interpretation of the results will continue with the model's goodness-of-fit to be reviewed next.

To understand how well the model's independent variables explain variability of the dependent variable, goodness-of-fit tests were reviewed. Warner (2012) noted that goodness-of-fit tests are key for binary logistic regression models because they ascertain how well the model fits the observed data. This helps to understand the magnitude and implications of the model's findings. To gain this understanding, Nagelkerke R-Squared, which denotes what percentage of the change in the dependent variable can be attributed to the addition of the independent variables, and the Hosmer and Lemeshow test, which denotes the significance of the predictability, will be reviewed.

The Nagelkerke R-Square is a measure to ascertain the variation of the dependent variable explained by the independent variables. Nagelkerke R-Square is commonly used in binary logistic regression models to demonstrate the models' goodness-of-fit (Warner, 2012). For all of the cryptocurrencies, the Nagelkerke R-Square was no larger than 0.033. This means that no more than 3.3% of arbitrage opportunities are correctly predicted with the addition of volatility and liquidity to the model for each cryptocurrency. Cohen (1988) would denote that the effect size of this measure is small to the point of meaninglessness. This means that when the independent variables are added to the model, they are not increasing the predictability of the dependent variable and therefore do not have a good model fit.

The next goodness-of-fit test to be reviewed is the Hosmer and Lemeshow Test. The Hosmer and Lemeshow Test ascertains if there is a significant difference between the observed and predicted occurrences within the model (Warner, 2012). For the individual model's Hosmer and Lemeshow Test, not one of the cryptocurrencies scored higher than 0.93. A significant result less than 0.95 means that the results are insignificant, and that the model inadequately fits the data.

The results of both the Nagelkerke R-Square and the Hosmer and Lemeshow Tests demonstrate the immaterial and insignificant goodness-of-fit of the binary logistic regression model for each cryptocurrency. This demonstrates the limited explanatory power of the model and that the observed and predicted models are almost equal. The addition of the volatility and liquidity measure to the model inadequately explains the occurrence of arbitrage opportunities for each individual cryptocurrency as a financial asset in Canada. To complete the analysis of the model's results, the model's odds ratios will be reviewed.

Within the analysis of the binary logistic regression model, there is a need to comment on the strength and direction of the correlation of the relationship between the dependent and independent variables. In binary logistic regression models, odds ratios are used to quantify the relationship between the dependent and independent variables (Warner, 2012). The exponential of Beta measurement—Exp (β), represents the direction and strength of the relationship between the dependent and independent variables. This measure must be considered along with a critical tendency measurement, in this case a significance equal to or less than 5%. Based on the Exp(β) measure, there are mixed results for the different cryptocurrencies. For Bitcoin, all relationships combinations between dependent and independent variables are considered insignificant. For Ethereum, the main relationship is for liquidity, where a one unit increase in liquidity will cause a 69% reduction in arbitrage opportunity. This relationship is considered significant. For Cardano, the main relationship is for liquidity, where a one unit increase in liquidity will mean an arbitrage opportunity is 4.2 times more likely. This relationship is considered significant. Finally, for Dogecoin, the main relationship is for volatility, where a one unit increase in volatility will mean an arbitrage opportunity is 1.5 times more likely. This relationship is considered significant. Hence, the predictability relationship between the dependent and independent variables is not generalized across different cryptocurrencies within the Canadian market. A summary of key measurements from the individual cryptocurrencies' binary logistic regression models can be found in Table 13.

Table 13

Summary of Key Measurements From Individual Cryptocurrency Models

Cryptocurrencies	Cases	Sig	Goodness-of-fit		Main Odds Ratio		
			NR^2	H&L Test	Type	Sig	Exp(**β**)
Bitcoin	744	.733	.002	.91	All insignificant		
Ethereum	744	.019	.028	.93	Liquid	.003	0.314
Cardano	744	.000	.033	.86	Liquid	.032	4.152
Dogecoin	744	.026	.017	.74	Volatile	.026	1.51

Note. NR^2 refers to Nagelkerke R-Square; H&L Test refers to Hosmer and Lemeshow Test; Sig refers to significant.

Summary

Arbitrage opportunities for cryptocurrency as a financial asset in the Canadian market is influenced by volatility and liquidity. Based on these findings from the All Cryptocurrency binary logistic regression model, I rejected null hypothesis for RQ2. The findings indicate that while the relationship is weak, there is still a relationship between arbitrage opportunities for cryptocurrency as a financial asset in Canada when volatility and liquidity are present. When the cryptocurrency is considered volatile (equal to or greater than 1.5x β then the odds of an arbitrage opportunity increased by almost 1.3 times. When the cryptocurrency is considered liquid (bid-ask spread is 3bsp or less) the odds of arbitrage opportunities decreased to 0.7 times.

The finding of arbitrage opportunities for cryptocurrency as a financial asset in the Canadian market is influenced by volatility and liquidity aligns to the current literature. The literature review conducted for this study and detailed in Chapter 2 found arbitrage opportunities for cryptocurrency as a financial asset is influenced by volatility and liquidity. The findings for RQ2 demonstrate the generalization of current knowledge on the existence of arbitrage opportunities for cryptocurrency as a financial asset in the Canadian cryptocurrency market. These findings fill a gap in the current literature, which will be further reviewed in Chapter 5.

Summary

In Chapter 4, I addressed the data collection process and data analysis to derive results of the study. I first reviewed the data collection process for primary and secondary datasets. Then I addressed descriptive data for each dataset and how data were organized for analysis. Finally, I demonstrated how data were used to answer RQ1 and RQ2.

The results derived from the analysis based on the data collected were able to answer the research questions of the study. For RQ1, I found arbitrage opportunities do exist for cryptocurrency as a financial asset in Canada. For, I found volatility and liquidity significantly influenced arbitrage opportunities for cryptocurrency as a financial asset in Canada, but the predictive relationship was immaterial. With the completion of the presentation of the results and how the results were used to answer the research questions, this study will focus on the synthesis and meaningfulness of the findings. It will do this by discussing the limitations and implications of findings to current knowledge, practices, and future research.

Chapter 5: Discussion, Conclusions, and Recommendations

Since its introduction in 2008, cryptocurrency has experienced a meteoric rise, leaping from being worth nothing to generating market capitalization in the trillions of dollars. This unprecedented growth in popularity of cryptocurrency as a financial asset has challenged professionals and scholars alike to understand how to measure cryptocurrency's performance to support average and inexperienced investors. The purpose of this quantitative study was to test the LOP on cryptocurrency and cryptocurrency exchanges in Canada. To address the purpose of this study, two research questions were created to establish if arbitrage opportunities were occurring for cryptocurrency as a financial asset in Canada as well as if volatility and liquidity were influencers of arbitrage opportunities. To address these research questions, a quantitative statistical analysis method using descriptive statistics and binary logistic regression and nonexperimental cross-sectional research design were used.

Results of analysis indicated arbitrage opportunities did exist for cryptocurrency as a financial asset in Canada. Results also indicated volatility and liquidity were influencers of arbitrage opportunities, but the relationship was immaterial. Adding to the existing body of knowledge regarding cryptocurrency will better equip professionals and scholars to support and protect average and inexperienced investors in cryptocurrency, especially those who are accepting increased risks by investing in cryptocurrency they neither have the risk management skills or financial stability to assume. The purpose of this chapter is to analyze and interpret results from the study. In order to do so, this chapter will cover the interpretations of findings, limitations of the study, recommendations for future research, and implications for social change for the findings.

Interpretation of Findings

Chapter 4 clearly and accurately presents the process and analysis to derive results of the study. Results derived from analysis based on data were able to answer research questions. For RQ1, it was found that arbitrage opportunities do exist for cryptocurrency as a financial asset in Canada. For RQ2, it was found that volatility and liquidity influence arbitrage opportunities for cryptocurrency as a financial asset in Canada, but the relationship was immaterial. Contextualizing these findings to existing literature will help in terms of drawing conclusions and advancing knowledge about cryptocurrency as a financial asset.

The Findings served to extend knowledge regarding what is known about cryptocurrency. I focused on the four leading cryptocurrencies in Canada: Bitcoin, Ethereum, Cardano, and Dogecoin. To help interpret findings, I focused on how they advanced current literature. These sections are a study beyond Bitcoin, Canadian market, existence of arbitrage opportunities, influencers of arbitrage opportunities, liquidity of cryptocurrency, and theoretical context.

A Study Beyond Bitcoin

One of the collective trends I noticed in the literature review is that the vast majority of studies focused only on Bitcoin. While Bitcoin is the dominant cryptocurrency, it is just one of almost 10,000 different cryptocurrencies. Zhang et al. (2018) noted a comprehensive understanding of cryptocurrency cannot be established by only studying Bitcoin, and more cryptocurrencies should be studied. In addition, recent studies have concluded need for future studies that are not focused solely on Bitcoin (Almeida, 2021; Corbet et al., 2019; Leung & Nguyen, 2019). Findings of this study not only confirmed existence of arbitrage opportunities and influencers but helped extend knowledge beyond the scope of just Bitcoin.

Canadian Market

Findings of the study served to extend knowledge regarding what is known about the Canadian cryptocurrency market. During the literature review, there were no articles that focused on the Canadian market, and only one article noted the Canadian market. This lack of focus in literature should be addressed due to Canada's advanced economic standing and high level of cryptocurrency acceptance. This is a gap in current literature regarding cryptocurrency as a financial asset. Cryptocurrency needs further research in different markets (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021; Makarov & Schoar, 2020). Findings of this study not only confirmed the existence of arbitrage opportunities and their influencers, but helped to extend knowledge to include the Canadian market.

Existence of Arbitrage Opportunities

Findings specific to RQ1 indicated arbitrage opportunities did exist for cryptocurrency as a financial asset in Canada. The review of the academic literature found significant knowledge that arbitrage opportunities do exist for cryptocurrency as a financial asset, these include market specific arbitrage opportunities (Borri & Shakhnov, 2020; Lee & Oh, 2022); cross-border arbitrage opportunities (Makarov & Schoar, 2019, 2020); and exchange-specific arbitrage opportunities (Bruzgė & Šapkauskienė, 2022b; Kabašinskas & Šutienė, 2021). This study validated and generalized the findings of these noted studies by demonstrating that arbitrage opportunities exist for cryptocurrency as a financial asset and connected the knowledge specifically to the Canadian Market.

Findings specific to RQ1 also served to extend knowledge for arbitrage opportunities beyond Bitcoin. As noted, I focused on the four leading cryptocurrencies in Canada, while the vast majority of recent studies were focused only on Bitcoin. To gain a comprehensive understanding of cryptocurrency, the collective of the knowledge cannot be established by only studying Bitcoin (Zhang et al., 2018). Of the noted recent studies pertaining to the finding for Research Question 1, only Kabašinskas and Šutienė (2021) regarded cryptocurrencies other than Bitcoin in their data collection and analysis. Findings of this study not only confirmed existence of arbitrage opportunities, but also helped extend knowledge beyond the scope of Bitcoin.

Data were collected during a 3-month period between 2023 and 2024. This is due to a gap in the literature based on the maturity of cryptocurrency as a financial asset. Recent studies have concluded that arbitrage opportunities all but disappeared or became unprofitable after 2018 due to their transition into a mature asset (Duan et al., 2021; Shynkevich, 2021). Other recent studies disconfirm with this conclusion (Kristoufek & Bouri, 2023; Krückeberg & Scholz, 2020). Demonstrating a gap within the literature. Data were collected between October 15, 2023 and January 14, 2024, to offer new knowledge to this gap within the literature. The date range of the data collected also addressed Delfabbro's et al. (2021) concern growth in cryptocurrencies is happening so rapidly that any data cited as recently as 3 months ago can be considered outdated.

Findings of this study offered new knowledge regarding the gap in literature pertaining to the maturity of cryptocurrency as a financial asset and if arbitrage opportunities disappeared after 2018. Findings confirm arbitrage opportunities for cryptocurrency exist when using recent data. This confirms the findings of recent studies of Kristoufek and Bouri (2023) and Krückeberg and Scholz (2020). Interestingly, the findings also confirmed the recent findings that arbitrage opportunities all but disappeared for cryptocurrency after 2018 due to its transition into a mature asset (Duan et al., 2021; Shynkevich, 2021). How the study was able to bridge the gap between two contradictory findings was based on the details of the findings.

While the overall findings of the study demonstrated that arbitrage opportunities do exist for cryptocurrency as a financial asset in Canada, the study was based on data collected from four different cryptocurrencies. Duan et al. (2021) and Shynkevich (2021) studies were focused only on Bitcoin. As the oldest and most popular cryptocurrency, it is fair to assume that Bitcoin may be more mature than other more recent and less popular cryptocurrencies. Using data that combines different cryptocurrencies and treats them as equals may be the cause of mixed results within the literature. Other factors, such as the drastic valuation difference by cryptocurrency, may cause cryptocurrencies to have different characteristics. At the midpoint of data collection (November 27, 2023) the average closing price of the four exchanges for Bitcoin was $50,461.21; Ethereum was $2,753.73; Cardano was $0.51156; Dogecoin was $0.106149. This is a demonstration of the vast valuation differences between the different cryptocurrencies and the potential limitations of attempting to focus on different cryptocurrencies and treating them as equals.

Based on the studies completed by Bruzgė and Šapkauskienė (2022b, 2022a), the tolerance for what is considered an arbitrage opportunity was set at $0.01 for Bitcoin. Based on the data collected for this study, the average daily closing price for Bitcoin was approximately $52,630. The $0.01 tolerance for arbitrage opportunity represents only a fraction of the average daily closing price. As a robustness check to the results of the study, a sensitivity analysis was completed on the assumption used for what is considered an arbitrage opportunity. If an arbitrary 1% of the average daily closing price, $526.30, was set as the tolerance for what is considered an arbitrage opportunity for Bitcoin, then cumulative percentage for arbitrage opportunities drastically reduces from 100% to a range of 3.2% to 0.0% - depending on the buy-sell exchange combination. This sensitivity analysis demonstrates that while arbitrage opportunities do exist within the Canadian cryptocurrency market, the extent of the opportunity is meager.

The study found that while arbitrage opportunities do exist in the Canadian market for cryptocurrency as a financial asset, but the opportunity is meager. This finding generalized the findings of Li and Liu (2024), who found that arbitrage opportunities for Bitcoin start to vanish at a spread of 1.02% for centralized and trustworthy exchanges and 1.65% for decentralized and untrustworthy exchanges. Shynkevich (2023) confirmed these findings, noting that since 2018 arbitrage opportunities still exist, but the profitability of the opportunities have significantly declined. The findings of this study and the other noted studies bring into question a limitation of the study based on the effect of tolerances to the scope of what is considered an arbitrage opportunity to the generalizability of the findings.

With the generalization of the findings that arbitrage opportunities for cryptocurrencies within the Canadian market exist, a natural follow up question would be how long to the arbitrage opportunities exist if they are small. A study by Hansson (2022) found that arbitrage opportunities do exist for cryptocurrency as a financial asset, but the market adjust and quickly ends the arbitrage opportunities. The speed in which the arbitrage opportunities are corrected is beyond the scope of this study. This does create an interesting topic for future research.

Influencers of Arbitrage Opportunities

Cryptocurrency is regarded as a financial asset. Mature financial assets have certain characteristics that professional investors have come to rely upon to help them reduce risk. The academic literature considered cryptocurrency to be both mature (Dyhrberg et al., 2018) and immature (Celeste et al., 2020; Kang et al., 2022). This demonstrates a gap within the current body of literature. A mature asset is generally considered to be neither volatile nor illiquid. Financial assets that are neither volatile nor illiquid are seen to be price efficient, which mitigates the possibility of arbitrage opportunities.

The findings specific to RQ2 indicated that volatility and illiquidity were influencers of the arbitrage opportunities, but the relationships were immaterial. The review of the academic literature found mixed results pertaining to the relationship between arbitrage opportunities and volatility and liquidity for cryptocurrency as a financial asset. These results were used to demonstrate a gap in the current literature as influencers of arbitrage opportunities for cryptocurrency as a financial asset. This gap in the current literature was one justification for the significance of this study. This section will review the documentation of the mixed results by volatility and liquidity and demonstrate how the findings of the study helped to further the knowledge of what influences arbitrage opportunities for cryptocurrency as a financial asset.

The recent literature has studied the relationship volatility and liquidity have as an influencer of arbitrage opportunities for cryptocurrency as a financial asset. The results have been mixed. Recent studies have found that volatility and illiquidity are influencers of arbitrage opportunities for cryptocurrency as a financial asset (Bianchi, 2020; Bouri, Gil-Alana, et al., 2019; Brauneis et al., 2022; Hansen et al., 2024; Shahzad et al., 2021). Shu et al. (2023) found that it is the price inefficiency of cryptocurrency that results in the volatility and liquidity becoming influencers of arbitrage opportunities. However, other recent studies found that volatility and liquidity are influencers of arbitrage opportunities for cryptocurrencies as a financial asset (Kristoufek & Bouri, 2023; Krückeberg & Scholz, 2020). The findings of this study confirmed that volatility and liquidity are influencers of arbitrage opportunities for cryptocurrency as a financial asset. These findings helped to generalize the findings that support volatility and liquidity as influencers of arbitrage opportunities, specifically for the Canadian market.

Due to the weak influence of volatility and liquidity on arbitrage opportunities for cryptocurrency as a financial asset, other factors might be influencing the opportunities.

A study by Peng et al. (2023) concluded that along with volatility and liquidity several other factors were influencers of arbitrage opportunities for cryptocurrency as a financial asset. While beyond the scope of this study, the recent literature that denotes other influencers on price setting and therefore arbitrage opportunities for cryptocurrency as a financial asset should be noted.

Recent studies have linked arbitrage opportunities to the volatility of the overall markets rather than the individual cryptocurrencies. Major market disrupters, such as terrorist attacks (Almaqableh et al., 2022), the COVID-19 pandemic (Apergis, 2022; K. Q. Nguyen, 2022; Sarkodie et al., 2022), and major hacking attacks (Demiralay & Golitsis, 2021) are the influencers of the price disruption and subsequent arbitrage opportunities for cryptocurrency as a financial asset. These studies provide evidence that it is the unsystematic risk and not the systematic risk that is causing arbitrage opportunities. While these findings offer a variable to the cryptocurrency environment that was not considered during the construction of this study, the effect was inadvertently accounted for. The measurement used to determine the volatility of an individual cryptocurrency is based on the concept of β, which removes unsystematic risk.

One way to determine the systematic risk of a financial asset is to measure its β. The β is a measure of the systematic risk or volatility of a particular financial asset in relation to the overall market (Ross et al., 2022). The β assesses the sensitivity of a financial asset's returns to changes in the overall market, in this study the TSX. The β does this by comparing the price volatility of an individual financial asset to the price volatility of a benchmark index. This means that while the noted studies on price disruptions and market volatility are valid, the findings do not put into question the validity of this study's findings, because how the measurement for volatility was created.

Recent studies have found other factors to influence the price setting of cryptocurrencies and the creation of arbitrage opportunities. To fully understand the findings of this study, the other influencers should be noted. Beyond volatility and liquidity, other main influencers on the price setting of cryptocurrency and therefore arbitrage opportunities are technology (Chico-Frias, 2021; Chowdhury et al., 2022; Karaömer, 2022), economics (Huang et al., 2022; Karaömer, 2022; T. V. Nguyen et al., 2022; Wang et al., 2023), investors' attitude (Gurrib & Kamalov, 2022; Nepp & Karpeko, 2024; Rubbaniy et al., 2021; Sapkota, 2022), and social media (Aslanidis et al., 2022; Bakas et al., 2022; Chuffart, 2022). The review of these other influences on the price setting of cryptocurrency is beyond the scope of this study. Conversely, this topic of interest will be covered in the Limitations and Recommendations sections of this Chapter.

A goal of this study was to help to expand the knowledge for cryptocurrency beyond Bitcoin. A study by Bianchi et al. (2022) found that while arbitrage opportunities were influenced by volatility and liquidity, the influence was more amplified for cryptocurrencies with smaller market capitalization. This is a demonstration that while Bitcoin, Ethereum, Cardano, and Dogecoin are all cryptocurrencies, they may not all have the same characteristics or significance to the market. Based on these findings, the fact that the study treats all cryptocurrencies the same may be a limitation to the study.

Liquidity of Cryptocurrency

While the literature can agree that when arbitrage opportunities are found, volatility has been an influencer. The gap in the literature seems to be focused on the role liquidity plays as an influencer of arbitrage opportunities for cryptocurrency as a financial asset. Brauneis and Mestel (2018) concluded that cryptocurrency's price efficiency was influenced by its liquidity – specifically the lack of liquidity or illiquidity. Based on economic theory, the more liquid a financial asset is, the greater price efficiency it has, and the least likely arbitrage opportunities are to exist. Other pieces of recent literature have concurred with the findings that illiquidity was an influencer of arbitrage opportunities for cryptocurrency as a financial asset (Brauneis et al., 2022; Bruzgė & Šapkauskienė, 2022a, 2022b; Dubey, 2022; Makarov & Schoar, 2019). The financial explanation for this relationship is that an illiquid financial asset cannot process information as quickly as a liquid financial asset due to the lack of buyers or sellers to absorb the information into the market price, causing the arbitrage opportunities.

Not all studies have found illiquidity as an influencer of arbitrage opportunities for cryptocurrency as a financial asset. In contrast, recent studies have indicated that it was in liquid markets that the arbitrage opportunities were in abundance (Karaömer, 2022; Krückeberg & Scholz, 2020; Nakagawa & Sakemoto, 2022). The authors noted that in recent years, as cryptocurrencies became more popular, the number of arbitrage opportunities increased. These findings were generalized by Kristoufek and Bouri (2023), who concluded that arbitrage opportunities increased when markets were liquid and there was high price volatility. The financial explanation for this relationship is that a liquid financial asset is not given the time necessary for everyone to process the information, having different decisions being made with different pieces of information, causing the arbitrage opportunities.

The findings of this study confirm the relationship that when cryptocurrency is considered liquid, it is less likely to have arbitrage opportunities. This confirms the findings by Li and Liu (2024) that found when volatility was controlled, arbitrage opportunities were smaller for liquid cryptocurrencies. This is a generalization of the findings to the Canadian market. Upon further analysis, I do not conclude this to be a definitive disconfirmation of the studies that had contrary findings. It must be noted that the goodness-of-fit of the results were found to be immaterial. This means that while there is a relationship for illiquidity as an influencer of arbitrage opportunities, this relationship was found to be weak to the point of non-existent.

Finally, the assumption that the cryptocurrency and not the exchanges are the cause of the arbitrage opportunity needs to be reviewed. A study by Morin and Moore (2023) found that liquidity is an influencer of arbitrage opportunities, but it was not the characteristic of the cryptocurrency, but the characteristic of the cryptocurrency exchange. The study demonstrates that it is the characteristics of the type of exchange that influence the level of arbitrage opportunities (centralized or decentralized). This factor was not accounted for during the selection of the exchanges for this study and could be seen as a limitation of the study.

Concerns over if exchanges with different platforms (centralized and decentralized) have different characteristics and influencers that may have inadvertently affected the findings of the study should be considered. While this will be noted as a limitation of the study, recent literature has found that different cryptocurrency exchange platforms' ability to uniquely compute the closing price does not distort the overall process of the underlying cryptocurrency and its data's scholarly value (Alexander & Dakos, 2020; Vidal-Tomás, 2022). This means, that while the types of different exchanges was not considered during the exchange selection process may have an influence on the findings of this study, it does not render the findings obsolete or invalid. This consideration will be further reviewed in the Limitations and Recommendations sections of this Chapter.

Theoretical Context

The theoretical framework of this study is LOP. The origins of LOP are not fully known, but dates back to mid-1700s in France. Miljkovic (1999) and Persson (2008) attribute the modern day understanding of the LOP to Giovannini (1988), which defines the LOP as a model that demonstrates that the value of an asset, such as currency, should be the same value regardless of the market, and the value should fluctuate in tangent between markets. When prices are normalized for localized costs, such as duties, fees, transportation, and transaction costs, the LOP established that identical goods must be sold for identical prices regardless of the market.

The LOP is a generally accepted financial principle and is a common theoretical framework to understand arbitrage opportunities. The LOP is considered violated when there is a lack of price duality between markets, when this occurs, this is known as an arbitrage opportunity. Recent cryptocurrency studies that have used the LOP as the theoretical framework have had successful results (Kabašinskas & Šutienė, 2021; Kristoufek, 2019; Makarov & Schoar, 2020; Pieters & Vivanco, 2017; Shynkevich, 2021; Witzel, 2005). Common influencers of if the LOP is violated or not are volatility and liquidity. This section will now review the theoretical implications of the findings of this study as the volatility and liquidity as influencers of arbitrage opportunities for cryptocurrency as a financial asset.

One influencer of the violation of the LOP is the volatility of the financial asset. Simply defined, volatility is the amount of risk associated to a financial asset based on fluctuations to its market price—the greater the fluctuations, the more volatile. Based on economic theory, the more volatile a financial asset is, the more likely there will be arbitrage opportunities. This is because when volatility is high current prices may be over or under valuated in individual markets due to panic selling, herd mentality, and automative trading algorithms reacting to market changes. As volatility increases for cryptocurrency, arbitrage opportunities should increase.

One influencer of the violation of the LOP is the liquidity of the financial asset. Simply defined, liquidity is how quickly a financial asset can be turned into cash—the more quickly, the more liquid. Based on economic theory, the more liquid a financial asset is, the least likely there will be arbitrage opportunities. This is because there are less barriers to stop available information from timely and reliably affecting the market price of a financial asset. As liquidity increases for cryptocurrency, arbitrage opportunities should decrease.

The findings of this study were that while volatility and illiquidity were influencers of arbitrage opportunities, their influences were weak. The interpretations of these findings on the theoretical context of the study are that the economic theory around the concepts of why volatility and liquidity would be influencers of arbitrage opportunities were upheld. Furthermore, the findings upheld the economic theory that there are several influencers of arbitrage opportunities and it is not the result of one or two influencers. A study by Peng et al. (2023) noted that there has to be several main influencers for price setting of cryptocurrency by exchange, and therefore influencers of arbitrage opportunities for cryptocurrency as a financial asset. This demonstrates the need for future research in the area of arbitrage opportunities for cryptocurrency as a financial asset.

Summary

The interpretation of the findings has helped to contextualize the results of this study to the vast sea of existing literature. This was done by comparing how the findings added to, aligned with or diverged from previous studies and provided insight into how the findings have helped to advance the current knowledge pertaining to arbitrage opportunities for cryptocurrency as a financial asset. The findings of this study helped to generalize the current understanding of cryptocurrency and gaps within the literature by expanding the knowledge beyond just Bitcoin and adding the Canadian cryptocurrency market data to the knowledge repository for arbitrage opportunities for cryptocurrency as a financial asset. Additionally, the findings of this study helped to resolve mixed results within the literature by demonstrating that arbitrage opportunities do exist for cryptocurrency, but this existence is highly affected by how arbitrage opportunities are defined. Other areas of mixed results that this study added its understanding to were based on the influencers of arbitrage opportunities–specifically volatility and illiquidity and how they fit into the context of the theoretical framework of this study. Next, this section will reflect upon any weaknesses within the study that may have affected the results.

Limitations of the Study

The purpose of this section is to critically reflect on the process of the study. This section will review the weaknesses of the study that were uncovered as I moved from the planning stage to execution stage, and comment on the effect these limitations may have had on the generalizability or reliability of the results of the study. Within Chapter 1, it was noted that I did not see any major limitations to the study. Upon reflection after completing the study, I can now see that this was an overconfident and erroneous statement. The remainder of this section will review the limitations that were found within the execution of this study and within its results. These limitations were ease of data collection, scope of data collected, raw dataset was transformed, rapid change of the cryptocurrency markets, price setting factors, dominance of Bitcoin, and contrast between centralized and decentralized cryptocurrency exchanges.

Ease of Data Collection

The expectation within the design of this study was that the data required was free and readily available. While this statement is true, I extrapolated it to the assumption that obtaining historical data would be either easily accessible from the internet or forthrightly offered by the exchanges upon request. In actuality, the historical data was not readily available on some of the exchanges' websites. To compensate for this, a system was created to collect the data daily from the exchanges' websites.

Upon review of the exchanges' websites and the information available, it was decided that an automatic tool would be created to collect data directly from the website. This is referred to as scraping data or pulling data and was referred to as a 'pull' in this study. An automatic tool was created in Microsoft Excel. A manual tool was also used as support to the automatic tool in case of a system failure. While the information collected from the new plan offered the same dataset as the originally expected dataset, it still added complexity to the data collection process that was originally not anticipated, and substantially reduced the repeatability to replicate the exact same dataset.

Scope of Data Collected

An additional challenge during the data collection process was that cryptocurrency exchanges run continuously, 24 hours a day, 7 days a week, including statutory holidays. This continuous flow is unlike traditional financial markets, which typically run from 9:30 AM to 4:30 PM, Monday to Friday and close for weekends and statutory holidays. Further to this challenge, none of the targeted exchanges kept detailed archival information on the bid or ask prices. This caused a challenge with designating the end of day data and recording the bid and ask prices.

The original plan was to manually collect all the archival data direct from the exchanges' websites or request the data if information was missing on the website. To compensate for the lack of data consistency from either the exchanges' website, the

Microsoft Excel tool was set to automatically pull the required data from the exchanges' websites at the same time every day at 11:59.59 PM, and weekends and statutory holidays were removed from the dataset. The use of a set time at the end of the day to collect daily data for cryptocurrency follows the structure successfully used by Bianchi et al. (2022) and there study for cryptocurrency. Once again, while the information collected from the new plan offered the same dataset as the originally expected dataset, it still added complexity to the data collection process that was originally not anticipated.

Overall, the need to collect the data daily, arbitrarily select a time to pull the data, and eliminate data for times when other markets were closed changed the data collection from its original plan. While these noted changes to the planned data collection process and the scope of the data collected did not cause serious restrictions to the data collection, they were still noted as limitations. The original expectation was that the data was easily attainable to everyone at any time. Under the new process, while the information is still easily attainable to everyone, once the moment has passed, the information becomes harder to obtain. This means that if one were to attempt to perfectly replicate the data collected from October 15, 2023 to January 14, 2024, it may not be possible to do so, thus reducing the repeatability of the findings for the study. In addition, every time the original data set is manipulated, such as with set pull times and removal of weekends and statutory holidays, the reliability of the data collection can become compromised. Based on these two concerns, ease of data collected and scope of data collected are both seen as limitations of the study.

Raw Dataset was Transformed

As noted in Chapter 4, the independent variables were transformed from continuous measurements in the raw data collected to a dichotomous (volatility datapoint) and categorial (liquidity datapoint) measurements. The data collected was transformed to help the data adhere to generally accepted finance principles and the scope of the study. To ensure that the binary logistic regression model was the appropriate statistical test for the analysis of the data collected, its assumptions had to be reviewed. It was important to confirm adherence to the assumptions of a statistical test to ensure the validity, reliability, and generalizability of the findings.

The assumptions for data used in a binary logistic regression statistical test were checked for both the raw and transformed datasets of this study. All assumptions were confirmed for both datasets, except the assumption of linearity of the logit. The linear relationship between the independent variables can only be tested for data points that are continuous. While the independent variables within the raw dataset are continuous, the independent variables within the transformed dataset are not continuous. Due to this, only the raw dataset was checked for linearity of the logit. The raw dataset was confirmed to have adhered to the linearity of the logit assumption. While it was determined that testing only the raw data set for linearity of the logit was sufficient, this distinction needs to be made clear as a limitation of the study.

Rapid Change of Cryptocurrency Markets

Another limitation of the data collection process was that the cryptocurrency environment is changing too rapidly. I began this study at the start of 2022. Since then, several major changes have occurred within the cryptocurrency marketplace that have affected the Canadian cryptocurrency market as well as the world's cryptocurrency markets. In no particular order, some of the major occurrences have been: the collapse of FTX, one of the world's largest cryptocurrency exchanges; the collapse of TerraUSD, one of the world's largest cryptocurrency; El Salvador adopting Bitcoin as an official currency; Binance—the world's largest cryptocurrency exchange—stoppage of doing business in Canada over regulation concerns; the acquisition of one of the cryptocurrency exchanges in the study by another of this study's cryptocurrency exchange and its subsequent delisting halfway through the data collection, resulting in the need to amalgamate the two datasets; and the delisting of 286 cryptocurrencies worldwide. It is naïve to think that these major changes did not have a ripple effect on the data collected or its generalization to future studies. This systemic risk within the data collected can call into question the repeatability and generalizability of my findings.

Other Price-Setting Factors

The findings of the study denoted a weak influence for volatility and illiquidity on arbitrage opportunities for cryptocurrency as a financial asset. A study by Peng et al. (2023) noted that there has to be several main influencers for price setting of cryptocurrency by exchange, and therefore influencers of arbitrage opportunities for cryptocurrency as a financial asset. The recent literature has found these other main influences to be technology (Chico-Frias, 2021; Chowdhury et al., 2022; Karaömer, 2022), economics (Huang et al., 2022; Karaömer, 2022; T. V. Nguyen et al., 2022; Wang et al., 2023), investors' attitude (Gurrib & Kamalov, 2022; Nepp & Karpeko, 2024;

Rubbaniy et al., 2021; Sapkota, 2022), and social media (Aslanidis et al., 2022; Bakas et al., 2022; Chuffart, 2022). While the findings of this study indicate that volatility and illiquidity have a meager influence on arbitrage opportunities for cryptocurrency as a financial asset in Canada, the noted studies suggest there are more factors the need to be considered to fully understand this topic of interest. Not accounting for the other factors is a limitation of this study. These other factors could be considered as recommendations for future research.

Dominance of Bitcoin

A limitation of the study is in direct contrast to a decision that was made to fill a gap in the literature. One of the noted gaps in the literature is that the vast majority of studies completed for not only arbitrage opportunities for cryptocurrency as a financial asset but also for studies of cryptocurrency in general, are solely focused on Bitcoin. The concern was that the attempt to add to the knowledge of cryptocurrency by studying more than just Bitcoin may have skewed the data.

While Bitcoin is known as the first decentralized currency, it is also ranked as the top cryptocurrency in terms of trade volume, price, and market capitalization (Leung & Nguyen, 2019), accounting for 41.4% of the world market share (de Best, 2022). Bitcoin's dominance is the same in Canada, with the other three cryptocurrencies—Ethereum, Cardano, and Dogecoin—in totality accounting for approximately half the market capitalization and trades as Bitcoin. This demonstrates Bitcoin's overwhelming influence on the cryptocurrency markets. But, within the setup of data collected and its input into the binary logistic regression model, Bitcoin's data was given equal weighting to the other cryptocurrencies. Meaning that Bitcoin was given only a ¼ weighting within the model, the same as the other three cryptocurrencies. This decision puts into question the generalizability and variability of the results, as it is not a proper representation of the population being studied.

Contrast Between Centralized and Decentralized Cryptocurrency Exchanges

Cryptocurrency exchanges are platforms that enable investors to perform their buy and sell transactions. There are two main types of cryptocurrency exchanges: centralized cryptocurrency exchanges (CEX) and decentralized cryptocurrency exchanges (DEX). CEXs are operated and controlled by a consolidating entity that facilitates all of the trades. DEXs are operated without a consolidating entity and relies solely on blockchain technology and smart contracts to facilitate peer-to-peer trades. While CEXs offer greater ease of use and higher liquidity, it comes at the cost of higher fees and weaker security and control over funds in comparison to DEXs. During the exchange selection process only criteria for regulatory and transactional costs were considered, and the concept that there are two different types of cryptocurrency exchanges was not considered. To ensure that the exchanges selected had the same regulatory and transactional costs, three selection criteria were made: the exchange must support the four noted cryptocurrencies of the study; prices are quoted in Canadian dollars and paid out in Canadian dollars (to remove foreign exchange costs); and the exchange had to be approved by Canada's largest security committee—the Ontario Security Committee. Inadvertently, the final criteria limited the study to select only CEXs.

The cryptocurrency selection criteria were unwittingly biased toward the selection of CEXs. This oversight introduces a limitation to the study. Recent studies have noted different findings between CEXs and DEXs for arbitrage opportunities for cryptocurrency as a financial asset (Hansen et al., 2024; Hansson, 2022; Li & Liu, 2024; Morin & Moore, 2023). The different characteristics of the different types of exchange had been documented to influence the existence and influencers of arbitrage opportunities for cryptocurrency as a financial asset. The fact that this type of exchange was not accounted for in this study is a limitation to this study and offers insights into future research.

Summary

This section critically reflected on the processes of the study and highlighted any limitations that may have affected the generalizability or reliability of the results of the study. The reflection highlighted limitations concerning how the data was pulled and manipulated during the data collection process, the transformation of the raw data collected, the ever-changing cryptocurrency environment, other price setting factors, the dominance of Bitcoin within the Canadian cryptocurrency market not being properly accounted for, and the contrast between centralized and decentralized cryptocurrency exchange and the effect this may have on arbitrage opportunities. These limitations, while influencing the generalizability or reliability of the results ,are factored by the scope of the study. Therefore, these limitations should be reviewed in light of potential avenues for future research. The next section will review the recommendations for future research.

Recommendations

The purpose of this section is to demonstrate how this study can be used to facilitate the development and growth of the knowledge of arbitrage opportunities for cryptocurrency as a financial asset and cryptocurrency in general. To do this, key areas denoted as limitations to the study or key areas which the study offers the framework to build upon will be highlighted. This section will look at not only the results of the study but also the design of the study.

In comparison to more traditional financial assets, cryptocurrency is a relatively new financial asset. To this end, much of the literature within the literature review noted a recommendation for future research to simply continue to collect knowledge on cryptocurrency for different populations and the generalizability of current findings. This study reiterates this call for scholars continuing to study cryptocurrency to simply continue to collect data on a financial asset that is still in its infancy, in any aspect.

While this study did find arbitrage opportunities for cryptocurrency as a financial asset, its relationship to volatility and illiquidity was considered immaterial. This leads to the question if there are more influential components to how the cryptocurrency prices are set and, therefore, drivers of arbitrage opportunities. The testing of other factors would help to grow the overall knowledge for cryptocurrency as a financial asset. Therefore, another recommendation for future research would be to collect data on and vigorously investigate other price setting influencers for cryptocurrency, such as economics, and investors’ attitude.

As noted, arbitrage opportunities for cryptocurrency as a financial asset, its relationship to volatility and illiquidity was considered immaterial. Another recommendation for future research would be to look at other factors that may be influencing arbitrage opportunities for cryptocurrency as a financial asset. Further to this thought, while the binary logistic regression model was aligned to this study, a more rigorous statistical tool may be used to get greater insight into the relationship between arbitrage opportunities for cryptocurrency as a financial asset and volatility and illiquidity.

As noted in the limitations, the cryptocurrency environment is changing rapidly. Delfabbro et al. (2021) noted that growth in cryptocurrency is happening so quickly that any data cited as recently as 3 months ago can be considered outdated. The ever-changing environment of the cryptocurrency markets in itself is a call for the need for future research. A duplication of this study may offer different insights into the inner workings of cryptocurrency and how it is evolving over time.

Another limitation of this study was having a study that encompasses more than just Bitcoin, but does not factor for the dominance that Bitcoin has over the current cryptocurrency markets. A recommendation for future research is a study for arbitrage opportunities that collects data for different cryptocurrencies and factors in the effect of the dominance that Bitcoin has over the market. This may help us understand if Bitcoin on its own has become a mature financial asset, while gaining an understanding of the maturity progression of other cryptocurrencies and how this is affecting the cryptocurrency market as a whole.

Tolerances were used to help define what was considered an arbitrage opportunity, if a cryptocurrency was considered volatile, and if a cryptocurrency was considered liquid. While the justification of the selection of these tolerances was based on the current literature, based on a robustness check to the sensitivity of the results, it was found that a change in one of these tolerances may offer different results and offer greater insight into the workings of arbitrage opportunities for cryptocurrency as a financial asset and cryptocurrency in general. The potential for future research based on the tolerances of this study was demonstrated in the Limitations section; changing the tolerance set for what was considered an arbitrage opportunity for Bitcoin resulted in Bitcoin no longer being regarded as having arbitrage opportunities as a financial asset. Therefore, similar studies with different tolerance is a recommendation for future research.

This study found that arbitrage opportunities existed for cryptocurrency as a financial asset in Canada. With that said, no consideration was given to how long market forces took to correct the opportunity. Because closing prices were used, no factoring for correction timing was used. Such a factor was outside of the scope of this study. To gain a more complete understanding of this topic of interest, a recommendation of future research would be to look at how long arbitrage opportunities are available and if market forces would correct this opportunity, as the LOP would suggest.

A noted trend in the Literature Review was that the literature for arbitrage opportunities for cryptocurrency as a financial asset and studies on cryptocurrency in general are dominated by quantitative research. There is a gap in the literature as to gaining an understanding of the lived experiences of investors for arbitrage opportunities for cryptocurrencies as a financial asset and cryptocurrency in general. A recommendation for future research would be to conduct a qualitative study pertaining to this topic of interest.

Finally, recent studies have demonstrated that CEXs and DEXs are different and have different influences on how the platforms help to facilitate trades and how arbitrage opportunities form (Hansen et al., 2024; Li & Liu, 2024; Morin & Moore, 2023). These differences were not accounted for during the selection of exchanges for this study. Due to the criteria for selecting the exchanges, only CEXs were selected. A recommendation for future research would be to add DEXs to the data collection process for the Canadian market. In addition, another recommendation could be to directly compare CEXs to DEXs to see if arbitrage opportunities exist and what differences in influencers may be.

This section has reviewed this study to identify areas where future research is warranted to help advance the knowledge for this topic of interest. This section not only focused on areas that would support the generalization of the findings of this study, but also focused on recommendations that would address the limitations of this study and limitations to the body of research completed for arbitrage opportunities for cryptocurrency as a financial asset and cryptocurrency in general. It is important to continue research for this topic of interest due to the positive social impact that would be gained by having a better understanding of cryptocurrency as a financial asset. The next section will review the implications of this study.

Implications

The epic rise of cryptocurrencies has gained a lot of attention from the media and the general public. With the rapid growth of cryptocurrencies, both experienced and inexperienced investors are being attracted to invest (Delfabbro et al., 2021). The danger this presents is that average and inexperienced investors have neither the risk management nor the financial stability to lose a portion, or all, of their savings. Without a full understanding of cryptocurrency, average and inexperienced investors are being exposed to unanticipated dangers to their financial stability based on overexposure to risk, addiction or irrational behaviors, illicit activities, and theoretical context. An increased understanding of cryptocurrency as a financial asset needs to be created by professional investors and scholars to help protect average and inexperienced investors.

Overexposure to Risk

Due to cryptocurrency's high volatility, social media misrepresentations, and a lack of generally accepted financial principles to support trading rituals, average and inexperienced traders may be exposing themselves to unwanted or even unnecessary risk. Recent studies have found that cryptocurrency investments are mostly made for speculation purposes and may be unwittingly exposing the average and inexperienced financial investor to unwanted or unnecessary risk (Baur, Dimpfl, et al., 2018; Baur, Hong, et al., 2018; Corbet et al., 2018). This risk is compounded by the fact that non-professional investors in cryptocurrency erroneously regard their investment as having the same characteristics as more common, traditional financial assets (Kim et al., 2020). The combination of misguiding investment strategies and misleading trust in inadequate performance indicators places the average and inexperienced investors in danger of overexposing themselves to risk.

Gaining a better understanding of how cryptocurrency and cryptocurrency exchanges function will help professional investors and scholars to guide the average and inexperienced investors. This understanding will allow for strategies to be developed. These strategies could include preventative measures to discourage average and inexperienced investors from making unmanageable speculative investment decisions with cryptocurrency and educational tools to teach investors the difference between cryptocurrency and other traditional financial assets. These measures and solutions would be beneficial for prospective average and inexperienced investors. To do this, a complete understanding of cryptocurrency as a financial asset is required; this includes proving if arbitrage opportunities exist for cryptocurrency as a financial asset in the Canadian market.

Addiction and Irrational Behaviors

Some of the overexposure to risk may not have to do with inexperience, but the mental state of the investor. Recent studies have likened the behaviors of non-professional investors of cryptocurrencies to that of online gamblers (Delfabbro et al., 2021; Mills & Nower, 2019), risk-seekers (Pelster et al., 2019), and irrational investors (Almeida & Gonçalves, 2023; Ballis & Drakos, 2020; Kaiser & Stöckl, 2020; Tjondro et al., 2023). Almeida and Gonçalves (2023) and Delfabbro et al. (2021) noted the need for professionals and scholars to gain a better understanding of strategies to protect average and inexperienced cryptocurrency investors from self-harm, while still allowing them to benefit from investing in cryptocurrencies. Addiction and irrational behaviors are a very real problem for average and inexperienced investors of cryptocurrency as a financial asset. The knowledge needs to be created for cryptocurrency to allow the professional investors and scholars the understanding needed to help protect the average and inexperienced investor from themselves.

Gaining a better understanding of how cryptocurrency and cryptocurrency exchanges function will help professional investors and scholars to guide the average and inexperienced investors. This knowledge and other understandings would be beneficial for prospective average and inexperienced investors. This knowledge could be how to detect addictive and irrational investment behaviors and protocols or regulations on how individuals will be protected from such behaviors. To gain this knowledge, a complete understanding of cryptocurrency as a financial asset is required; this includes proving if arbitrage opportunities exist for cryptocurrency as a financial asset in the Canadian market.

Illicit Activities

Cybercriminality is a term used to summarize the illicit activities that are facilitated or financed via the dark web or criminal virtual networks. Speaking at a Senate financial committee, the Secretary of the Treasury for the United States, Janet Yellen, noted that cryptocurrency is mainly used for illicit financing (Lennon, 2021). The general assumption is that cryptocurrency is not just used to finance illicit activities, but facilitates it as well. However, recent studies have started to demonstrate how cryptocurrency exchanges' internal activities are exposing the investors to threats of illicit activities (Dudani et al., 2023; McLaughlin et al., 2023). Particular to arbitrage opportunities, a study by McLaughlin et al. (2023) found that arbitrage opportunities are the results of exchanges' internal activities known as *skimming*. Skimming is the process of an exchange taking the arbitrage as profit rather than allowing the investor to profit from the arbitrage. The economic impact of skimming destabilizes the legitimacy and security of both cryptocurrency and the market, and is theft of the investors' financial assets.

Gaining a better understanding of how cryptocurrency and cryptocurrency exchanges function will help professional investors and scholars to guide the average and inexperienced investors. Demonstrating not only that cryptocurrency can be used for illicit activities, but creating the link on how owning cryptocurrency exposes an investor to illicit activities will assist in helping to gain acceptance for the need for improved cryptocurrency forensics techniques and improved inter-agency coordination and regulations. Making the link between owning cryptocurrency and its exposure to illicit activities would be beneficial for protecting the average and inexperienced investor. To make this link, a complete understanding of cryptocurrency as a financial asset is required; this includes proving if arbitrage opportunities exist for cryptocurrency as a financial asset and, if so, what the influencers of the arbitrage opportunities may be.

Theoretical Context

The theoretical framework of this study is LOP. The origins of LOP are not fully known, but dates back to mid-1700s France. Miljkovic (1999) and Persson (2008) attribute the modern day understanding of LOP to Giovannini (1988), which defines LOP as a model that demonstrates that the value of an asset, such as currency, should be the same value regardless of the market, and the value should fluctuate in tangent between markets. When prices are normalized for localized costs, such as duties, fees, transportation, and transaction costs, LOP established that identical goods must be sold for identical prices regardless of the market.

LOP is a generally accepted financial principle and is a common theoretical framework to understand arbitrage opportunities. LOP is considered violated when there is a lack of price duality between markets, when this occurs, this is known as an arbitrage opportunity. Recent cryptocurrency studies that have used LOP as the theoretical framework have had successful results (Kabašinskas & Šutienė, 2021; Kristoufek, 2019; Makarov & Schoar, 2020; Pieters & Vivanco, 2017; Shynkevich, 2021; Witzel, 2005). Common influencers of if LOP is violated or not are volatility and liquidity. This section will now review the theoretical implications of the findings of this study as the volatility and liquidity as influencers of arbitrage opportunities for cryptocurrency as a financial asset.

The findings of this study were that while volatility and illiquidity were influencers of arbitrage opportunities, their influences were weak. The implications of these findings on the theoretical context of the study are that the economic theory around the concepts of why volatility and liquidity would be influencers of arbitrage opportunities were upheld. Furthermore, the findings upheld the economic theory that there are several influencers of arbitrage opportunities and it is not the result of one or two influencers. This supports the traditional view of economic theory within the study.

Summary

It is the responsibility of professional investors and scholars to create the knowledge necessary to protect average and inexperienced investors. Bruzgė and Šapkauskienė (2022b) noted that a more in-depth understanding of arbitrage opportunities would allow investors a better understanding of the interrelationships between cryptocurrency markets and how this can be employed to create safe and optimal financial portfolios. With a full understanding of cryptocurrency, professionals and scholars can direct average and inexperienced investors away from the dangers to their financial stability of overexposure to risk, addiction or irrational behaviors, illicit activities, and theoretical context. The increased understanding of cryptocurrency and cryptocurrency exchanges would have the positive social impact of helping to preserve average and inexperienced investors' savings for retirement and their children's education by reducing unnecessary or unwanted risk. The positive social change implications can enable professionals to gain greater insights into supporting and educating investors in high-risk cryptocurrencies who lack risk management knowledge or financial stability to lose a portion or all of their savings. This demonstrates the positive social change significance of this study.

Conclusions

This chapter serves as the culmination of my study. It brings together all of the components of my dissertation. The purpose of my study was to test the theory of LOP on cryptocurrency and cryptocurrency exchanges in Canada. To fulfill this purpose, a quantitative statistical research and analysis design was created. The completion of this study advanced the knowledge of cryptocurrency in several ways. First, the study addressed gaps in the literature based on collective trends: a lack of understanding for cryptocurrency beyond Bitcoin; a lack of understanding for the Canadian cryptocurrency market. Second, the study addressed gaps in the literature based on collective inconclusive findings: does arbitrage opportunities for cryptocurrency as a financial asset still exist; are volatility and liquidity influencers of arbitrage opportunities for cryptocurrency as a financial asset. Finally, the study answers the call by academics and practitioners alike for continued research of cryptocurrency due to its rapidly changing characteristics and environment.

The findings of this study were that arbitrage opportunities does exist for cryptocurrency as a financial asset in the Canadian market, and that volatility and illiquidity had a meager influencing effect of these opportunities. Based on this study and its findings, this chapter articulates the interpretation of the findings considering the current literature, highlights the limitations of the study, denoted the recommendations for future research, and comments upon the study’s implications for positive social impact. Based on these components, this chapter completes this study by demonstrating the contribution the study has made on the advancement of knowledge for cryptocurrency as a financial asset and cryptocurrency in general.

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Appendix A: Letter Request for Archived Data

June 12, 2023

[Recipient's Name]
[Recipient's Position]
[Name of Cryptocurrency Exchange]
[Address]
[City, State, ZIP Code]

Subject: Request for Archival Data

Dear [Recipient's Name],

I hope this letter finds you well. My name is Francis Taylor and I am a PhD Candidate at Walden University, Minnesota (Student Identification Number: A########). The topic of interest for my dissertation is to demonstrate the existence of arbitrage opportunities between cryptocurrency exchanges in the Canadian market, and if there are arbitrage opportunities are they influenced by the cryptocurrency's volatility and liquidity.

As a leading cryptocurrency exchange in Canada, I have selected [Name of Cryptocurrency Exchange] as one of six Canadian exchanges to be a part of my study. I am writing to request archival data. The requested data is very limited, and is readily available on your website as current data, but not historical data.

I kindly request access to the following archival data pertaining to your cryptocurrency exchange:

1. Primary data (data required to complete the study): daily closing price, bid price, and ask price by cryptocurrency.
2. Secondary data: daily trade volumes and values by cryptocurrency.
3. From the time period of December 31, 2018 to December 31, 2022.

4. For cryptocurrencies Bitcoin (BTC), Ethereum (ETH), Cardano (ADA), and Dogecoin (DOGE).

Of course, if you have this data within a much larger dataset, I would be happy to use that dataset and extract the information that I need. If it is feasible, I would greatly appreciate receiving the archival data in electronic format (e.g., CSV or Excel) for ease of analysis. Additionally, any documentation or format guidelines associated with the data would be helpful for ensuring accurate interpretation.

I assure you that any data provided will be used solely for academic research purposes and will be treated with utmost confidentiality. The findings derived from this research will be published once my dissertation is approved and defended, contributing to the broader knowledge base in the field of cryptocurrencies.

I know my request of providing archival data involves extra effort and resources. I am sorry to ask you to do more work, and I am grateful for your time.

Thank you for considering my request. I am eager to delve into this research and contribute to the understanding of the cryptocurrency market. Should you have any questions or require further information, please do not hesitate to contact me via email (aaaaaaa.aaaaaa@waldenu.edu) or phone (###-###-####).

I look forward to your positive response and the possibility of accessing the requested archival data. Thank-you for your attention and support.

Sincerely,

Francis Taylor

Appendix B: SPSS Report for All Cryptocurrencies

Logistic Regression

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	2976	100.0
	Missing Cases	0	.0
	Total	2976	100.0
Unselected Cases		0	.0
Total		2976	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
No Arbitrage	0
Arbitrage	1

Categorical Variables Codings

		Frequency	Parameter coding (1)	Parameter coding (2)
Liquidity	Illiquid	2319	1.000	.000
	Average	453	.000	1.000
	Liquid	204	.000	.000
Volatile	Involatile	654	1.000	
	Volatile	2322	.000	

Block 0: Beginning Block

Classification Table[a,b]

	Observed		Predicted: Arbitrage: No Arbitrage	Predicted: Arbitrage: Arbitrage	Predicted: Percentage Correct
Step 0	Arbitrage	No Arbitrage	1499	0	100.0
		Arbitrage	1477	0	.0

	Overall Percentage			50.4

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.015	.037	.163	1	.687	.985

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Volatile(1)	8.754	1	.003
		Liquidity	9.504	2	.009
		Liquidity(1)	4.528	1	.033
		Liquidity(2)	9.266	1	.002
	Overall Statistics		17.502	3	.001

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	17.561	3	.001
	Block	17.561	3	.001
	Model	17.561	3	.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	4107.889[a]	.006	.008

a. Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	1.014	3	.798

Contingency Table for Hosmer and Lemeshow Test

		Arbitrage = No Arbitrage		Arbitrage = Arbitrage		
		Observed	Expected	Observed	Expected	Total
Step 1	1	218	214.426	151	154.574	369
	2	40	43.574	44	40.426	84
	3	919	920.158	896	894.842	1815
	4	66	68.416	72	69.584	138
	5	256	252.426	314	317.574	570

Classification Table[a]

			Predicted		
			Arbitrage		Percentage Correct
Observed			No Arbitrage	Arbitrage	
Step 1	Arbitrage	No Arbitrage	1177	322	78.5
		Arbitrage	1091	386	26.1
	Overall Percentage				52.5

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Volatile(1)	.252	.089	8.000	1	.005	1.287	1.081	1.533
	Liquidity			8.731	2	.013			
	Liquidity(1)	-.045	.147	.093	1	.760	.956	.717	1.275
	Liquidity(2)	-.344	.170	4.102	1	.043	.709	.508	.989
	Constant	.017	.143	.014	1	.906	1.017		

a. Variable(s) entered on step 1: Volatile, Liquidity.

Appendix C: SPSS Report for Bitcoin

Logistic Regression

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	744	100.0
	Missing Cases	0	.0
	Total	744	100.0
Unselected Cases		0	.0
Total		744	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
No Arbitrage	0
Arbitrage	1

Categorical Variables Codings

			Parameter coding	
		Frequency	(1)	(2)
Liquidity	Illiquid	570	1.000	.000
	Average	57	.000	1.000
	Liquid	117	.000	.000
Volatile	Involatile	189	1.000	
	Volatile	555	.000	

Block 0: Beginning Block

Classification Table[a,b]

Observed			Predicted: Arbitrage — No Arbitrage	Predicted: Arbitrage — Arbitrage	Predicted: Percentage Correct
Step 0	Arbitrage	No Arbitrage	0	372	.0
		Arbitrage	0	372	100.0
	Overall Percentage				50.0

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)
Step 0	Constant	.000	.073	.000	1	1.000	1.000

Variables not in the Equation

			Score	*df*	Sig.
Step 0	Variables	Volatile(1)	1.199	1	.274
		Liquidity	.123	2	.941
		Liquidity(1)	.120	1	.729
		Liquidity(2)	.019	1	.890
	Overall Statistics		1.285	3	.733

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	*df*	Sig.
Step 1	Step	1.286	3	.733
	Block	1.286	3	.733
	Model	1.286	3	.733

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1030.117[a]	.002	.002

a. Estimation terminated at iteration number 2 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	*df*	Sig.
1	.539	3	.910

Contingency Table for Hosmer and Lemeshow Test

		Arbitrage = No Arbitrage		Arbitrage = Arbitrage		
		Observed	Expected	Observed	Expected	Total
Step 1	1	221	222.273	211	209.727	432
	2	23	21.134	19	20.866	42
	3	40	40.593	41	40.407	81
	4	66	64.727	72	73.273	138
	5	22	23.273	29	27.727	51

Classification Table[a]

			Predicted		
			Arbitrage		Percentage Correct
Observed			No Arbitrage	Arbitrage	
Step 1	Arbitrage	No Arbitrage	284	88	76.3
		Arbitrage	271	101	27.2
	Overall Percentage				51.7

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Volatile(1)	.182	.169	1.161	1	.281	1.200	.861	1.671
	Liquidity			.086	2	.958			
	Liquidity(1)	-.053	.204	.069	1	.793	.948	.636	1.413
	Liquidity(2)	-.008	.323	.001	1	.980	.992	.526	1.870
	Constant	-.005	.192	.001	1	.981	.995		

a. Variable(s) entered on step 1: Volatile, Liquidity.

Appendix D: SPSS Report for Ethereum

Logistic Regression

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	744	100.0
	Missing Cases	0	.0
	Total	744	100.0
Unselected Cases		0	.0
Total		744	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
No Arbitrage	0
Arbitrage	1

Categorical Variables Codings

		Frequency	Parameter coding	
			(1)	(2)
Liquidity	Illiquid	570	1.000	.000
	Average	135	.000	1.000
	Liquid	39	.000	.000
Volatile	Involatile	165	1.000	
	Volatile	579	.000	

Classification Table[a,b]

	Observed		Predicted		
			Arbitrage		Percentage Correct
			No Arbitrage	Arbitrage	
Step 0	Arbitrage	No Arbitrage	373	0	100.0
		Arbitrage	371	0	.0
	Overall Percentage				50.1

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)
Step 0	Constant	-.005	.073	.005	1	.942	.995

Variables not in the Equation

			Score	*df*	Sig.
Step 0	Variables	Volatile(1)	.016	1	.899
		Liquidity	9.746	2	.008
		Liquidity(1)	.426	1	.514
		Liquidity(2)	4.637	1	.031
	Overall Statistics		9.752	3	.021

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	*df*	Sig.
Step 1	Step	9.922	3	.019
	Block	9.922	3	.019
	Model	9.922	3	.019

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1021.475[a]	.013	.018

a. Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	*df*	Sig.
1	.447	3	.930

Contingency Table for Hosmer and Lemeshow Test

		Arbitrage = No Arbitrage		Arbitrage = Arbitrage		
		Observed	Expected	Observed	Expected	Total
Step 1	1	13	14.112	11	9.888	24
	2	66	64.888	45	46.112	111
	3	62	64.171	67	64.829	129
	4	220	217.829	221	223.171	441
	5	12	12.000	27	27.000	39

Classification Table[a]

			Predicted		
			Arbitrage		Percentage Correct
Observed			No Arbitrage	Arbitrage	
Step 1	Arbitrage	No Arbitrage	79	294	21.2
		Arbitrage	56	315	84.9
	Overall Percentage				53.0

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Volatile(1)	-.014	.178	.006	1	.937	.986	.695	1.398
	Liquidity			9.386	2	.009			
	Liquidity(1)	-.791	.357	4.904	1	.027	.453	.225	.913
	Liquidity(2)	-1.157	.389	8.838	1	.003	.314	.147	.674
	Constant	.815	.351	5.386	1	.020	2.260		

a. Variable(s) entered on step 1: Volatile, Liquidity.

Appendix E: SPSS Report for Cardano

Logistic Regression

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	744	100.0
	Missing Cases	0	.0
	Total	744	100.0
Unselected Cases		0	.0
Total		744	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
No Arbitrage	0
Arbitrage	1

Categorical Variables Codings

			Parameter coding	
		Frequency	(1)	(2)
Liquidity	Illiquid	603	1.000	.000
	Average	123	.000	1.000
	Liquid	18	.000	.000
Volatile	Involatile	150	1.000	
	Volatile	594	.000	

Block 0: Beginning Block

Classification Table[a,b]

Observed			Predicted: Arbitrage No Arbitrage	Predicted: Arbitrage Arbitrage	Predicted: Percentage Correct
Step 0	Arbitrage	No Arbitrage	373	0	100.0
		Arbitrage	371	0	.0
	Overall Percentage				50.1

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)
Step 0	Constant	-.005	.073	.005	1	.942	.995

Variables not in the Equation

			Score	*df*	Sig.
Step 0	Variables	Volatile(1)	5.821	1	.016
		Liquidity	11.553	2	.003
		Liquidity(1)	7.168	1	.007
		Liquidity(2)	2.707	1	.100
	Overall Statistics		17.843	3	.000

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	*df*	Sig.
Step 1	Step	18.743	3	.000
	Block	18.743	3	.000
	Model	18.743	3	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1012.654[a]	.025	.033

a. Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	*df*	Sig.
1	.301	2	.860

Contingency Table for Hosmer and Lemeshow Test

		Arbitrage = No Arbitrage		Arbitrage = Arbitrage		
		Observed	Expected	Observed	Expected	Total
Step 1	1	76	75.092	44	44.908	120
	2	239	240.634	241	239.366	480
	3	9	9.908	12	11.092	21
	4	49	47.366	74	75.634	123

Classification Table[a]

	Observed		Predicted		
			Arbitrage		Percentage Correct
			No Arbitrage	Arbitrage	
Step 1	Arbitrage	No Arbitrage	315	58	84.5
		Arbitrage	285	86	23.2
	Overall Percentage				53.9

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Volatile(1)	.473	.188	6.351	1	.012	1.605	1.111	2.320
	Liquidity			10.359	2	.006			
	Liquidity(1)	1.779	.641	7.692	1	.006	5.922	1.685	20.814
	Liquidity(2)	1.424	.662	4.624	1	.032	4.152	1.134	15.198
	Constant	-1.784	.639	7.785	1	.005	.168		

a. Variable(s) entered on step 1: Volatile, Liquidity.

Appendix F: SPSS Report for Dogecoin

Logistic Regression

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	744	100.0
	Missing Cases	0	.0
	Total	744	100.0
Unselected Cases		0	.0
Total		744	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
No Arbitrage	0
Arbitrage	1

Categorical Variables Codings

			Parameter coding	
		Frequency	(1)	(2)
Liquidity	Illiquid	576	1.000	.000
	Average	138	.000	1.000
	Liquid	30	.000	.000
Volatile	Involatile	150	1.000	
	Volatile	594	.000	

Block 0: Beginning Block

Classification Table[a,b]

Observed			Predicted: Arbitrage - No Arbitrage	Predicted: Arbitrage - Arbitrage	Predicted: Percentage Correct
Step 0	Arbitrage	No Arbitrage	381	0	100.0
		Arbitrage	363	0	.0
	Overall Percentage				51.2

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)
Step 0	Constant	-.048	.073	.435	1	.509	.953

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Volatile(1)	5.488	1	.019
		Liquidity	4.281	2	.118
		Liquidity(1)	1.954	1	.162
		Liquidity(2)	3.800	1	.051
	Overall Statistics		9.219	3	.027

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	*df*	Sig.
Step 1	Step	9.274	3	.026
	Block	9.274	3	.026
	Model	9.274	3	.026

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1021.693[a]	.012	.017

a. Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	*df*	Sig.
1	.613	2	.736

Contingency Table for Hosmer and Lemeshow Test

		Arbitrage = No Arbitrage		Arbitrage = Arbitrage		
		Observed	Expected	Observed	Expected	Total
Step 1	1	68	68.926	46	45.074	114
	2	239	239.552	223	222.448	462
	3	23	20.596	19	21.404	42
	4	51	51.926	75	74.074	126

Classification Table[a]

			Predicted		
			Arbitrage		Percentage Correct
	Observed		No Arbitrage	Arbitrage	
Step 1	Arbitrage	No Arbitrage	320	61	84.0
		Arbitrage	280	83	22.9
	Overall Percentage				54.2

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	*df*	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Volatile(1)	.412	.186	4.929	1	.026	1.510	1.050	2.174
	Liquidity			3.736	2	.154			
	Liquidity(1)	-.180	.381	.224	1	.636	.835	.396	1.763
	Liquidity(2)	-.531	.411	1.672	1	.196	.588	.263	1.315
	Constant	.106	.377	.079	1	.778	1.112		

a. Variable(s) entered on step 1: Volatile, Liquidity.