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Two Essays on Industrial Hemp Firms in the United States

Abraham Olakunle Ajibade
University of Kentucky, abrahamjibbs1703@gmail.com
Author ORCID Identifier:
https://orcid.org/0009-0002-2534-0688
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Abraham Olakunle Ajibade, Student

Dr. Tyler B. Mark, Major Professor

Dr. Tyler B. Mark, Director of Graduate Studies

TWO ESSAYS ON INDUSTRIAL HEMP FIRMS IN THE UNITED STATES

THESIS

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of Master of Science in the
College of Agriculture, Food and Environment
at the University of Kentucky

By

Abraham Olakunle Ajibade

Lexington, Kentucky

Director: Dr. Tyler B. Mark, Associate Professor of Agricultural Economics

Lexington, Kentucky

2023

https://orcid.org/0009-0002-2534-0688

ABSTRACT OF THESIS

TWO ESSAYS ON INDUSTRIAL HEMP FIRMS IN THE UNITED STATES

After a long absence from American fields, industrial hemp was reintroduced to growing fields starting with state pilot programs in 2014 and received the green light for commercial cultivation in the US through the 2018 Farm Bill. Being an industry in its resurgence, investment is crucial for growth and the stock market and over-the-counter markets help US hemp firms get these much-needed funds for growth and expansion. This thesis consists of two essays on US hemp firms.

The first essay uses descriptive statistics, correlation analysis, and the Kruskal-Wallis Test to investigate how US hemp stocks compare to mid-cap and large-cap stocks, over four years. The results show that US hemp stock returns are less volatile when compared to mid-cap and large-cap stocks. The results also a significant difference between the distributions of the price movement of US hemp stocks and mid-cap and large-cap stocks in this study, indicating that US hemp stocks and other mid-cap and large-cap stocks are not chosen from the same populations of stocks and would likely yield different returns in investment portfolios.

The second essay uses the Nonlinear Autoregressive Distributed Lag Model to estimate the short and long-term effects of four selected macroeconomic factors on the stock prices of US hemp firms, over a four-year period. The results show that asymmetrical relationships exist in both the short run and long run between US hemp stock prices and the selected macroeconomic indicators. They also suggest that positive movements in these macroeconomic indicators have larger impacts on the stock prices of US hemp firms than negative movements, suggesting that the stock prices of US hemp firms respond more to positive movements in macroeconomic indicators than they do to negative movements in macroeconomic indicators.

Using these results, stakeholders in the US hemp industry can strive to adjust their budgets and better allocate their resources to adapt to the prevailing conditions in the stock market and the US economy at large.

KEYWORDS: Industrial Hemp, Nonlinear Autoregressive Distributed Lag Model, Unit Root, Asymmetry, Macroeconomic Indicators, Panel Regression

Abraham Olakunle Ajibade
(Name of Student)

07/26/2023
Date

TWO ESSAYS ON INDUSTRIAL HEMP FIRMS IN THE UNITED STATES

By
Abraham Olakunle Ajibade

Dr. Tyler B. Mark
Director of Thesis

Dr. Tyler B. Mark
Director of Graduate Studies

[07/26/2023]
Date

DEDICATION

To my Lord and Savior, Jesus Christ, and my family, who have always supported me.

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CHAPTER 1. INTRODUCTION

At a 21% Compound Annual Growth Rate, the global hemp industry has been forecasted to reach $16.7 billion in value by 2030 (Research and Markets, 2022). This number may very well exceed the industry's potential growth but given the rising demand for products derived from hemp, the projected numbers for the global hemp industry point to a rapid expansion of the industry. In the United States, industrial hemp was reintroduced as part of state pilot programs established through the Agricultural Act of 2014 (i.e., the 2014 Farm Bill) and it was given the all-clear for commercial cultivation in the US after the Agriculture Improvement Act of 2018 (i.e., the 2018 Farm Bill) was approved (Mark, *et al*., 2020). This was after a production moratorium of over five decades. As an increasing number of US states legalize hemp production, there has been increased investor interest in the sector over the past few years.

Investors are conflicted about the hemp industry because of the regulatory uncertainty but market opportunities and potential financial opportunities in the industry. The increasing demand for hemp and hemp-derived products, especially oil extracts such as CBD has drawn investors to the hemp industry (Mark, *et al*., 2020). This optimism has also attracted new producers and suppliers to the industry prior to 2020 but the industry has struggled since.

Investment in the resurgent hemp industry is essential for its expansion, and the stock market and over-the-counter markets may support the US hemp industry by serving as avenues to secure these much-needed funds. This thesis puts forth two essays that analyze US industrial hemp stocks from two perspectives. The first perspective compares US industrial hemp stocks to other stocks while the second perspective looks at the

macroeconomic determinants of US industrial hemp stocks. Both perspectives on US industrial hemp stocks would help investors, managers, and policymakers make informed decisions on investing or participating in the US hemp industry.

The firms employed in this study are classified as industrial hemp firms due to their involvement with non-toxic hemp-derived products such as cannabidiol. Some are involved with marijuana (either medicinal, recreational, or both) but participate in the hemp industry as manufacturers, processors, retailers, or vertically integrated firms. Many hemp firms in the fiber and seeds sector of the industry are privately owned, making this study of importance to investors who have interests in publicly traded firms that are involved in the extracts sector of the hemp industry. Firms in the extracts sector of the industrial hemp industry operate dispensaries and sell cannabidiol products at retail or wholesale. Most firms in this study participate in the sale of cannabidiol along with cannabis ventures while a few exclusively participate in the hemp industry through the sale of cannabidiol.

In the first essay, we investigate how US hemp stocks compare to mid-cap and large-cap stocks in the US economy using a mix of descriptive statistics, correlation analysis, and the Kruskal-Wallis Test. The results show that US hemp stocks come with a high degree of price volatility but due to their low level of risk, they could be used to hedge against sliding losses in periods of market declines since their returns are not as responsive when compared to the overall stock market. In terms of price movements, US hemp stocks show a weak correlation with mid-cap and large-cap stocks, suggesting a low level of association. In addition, US hemp stocks are very different from mid-cap and large-cap stocks since the results suggest that US hemp stocks are not drawn from the same distribution as mid-cap and large-cap stocks. This disparity in distribution suggests that

hemp stocks could respond differently to macroeconomic factors when compared to mid-cap and large-cap stocks (Durodola and Chotee, 2019).

The second essay investigates the macroeconomic determinants of the stock prices of 32 industrial hemp firms in the US in the short run and long run using the nonlinear autoregressive distributed lag model over a four-year period. Based on the prior studies carried out by pioneer researchers like Fama (1981) and Chen, *et al*., (1986), as well as a plethora of other researchers, four major macroeconomic indicators - Interest Rates, Industrial Production, S&P 500 Index, and Global Oil Prices are employed in the second essay. The results suggest the presence of asymmetric relationships, both in the short run and long run between US industrial hemp stock prices and the selected macroeconomic indicators. The results also suggest that positive fluctuations in these macroeconomic indicators have a larger impact on the stock prices of US industrial hemp firms than negative fluctuations, suggesting that the stock prices of US industrial hemp firms respond more to positive movements in macroeconomic indicators than they do to negative movements in macroeconomic indicators.

The findings shed light on how US industrial hemp stocks compare to mid-cap and large-cap stocks, giving potential investors tools for including or excluding industrial hemp and non-industrial hemp stocks in their investment portfolios, based on their trends and returns. The findings also bring to light a better understanding of how macroeconomic indicators influence the stock prices of publicly traded industrial hemp firms. Using these findings, stakeholders in the hemp industry get valuable knowledge in making investment decisions, asset allocation, resource hedging, and policy design.

CHAPTER 2. HOW DO INDUSTRIAL HEMP STOCKS IN THE US COMPARE TO OTHER STOCKS?

2.1. Abstract

After a fifty-year hiatus from growing fields, industrial hemp was reintroduced into the United States agricultural sector through the 2014 Farm Bill, and commercial production was legalized in the 2018 Farm Bill. There is mixed enthusiasm for investment in the hemp industry given the demand for hemp and hemp-derived products. There is optimism about the potential growth of the industry, despite its speculative nature (some researchers have gone on to estimate that the global hemp industry would reach $16.7 billion in value by 2030). In this study, the behavior of US hemp stocks is compared to mid-cap and large-cap stocks. The study results suggest that US hemp stocks have a high price volatility but could be used to hedge against sliding losses in periods of market declines, due to their low beta coefficients, since their returns are not as responsive when compared to the overall stock market. Also, the results indicate a weak to moderate association between US hemp stocks and overall stock market indexes, while suggesting that US hemp stocks are not drawn from the same distribution as mid-cap and large-cap stocks. The results suggest that US hemp stocks, given their marked distinction from other stock categories, possess great potential for growth and lower risk and should be considered by investors when they look to diversify investments, hedge against losses during market declines, or just looking to improve the return prospects for their overall financial portfolio.

2.2. Introduction

Industrial hemp (called “hemp” in this study) and marijuana are frequently confused by users and non-users today (Malone, 2021). However, they have very distinct

differences, even though both belong to the same plant since hemp and marijuana are both taxonomically identified as *Cannabis Sativa* L. Hemp, according to Section 297A of the Agricultural Marketing Act of 1946 (AMA, 7 USC. 1621 et seq.), refers to any part of the cannabis plant, with the federally defined delta-9 tetrahydrocannabinol concentration of not more than 0.3 percent on a dry weight basis. (Agriculture Improvement Act of 2018, 2018; Mark, *et al*., 2020).

On the other hand, marijuana does not follow this basic definition as THC levels in marijuana reportedly average about 10%, with a high of 30%, and is deemed illegal and considered a Schedule I Substance under US federal laws. Deviating from federal laws, some US states passed legislation to allow marijuana to be used in some form or under some circumstances – medicinal, recreational, or industrial. In these states, the cultivation and distribution of marijuana is allowed under state law and is regulated by state authorities (Lehrecke, 2019; Johnson, 2019; Sacco, 2022).

The hemp industry has an interesting history in the US. From being a stable industry thriving in states like Kentucky, Illinois, and Colorado, participation in the industry was outlawed by the 1970 Controlled Substances Act. This legislation was aimed at outlawing marijuana in the US, but the hemp industry paid the ultimate price. Since the industry went under in the 1970s, the US has had to depend on imports to sustain its need for hemp products.

Hemp and hemp products are imported to the US more than any other country in the world, with most of the imports coming from Canada, China, and the European Union (Moran, 2014; Johnson, 2019). These hemp imports have helped to meet the domestic hemp demand in the US over the years. However, since the legalization of hemp production

in the US, some hemp industry experts have expressed concern about the competition these already established hemp-producing countries would bring to local hemp production in the US (Dhoubhadel, 2021).

After an absence of almost five decades from growing fields, hemp was reintroduced into the United States agricultural sector with the passing of the 2014 Farm Bill. This bill allowed for several pilot programs to grow the crop and carry out research on the crop via state departments of agriculture. Four states (Kentucky, Colorado, Oregon, and Vermont) launched pilot programs in 2014 and more states launched hemp pilot programs between 2015 and 2018 except for Idaho, Mississippi and South Dakota. Based on the 2014 Farm Bill, the USDA published the final rule that governs domestic hemp production in the United States (USDA AMS, 2021). The passing of the 2018 Farm Bill legalized commercial hemp production beyond these state pilot programs and states could then develop permanent hemp growing programs (Mark, *et al*., 2020).

As a growing number of states continue to legalize hemp production and coupled with the rising demand for hemp and hemp-based products in the US, the interest of investors in the industry has gained significant momentum (Dhoubhadel, 2021). With the passing of the 2018 Farm Bill, the industry attracted new producers and suppliers, and now, investors are optimistic and enthusiastic about the hemp industry. The growing enthusiasm for the industry is supported by several strong and somewhat uncertain projections about the industry. Some researchers forecast that the value of the global hemp industry would reach $16.7 billion by 2030, with a CAGR of about 21% (Research and Markets, 2022). Despite the uncertain projections of the potential growth of the industry, an obvious fact remains - access to capital is vital for the expansion and growth of firms involved in the

hemp business. To raise capital, the stock market is an attractive avenue as these hemp firms can expand their business and at the same time, spread the risk of owning a stake in the hemp business among stakeholders who buy their shares (Ake, 2010; Singh, 2016).

Despite the potential of the hemp industry, there is some uncertainty posed by state laws and federal legislation on marijuana (Kolodinsky & Lacasse, 2021). These laws and legislation bring some degree of concern to stakeholders in the hemp industry (Dhoubhadel, 2021). As more states in the US pass legislation to legalize the use of marijuana in medicinal or recreational form, there is growing concern among hemp industry stakeholders, as they predict that the legalization of marijuana brings unclear consequences for the reemerging hemp industry in the US. Beyond these policy uncertainties, the hemp industry also faces oversupply problems, import competition, marketing issues, production management issues, etc. (Dhoubhadel, 2021; Kolodinsky & Lacasse, 2021).

Hemp stocks, given the many uncertainties in legislation and regulations, fit into the category of stocks classified as speculative stocks. Speculative stocks are defined as high-risk, high-reward stocks (Financial Glossary, 2011). Speculative stocks are invested in for their short-term gains, with their potential typically based on a "gut feeling" more than any solid financial fundamentals (Butsch, 2022). Like most speculative stocks, hemp stocks have a potential for high rewards, even if such growth comes with a high risk for investors (Hayes, 2021; Brashear, 2021). When categorized by market capitalization, most hemp stocks are small-cap stocks (stocks with a market capitalization below 2 billion USD), and investors are always looking out for stocks to diversify their financial portfolios. These stocks can serve that purpose for investors, but more research is needed to determine

how they compare to the more stable mid-cap and large-cap stocks available to investors in the stock markets.

Figure 2.1 shows how the average stock price index of all hemp firms employed in this study moves in comparison to overall stock indexes such as the S&P 500, Russell 2000, NASDAQ, and Dow Jones since the start of 2019 after the 2018 Farm Bill was passed. These stocks represent the top mid-cap and large-cap stocks in the US economy. The graphic points out a distinct pattern, showing how hemp stocks trended upwards in a similar fashion to other stock indexes pre-2020 but fell off after. The decline could be due to several problems currently plaguing the industry – from legislative uncertainties to supply chain issues to technology restraints in the production process. The decline could also be attributed to the problem of oversupply in the industry and a decline in prices of hemp biomass, especially non-CBD biomass (Sterns, 2019; Dhoubhadel, 2021). Also, the magnitude of the upward and downward trends of US hemp stocks seems to be much more erratic, compared to other indexes. This suggests that the hemp firm could offer more risk to investors, compared to mid-cap and large-cap stocks in the US economy.

This study contributes to ongoing research in the US hemp industry by investigating how US hemp stocks compare to mid-cap and large-cap stocks after the 2018 Farm Bill was passed. This study aims to answer the following research questions:

(i) How volatile are hemp stock prices?

(ii) What is the level of risk for hemp stocks?

(iii) Are hemp stocks drawn from the same population as mid-cap and large-cap stocks?

These research questions will be answered using descriptive statistics, correlation analysis, and the Kruskal-Wallis Test. The similarities or differences in these stocks would serve as metrics potential investors could consider while making investments in the hemp industry. This study would provide a foundation for further research on investment in the US hemp industry.

2.3. Background (Issues Facing the Industrial Hemp Industry)

Interest in the hemp industry in the United States has increased since the passing of the 2014 and 2018 Farm Bills. Hemp industry stakeholders attribute the rising interest and rapid growth of the industry to the growing demand for certified hemp seeds and CBD-based products. (Sterns, 2019). Cannabidiol (CBD)-based products derived from industrial hemp are very popular in the US and are well known to the public due to their health and wellness benefits (Kim and Mark, 2023). Before the return of the crop to growing fields, the US imported hemp and hemp-based products from Canada, Europe, and China, with Canada accounting for most imports (Moran, 2014).

Given that the hemp industry is strongly driven by consumer demand, the legalization of marijuana in more US states has been a topic of concern to hemp industry stakeholders. Some stakeholders feel that even with increasing regulations in the hemp industry, the legalization of marijuana would not help the hemp industry moving forward as consumers might not necessarily become more cognizant of the differences between marijuana and hemp products. (Malone & Gomez, 2019).

While some hemp industry stakeholders see the regulatory and policy issues as a major concern, some are much more relaxed and view some of the uncertain regulatory

considerations as a good sign for the industry (Ellison, 2021). These stakeholders suggest that the legalization of marijuana, along with more consumer education about the plant, will improve the image of industrial hemp as consumers and the public become more enlightened about the differences between the two since public image has always factored into the demand for industrial hemp products (Parvez, *et al*., 2021).

From the perspective of investors, these regulatory irregularities pose more risk to investments in the hemp industry. From age restrictions to regulations on over-the-counter sales to the level of THC, there is always some uncertainty in the hemp industry. However, some investors are willing to bear the risk associated with the potential boom of the hemp industry, with some erring on the side of caution by investing in stocks involved in providing the ancillary services in the industry.

Beyond basic data, agronomic and economic research on hemp is in its infancy with most current information published in non-peer-reviewed journals or websites online. While that information can be widely accessible, it is often difficult to distinguish quality or applicability beyond a single circumstance (Mark, *et al*, 2020). Overall, a general lack of information increases the risk for potential investors in the hemp industry and this study hopes to contribute to the growing body of knowledge on the hemp industry.

Figure 2.2 presents the risks faced by some players in the hemp industry. According to Zēverte-Rivža & Adamovičs (2015), there are six risk categories – technological and production risks, personnel risks, environmental risks, economic and market risks, and agricultural and meteorological risks. Personnel risks posed the highest threat while environmental risks posed the least threat to hemp industry stakeholders. These six risk categories bring concern to growers, processors, wholesalers/retailers, or vertically

integrated enterprises in the hemp industry. Given that their potential investments fund activities with the industry, investors also share some of these risks once they make a foray into the hemp industry. The ever-changing economic and market conditions in which the hemp industry operates, coupled with regulatory uncertainties abound, all raise the risk associated with making investments in the hemp industry.

2.4. Literature Review

A closer look at the hemp industry in the United States reveals that it is an industry on the rise. Despite the potential for growth and expansion, the industry is still in its infancy and more research is needed to help stakeholders understand the industry. Agronomic and economic research on hemp is hard to come by and most information available is non-peer reviewed. Although this information is widely available, it is difficult to determine its quality or applicability. The body of knowledge regarding US hemp stock prices and performance is still in its infancy and at the time this study was undertaken, no other study on hemp stock prices had been published. By analyzing the stock prices of US hemp companies and comparing how these prices move in relation to mid-cap and large-cap stocks, this study attempts to start a conversation about investing in the US hemp industry and how the stocks of hemp firms in the US trend compared to overall stock markets.

Before the legalization of commercial hemp production in the US through the 2018 Farm Bill, hemp was not grown in the US for over fifty years. There is thin literature on the U.S hemp industry and most research available on comparing stock prices or performance are from the legal cannabis industry (mostly medicinal cannabis) or countries with developed legal cannabis and hemp industries like Canada. Researchers like Durodola

and Chotee (2019); Chen, *et al*., (2021); Weisskopf (2020); Cox and Cheng (2021), etc. have all researched stock prices and performance with some of the researchers comparing them to other stocks, and others like Andrikopoulos, Gebka, and Kallinterakis (2020) investigating how these stock prices move. The legal cannabis industry and industrial hemp industry may overlap in the US as the firms listed as legal cannabis firms are also involved in the hemp industry through their involvement in CBD oil and other hemp-derived products. No research on hemp stock prices in the US is available and most of the available literature is on the legal cannabis industry. In this section, a review of related literature is presented.

Chen, *et al*., (2021) investigated the historical stock return of 10 vertically integrated medicinal cannabis companies for the period between 2015 and 2020 (when the legalization of recreational cannabis was debated in Canada). The study was presented in two facets – an events study and a matched-pair comparative study. The events study analyzed the returns of these firms before and after recreational cannabis legalization while the matched-pair comparative study compared these vertically integrated firms to others in the same industry. The result from the event study shows that these firms performed better pre-legalization than they did post-legalization of recreational cannabis while the results from the matched-pair comparative study showed that the vertically integrated pairs did not outperform their matched pairs. The paper concluded that the legalization of recreational cannabis in Canada has not particularly boosted the cannabis industry, from a stock market standpoint.

Cox and Cheng (2021) investigated the performance of Canadian-listed cannabis equities over 24 years, between 1996 and 2020. These firms selected and analyzed in the

study were publicly traded legal cannabis firms, listed on the Toronto Stock Exchange, Canadian Securities Exchange, Toronto Venture Stock Exchange, and Over-the-Counter Markets. The researchers analyzed weekly data and found that the Canadian cannabis portfolio outperformed the overall stock market in Canada over the study period. The researchers concluded that if potential investors could look beyond the social, cultural, or legal issues facing the industry, they would find that considering Canadian-listed cannabis stocks in their investment portfolios would boost portfolio earnings, given that these stocks have high investment returns.

Durodola and Chotee (2019) investigated the behavior of cannabis stocks on the Toronto Stock Exchange over one year, from March 2018 to March 2019. The timeline of the study was such that it was six months before and six months after the legalization of cannabis for recreational use in Canada. The researchers used basic descriptive statistics, correlation analysis, and the Kruskal-Wallis test to analyze the behavior of the stocks. The study results indicated that cannabis stocks exhibited higher risk volatility compared to non-cannabis speculative stocks and large-cap stocks on the Toronto Stock Exchange. The results also point to similarities between cannabis and non-cannabis speculative stocks, even if cannabis stocks also possess unique characteristics, leading to varied responses to macroeconomic shocks or factors. The researchers concluded that investors have an interest in these stocks because of the potential for high earnings and recreational legalization, despite the risk associated with investing in these stocks.

Weisskopf (2020) investigated the stock price performance of 33 firms in the US and Canadian cannabis industry, between 2014 and 2018, using descriptive statistics, correlation analysis, and the Capital Asset Pricing Model. The researcher classified

cannabis stocks as "sin stocks," along with tobacco, gambling, and alcohol stocks, based on perceived cultural, religious, or legal grounds. The study indicated that the stock movement of the legal cannabis firms slightly outperformed the other sin industries. However, the results suggested that the stocks possess a higher risk compared to other sin industries and the overall stock markets. The study also reported that cannabis stocks do not provide significantly abnormal returns and show a moderate correlation to other sin industries but a weak correlation to the overall stock market. The study suggested that investors be aware of the risk involved with the industry, even if investors could reap some benefits by adding these stocks to their financial portfolios.

From the review of the prior literature presented above, investments made in the hemp industry could potentially yield normal or high returns, and legalization, in some form, positively influenced the stock price movements of the stocks. The researchers recommend that investors add these stocks as a means of portfolio diversification. However, these high returns come with high risk since the hemp industry is still an emerging industry saddled with the problems such as legislation and regulatory uncertainties, social stigma, and the unfamiliarity of investors with the risk and returns of securities (Weisskopf, 2020; Cox and Cheng, 2021).

However, most of the ongoing research regarding the performance of firms with activities in the hemp industry or legal cannabis is concentrated in Canada, with just a few focusing on the hemp firms in the US. The high concentration of the research on Canadian hemp industry is not unusual as Canada is ahead of the US when it comes to the hemp and legal cannabis industry and research on the US hemp industry is in its infancy. This study hopes to lay the foundations for further research on hemp stock performance. With the

results on the performance of hemp firms in the US when compared to mid-cap stocks and large-cap stocks traded on US stock exchanges, this study would provide much-needed information about the similarities or differences between U.S hemp stocks and overall stock markets, which would help US investors make decisions about investment choices and portfolio diversification.

2.5. Data and Methodology

2.5.1. Data

All stock price data used in this study were obtained from Yahoo Finance and were collected as weekly closing prices over four years from January 2019 to December 2022, giving 213 observations. Data collection began in January 2019, after the adoption of the 2018 Farm Bill in December 2018, since this study seeks to assess the performance of US hemp firms relative to mid-cap and large-cap stocks after the 2018 Farm Bill was passed on December 20, 2018. The start of the study period chosen coincides with the removal of hemp from the Schedule 1 Controlled Substance list and this study assesses the movement of hemp stocks after hemp could be grown in the US commercially.

The firms employed have either diversified or rerouted their ventures into the hemp industry after commercial hemp production was made legal at the federal level after the 2018 Farm Bill was passed. Additionally, stock price data before the 2018 Farm Bill was passed is only available for 18 of the 32 firms and the study objective is focused on the hemp industry post-passage of the 2018 Farm Bill. Weekly stock prices were obtained for 32 US hemp firms and 29 of the 32 firms in this study operate in the hemp industry and legal cannabis industry with just 3 firms (CV Sciences, cbdMD Inc., and Charlotte's Web)

operating strictly in the hemp industry (listed in Appendix 2). These 29 hemp firms do have some involvement in the legal cannabis industry, but the passing of the 2018 Farm Bill saw them make inroads into the hemp industry, dealing with hemp and hemp-derived products, especially cannabidiol extracts in its various forms - oils, gummies, capsules, tinctures, among others. Some of the listed firms also operate hemp dispensaries where these hemp products are sold at wholesale and retail levels. These firms are involved in the hemp industry through the cannabidiol extracts (mainly CBD oils) that make up most of the demand in the hemp industry.

377 mid-cap stocks and 492 large-cap stocks were used in this study. Along with the hemp stocks, they are sampled using the Kruskal-Wallis test, and a probability distribution of the relationship is created. The firms represented by these mid-cap and large-cap stocks operate in a range of industries from Manufacturing, Education & Training Services, Energy, and Technology to Biotechnology industries. For this analysis, all mid-cap stocks are chosen from the S&P Midcap 400 Index while the large-cap stocks are chosen from the S&P 500 Index. The S&P 500 Index represents the top 500 publicly traded firms in the US. The index was launched in 1957 and is weighted by the market capitalization of stocks. On the other hand, the S&P Midcap 400 Index represents the top 400 publicly traded mid-cap stocks in the US, launched in 1991 and serves as a gauge for midcap equities.

2.5.2. Research Method

This study makes use of descriptive statistics, correlation analysis, and the Kruskal-Wallis Test to answer the research questions. The descriptive statistics, through the coefficients of variation and beta coefficients, describes the level of price volatility and

level of risk associated with US hemp stocks while the correlation analysis through the correlation coefficients describe the association between hemp stocks and small-cap stocks (a stock with a market capitalization less than two billion USD), mid-cap (a stock with a market capitalization between two and ten billion USD) and large-cap stocks (a stock with a market capitalization above ten billion USD). The Kruskal-Wallis test provides a metric to evaluate the similarities or differences of hemp stocks when compared to mid-cap and large-cap stocks.

For the descriptive statistics and correlation analysis, the hemp stock prices are compared to five major US stock indexes – the Dow Jones, NASDAQ and S&P 500 (large-cap indexes); S&P Midcap 400 (mid-cap index); and Russell 2000 (small-cap index). These indexes represent the major categories of stock market indexes investors choose when adding stock options to their investment portfolios. The descriptive statistics describes the coefficient of variation and the beta coefficient of US hemp stocks when compared to these indexes. The beta coefficient, coupled with the coefficient of variation, helps characterize the volatility and degree of risk associated with US hemp stocks when compared to other stock market indexes. Up-to-date weekly stock prices are used to derive the beta coefficients and coefficients of variation of US hemp stocks over a four-year study period.

The beta coefficient describes the price risk of a stock in comparison to the overall market. (Levy, 1974; Lin and Falk, 2022). The beta coefficients derived in this study describe the degree of risk of US hemp stocks compared to the other stock indexes in the study. These indexes serve as a benchmark against which the US hemp stocks are compared for their risk. The value of the beta coefficients derived would give an idea of how risky

US hemp stock are compared to other investment indexes. The equation for the beta coefficient in this study is defined by:

$$\beta_i = \frac{Covariance(R_{Stock}, R_{Overallmarket})}{Variance(R_{Stock})}$$

where:

β_i represents the beta coefficient of the stock of interest , R_{Stock}represents the returns of the stock of interest, and $R_{Overallmarket}$ represents the returns from the overall market.

The coefficient of variation is a measure of dispersion around a central value. In the context of stock prices, the coefficient of variation describes the level of volatility in stock prices. High coefficients of variation suggest that a stock is risky and sensitive to changes in the market (Brabenec, *et al.*, 2020).

To build on the descriptive statistics analysis, a correlation analysis is performed between the hemp stocks and the stock market indexes employed in the study. For interpretation, the 32 hemp stocks are put in an index, weighted by price, like the S&P 500 Index. Using the correlation analysis, inferences on the type of relationships between these stock market indexes, and hemp stocks can be made. Correlation coefficients between 0 to 0.4 are considered weak, 0.4 to 0.7 considered moderate while coefficients above 0.7 are considered high.

Prior studies such as Sedgwick (2018) and Durodola and Chotee (2019) have used the Kruskal-Wallis test to analyze independent samples. The Kruskal-Wallis test is a nonparametric statistical test used to compare three or more independent groups for their similarity or difference. The Kruskal-Wallis test is a nonparametric alternative to the one-way ANOVA (analysis of variance) test, which assumes that the data are normally

distributed and that there is equal variance between groups. With the Kruskal-Wallis tests, these conditions do not necessarily need to be met. The test is also useful for examining groups of an unequal size number of participants (Conover, 1999; Hecke, 2010; Sharpe *et al*. 2018). The stock prices of all 32 hemp firms employed in this study are not normally distributed, justifying the use of the Kruskal-Wallis test over its parametric equivalent, the one-way analysis of variance.

The test ranks all the observations from lowest to highest and then calculates the sum of the ranks for each group. The test statistic is calculated by comparing the sum of ranks between the groups to the expected sum of ranks under the null hypothesis of no difference between groups. The resulting test statistic follows a chi-squared distribution with degrees of freedom equal to the number of groups minus one. However, researchers are not able to identify which groups are different from each other through the Kruskal-Wallis test, so a post-hoc analysis is needed to identify specific group differences. The equation for the Kruskal-Wallis test employed in this study is presented by:

$$K = (N-1)\frac{\sum_{i=1}^{g} n_i\,(\bar{r}_i - \bar{r}^2)^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}\left(r_{ij} - \bar{r}^2\right)^2}$$

$$\bar{r}_i = \frac{\sum_{j=1}^{n_i} r_{ij}}{n_i}$$

$$\bar{r} = \frac{1}{2}(N+1)$$

where:

$\bar{r}$ represents the average of all values of r_{ij}; n_i represents the number of observations in group i; r_{ij} represents the rank (among all observations) of observation j from group i; N

represents the total number of observations across all groups. The test statistic K is derived from a chi-squared distribution (since all $n_i \geq 5$).

This variant of the test presented in this study assumes the possibility of rank. The Kruskal Wallis-Test, just like the one-way AVOVA also comes with a set of formulated hypotheses. The null hypothesis suggests that the samples arise from an identical distribution while the alternative hypothesis states the samples arise from different distributions. Therefore, this study forms two set of hypotheses to answer the research questions:

(1) H_0: US hemp stocks and midcap stocks have the same distribution.

H_A: US hemp stocks and midcap stocks have different distributions.

(2) H_0: US hemp stocks and large cap stocks have the same distribution.

H_A: US hemp stocks and large cap stocks have different distributions.

The decision to reject or accept the null hypothesis is made based on the probability distribution of the Kruskal-Wallis test results. To derive the probability distribution, the Kruskal-Wallis test is simulated in three cycles of 1000, 5000 and 10000 iterations. If all three cycles yield the same outcome, the distribution of the 10000 iteration cycle would be presented in the results.

The p-values from each iteration are then used to create a probability distribution on how US hemp stocks compare to mid-cap and large-cap stocks. With this probability distribution, investors can tell if US hemp stocks and midcap or large-cap stocks are drawn from the same distributions. The probability distribution drawn from the Kruskal-Wallis

test would also help to either support or undermine the results from the descriptive statistics and correlation analysis.

2.6. Results

2.6.1 Descriptive Statistics and Correlation Analysis Results

Using descriptive statistics and correlation analysis, mid-cap and large-cap stocks are compared to US hemp stocks in this study. All 32 US hemp stocks in this study as grouped into an index, and then compared to mid-cap and large-cap stocks. The index is created as an average price index, similar to the S&P 500 index. The coefficient of variation and beta coefficients together help to give a picture of the price volatility and the level of risk for both sets of stocks. The correlation analysis shows the degree of association and aids in describing how these groups of stocks respond to macroeconomic shocks (Durodola and Chotee, 2019). Table 2.1 shows the descriptive statistics of selected US hemp stocks compared to mid-cap and large-cap stock indexes while Table 2.1 shows the correlation analysis results between US hemp stocks and these mid-cap and large-cap stocks.

The results of the descriptive statistics and correlation analyses are based on weekly data over a 4-year period. The descriptive statistics result shows the coefficients of variation and the beta coefficients of all 32 hemp stocks (when compared to an overall stock market.

Table 2.1 shows the coefficient of variation for all 32 firms employed in this study, individually and as a price-weighted index. The results show that as an index, weighted by price, US hemp stocks show a coefficient of variation of 50% when compared to the major stock indexes in this study. The results suggest that US hemp stock prices are more price

volatile when compared to the overall stock market – S&P 500 (17.3%), NASDAQ (23.3%), Dow Jones (12.89%), Russell 2000 (17.93%), and S&P Midcap 400 (17%). The higher the coefficient of variation, the more prices are likely to swing in either direction. Investors need to know by how much prices could potentially swing, either in the positive or negative direction. Despite the possibility of high earnings from hemp stocks, potential investors must understand that the hemp stocks bring along with them a high price volatility when compared to the overall stock market. Figure 2.3 shows the distribution of the coefficients of variation for each hemp firm when compared to the average coefficient of variation for all 32 hemp firms. The results show that about 22% of the stocks show a coefficient of variation just around or less than that of the index for all 32 hemp stocks (50%), 50% of the hemp stocks show a coefficient of variation between 50% and 100%, while 28% of the stocks show a coefficient of variation above 100%. These numbers show that not all US hemp stocks are risky to the same degree.

Table 2.2 shows the beta coefficients of all 32 US hemp stocks employed in this study. After taking a glance at the figures from the table, the hemp stocks have similar betas compared to each of the overall market indexes chosen (for example, Curaleaf Holdings has all its betas between 0.32 and 0.33 for all five stock market indexes). The results also show that the returns from US hemp stocks are less risky when compared to the overall stock market. From the beta coefficients, US hemp stocks over the study period yield less returns when compared to overall stock markets such as the S&P 500 Index, Russell 2000 Index, NASDAQ, Dow Jones and the S&P Midcap 400 index. On the flip side, because these stocks have beta coefficients below 1, with just five US hemp stocks (TPCO Holdings Corp., Ayr Wellness Inc., Verano Holdings Corp., Ascend Wellness

Holdings Inc., and Turning Point Brands Inc.) have beta coefficients above 0.4. These numbers suggest that these stocks would not cost investors as much as overall stock markets would during periods of market declines. Although the beta coefficient is not a stock predicting metric, it uses historical data to shed some light into how the returns of these stocks have trended when compared to the overall stock market in the US. Also, the beta coefficients suggest that US hemp stocks are not as risky as many industry experts and researchers have made them out to be due to their speculative nature.

Taken together, the results of the coefficients of variation and beta coefficient point out a few important guides for investors - US hemp stocks do come with high price volatility due to their high coefficient of variation, but the returns do not lead to portfolio depreciation just because the stocks are regarded as speculative. These stocks also have low risk when compared to overall stock markets and do not dip as hard in times of market declines and could be seen as stocks to protect against sliding losses in financial portfolios.

Table 2.3 shows the correlation results between the price-weighted index of all 32 firms employed in this study and five overall stock market indexes. The correlation analysis results show that these US hemp stocks show a weak correlation to major stock indexes. Specifically, they show very weak correlations to large-cap indexes like the S&P 500, Dow Jones, and NASDAQ Indexes while they show weak positive correlations to small-cap and mid-cap stock indexes like the Russell 2000 and S&P Midcap 400 Index respectively. The correlation results are similar to the results from Weisskopf (2020) who found that speculative stocks in "sin" industries show a weak correlation to overall stock markets. However, when compared to one another, all five indexes show a strong positive correlation, suggesting that these overall stock market indexes trend in the same direction,

regardless of the stock category – large-cap or mid-cap. The correlation results suggest that US hemp stocks do not necessarily respond to changes in the macroeconomy like the overall stock market. This suggests that US hemp stocks could be used as hedge stocks in financial portfolios since they do not necessarily move as fast as overall stock markets do. Also, the low risk level associated with US hemp stocks could be a reason potential investors and financial managers use them in financial portfolios.

The results of the correlation analysis support the results of the descriptive statistics presented earlier, as US hemp stocks do not move the same way when compared to the overall stock market. They might be volatile in terms of their prices but do not pose as high a risk as they have been labelled. To make further inferences on the individual US hemp stocks and how they compare to these large-cap and mid-cap stocks, the Kruskal-Wallis test is employed as a tool of analysis.

2.6.2 Kruskal Wallis Test Results

After 10,000 iterations, the sampling distribution of the Kruskal-Wallis test for US hemp stocks compared to mid-cap and large-cap stocks is derived. The results shows the rejection of the null hypothesis for the Kruskal-Wallis test between US hemp stocks and midcap stocks. The results also show that the Kruskal-Wallis test between US hemp stocks and large-cap stocks leads to the rejection of the null hypothesis at all 10,000 iterations. Figures 2.4 and 2.5 show the sampling distribution of the Kruskal-Wallis test statistic for US hemp stocks, when compared to mid-cap stocks and large-cap stocks.

These sampling distributions of the Kruskal-Wallis test in both cases lead to the rejection of the null hypothesis. This indicates that US hemp stocks are not drawn from the same distribution as mid-cap stocks and large-cap stocks. For investors, these results

provide more insight into the nature of US hemp stocks compared to overall markets. The results suggest that since these stocks are not drawn from similar distributions, they cannot be expected to have the same degree of response to market shocks or macroeconomic shocks in the US economy.

Also, the results also give more insight into the results from the descriptive statistics and correlation analysis. The Kruskal-Wallis test results suggest that the low levels of correlation observed between the movement of US hemp stocks and mid-cap stocks, or large-cap stocks could be attributed to the fact that these groups of stocks are not drawn from similar populations, and this could be responsible for the marked differences in the level of risk and volatility observed in these stocks. Potential investors in the US hemp industry could gain from the characteristics of the hemp stocks given that they do not exactly respond to shocks in the economy like mid-cap and large-cap stocks and have a lower level of return volatility, which could be invaluable to financial portfolios in times of market decline, even if they do not trend as high as mid-cap and large-cap stocks during periods of a market boom. Overall, the results suggest that US hemp stocks could be considered by investors to be included in their financial portfolios.

2.7. Conclusion

After an absence of over fifty years from growing fields, industrial hemp was reintroduced into the United States agricultural sector through the 2014 Farm Bill and with commercial production legalized after the 2018 Farm Bill was passed, the US hemp industry has become attractive to potential investors who are optimistic about the potential gains to be made from the industry. The growing interest in the industry is due in part to

the rising demand for hemp and hemp-derived products and the wild optimism about the potential growth of the industry, despite its speculative nature (Research and Markets, 2022 have gone on to estimate that the global hemp industry would reach $16.7 billion in value by 2030).

Using publicly available data from Yahoo Finance, the behavior of US hemp stocks is computed and compared to mid-cap and large-cap stocks over a four-year period, from January 2019 to December 2022, using a mix of statistical tools - descriptive statistics, correlation analysis, and the Kruskal-Wallis test. The descriptive statistics results show that US hemp stocks come with a high degree of price volatility for investors, but they could be used to hedge against sliding losses in period of market declines since their returns are not as responsive when compared to the overall stock market (low beta coefficients).

The correlation analysis results indicate weak to moderate association between US hemp stocks and overall stock market indexes, while the Kruskal-Wallis test results provided support for the earlier results, suggesting that US hemp stocks are not drawn from the same distribution as mid-cap and large-cap stocks. US hemp stocks do not exactly respond to shocks in the economy like mid-cap and large-cap stocks and have a lower level of return volatility. Also, the beta coefficient results suggests that US hemp stocks may slide as high as mid-cap and large-cap stocks in bear market conditions, they could prove invaluable in bearish market conditions.

The descriptive statistics and correlation analysis results expands on studies carried out in the legal cannabis industries by Durodola and Chotee (2019) and Weisskopf (2020) by employing a much larger sample size for estimating price volatility and risk. The results in the study are also groundbreaking and unique to the US hemp industry and is the first of

its kind to study US hemp stocks using the Kruskal-Wallis test. These methods help answer the research question asked in this study - Hemp stock prices are very volatile, possess a low level of risk when compared to overall stock markets and are not drawn from the same population as mid-cap and large-cap stocks.

Based on the results from the descriptive statistics and correlation analysis, US hemp stocks, show a marked distinction from other stock categories, US hemp stocks have a great potential for growth and lower return risk when compared to overall stock markets, could be considered by potential investors when they look to diversify investments, hedge against losses during market declines, or just looking to improve the return prospects for their overall financial portfolio. In summary, potential investors and financial managers should see US hemp stocks in a different light. Though volatile due to the reemerging nature of the industry, the results point to a more optimistic outlook for these stocks when they are included in financial portfolios.

Tables and Figures for Chapter 2

Table 2.1. Descriptive Statistics of US Hemp Stocks

Firm	N	Mean	Standard Deviation	Coefficient of Variation
Curaleaf Holdings Inc.	221	8.13	3.36	41.5%
Green Thumb Industries Inc.	221	15.75	8.07	51.34%
Trulieve Cannabis Corp.	221	18.77	11.19	59.74%
Verano Holdings Corp.	113	10.27	5.49	53.7%
Cresco Labs Inc.	221	7.03	3.39	48.3%
Turning Point Brands Inc.	221	33.47	10.34	30.96%
Columbia Care Inc.	206	3.36	1.70	50.76%
Ascend Wellness Holdings Inc.	96	4.69	3.29	70.55%
Glass House Brands Inc.	193	7.16	3.15	44.06%
Grow Generation Corp.	221	14.21	15.48	109.13%
Planet 13 Holdings Inc.	221	2.79	1.85	66.73%
WM Technology	182	9.30	5.72	61.68%
4Front Ventures Corp.	221	0.77	0.49	51.71%
MariMed Inc.	221	0.95	0.96	101.61%
iAnthus Capital Holdings Inc.	221	0.96	1.6	163.01%
Jushi Holdings Inc.	197	2.82	1.89	66.98%
Medicine Man Inc.	221	2.03	0.73	36.24%
Acreage Holdings Inc.	130	2.45	1.91	78.13%
Medical Marijuana Inc.	221	0.03	0.02	70.85%
Ayr Wellness Inc.	121	15.25	11.07	72.9%
Homology Medicines Inc.	221	10.49	7.47	71.35%
*Charlotte's Web	221	5.55	5.86	104.02%
TPCO Holding Corp.	131	3.78	3.77	99.14%
Tilt Holdings Inc.	116	0.29	0.17	58.33%
Med Men Enterprises	221	0.64	0.93	146.56%
Goodness Growth Holdings Inc.	210	1.48	0.94	63.69%
StateHouse Holdings Inc.	198	0.90	0.75	84.15%
*cbdMD Inc.	221	104.13	75.435	72.44%
Unrivaled Brands Inc.	221	0.26	0.24	93.24%
Agrify Corporation	113	80.37	79.32	99.14%
*CV Sciences	221	1.13	1.62	143.97%
Lowell Farms Inc.	204	1.22	1.70	139.32%
Hemp Stocks Index	221	81.15	41.18	50.74%

* denotes a firm strictly in the hemp industry
Source: Author Calculation.

Table 2.2. Beta Coefficients of US Hemp Stocks Compared to Major Stock Indexes

Firm	SP500	DOW JONES	NASDAQ	RUSSELL	MIDCAP
Curaleaf Holdings Inc.	0.32	0.32	0.32	0.32	0.33
Green Thumb Industries Inc.	0.36	0.37	0.34	0.37	0.37
Trulieve Cannabis Corp.	0.33	0.33	0.32	0.35	0.35
Verano Holdings Corp.	0.56	0.56	0.54	0.55	0.56
Cresco Labs Inc.	0.34	0.34	0.34	0.35	0.36
Turning Point Brands Inc.	0.50	0.51	0.50	0.50	0.51
Columbia Care Inc.	0.33	0.34	0.32	0.33	0.34
Ascend Wellness Holdings Inc.	0.58	0.57	0.57	0.58	0.59
Glass House Brands Inc.	0.35	0.35	0.35	0.35	0.35
Grow Generation Corp.	0.21	0.21	0.22	0.21	0.21
Planet 13 Holdings Inc.	0.25	0.25	0.25	0.26	0.26
WM Technology	0.35	0.35	0.35	0.36	0.36
4Front Ventures Corp.	0.26	0.25	0.26	0.26	0.26
MariMed Inc.	0.11	0.11	0.11	0.12	0.11
iAnthus Capital Holdings Inc.	0.12	0.13	0.12	0.13	0.13
Jushi Holdings Inc.	0.29	0.29	0.29	0.28	0.29
Medicine Man Inc.	0.22	0.23	0.22	0.22	0.22
Acreage Holdings Inc.	0.30	0.30	0.29	0.31	0.31
Medical Marijuana Inc.	0.15	0.15	0.15	0.15	0.15
Ayr Wellness Inc.	0.41	0.42	0.41	0.42	0.42
Homology Medicines Inc.	0.34	0.34	0.33	0.34	0.35
*Charlotte's Web	0.24	0.24	0.24	0.24	0.25
TPCO Holding Corp.	0.42	0.42	0.42	0.43	0.43
Tilt Holdings Inc.	0.35	0.35	0.36	0.36	0.36
Med Men Enterprises	0.07	0.07	0.07	0.08	0.08
Goodness Growth Holdings Inc.	0.20	0.21	0.21	0.20	0.20
StateHouse Holdings Inc.	0.20	0.20	0.20	0.20	0.20
*cbdMD Inc.	0.20	0.20	0.21	0.21	0.21
Unrivaled Brands Inc.	0.09	0.10	0.10	0.10	0.10
Agrify Corporation	0.10	0.09	0.10	0.09	0.09
*CV Sciences	0.19	0.19	0.19	0.19	0.19
Lowell Farms Inc.	0.11	0.10	0.11	0.10	0.10

* denotes a firm strictly in the hemp industry
Source: Author Calculation.

Table 2.3: Correlation Analysis Results of US Hemp Stocks and other Stock Indexes

	Hemp Stocks	S&P 500	Dow Jones	NASDAQ	Russell 2000	S&P Midcap
Hemp Stocks	1.00	-0.038	0.024	0.084	0.332	0.129
S&P 500	-0.038	1.00	0.999	0.957	0.900	0.959
Dow Jones	0.024	0977	1.00	0.904	0.923	0.984
NASDAQ	0.084	0.957	0.904	1.00	0.903	0.896
Russell 2000	0.332	0.900	0.923	0.903	1.00	0.961
S&P Midcap	0.129	0.959	0.984	0.896	0.961	1.00

Source: Author Calculation

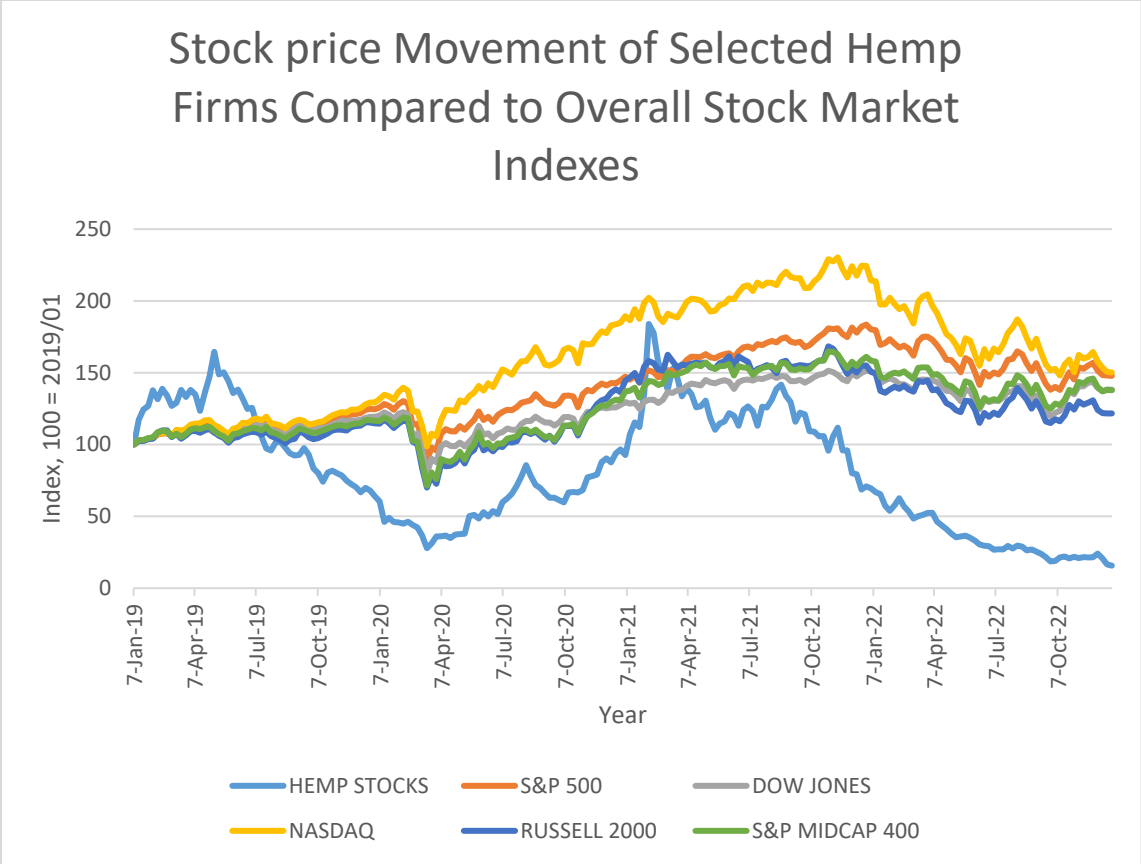


Figure 2.1: Movement of Hemp Firms Compared to Stock Market Indexes
Source: Author Calculation

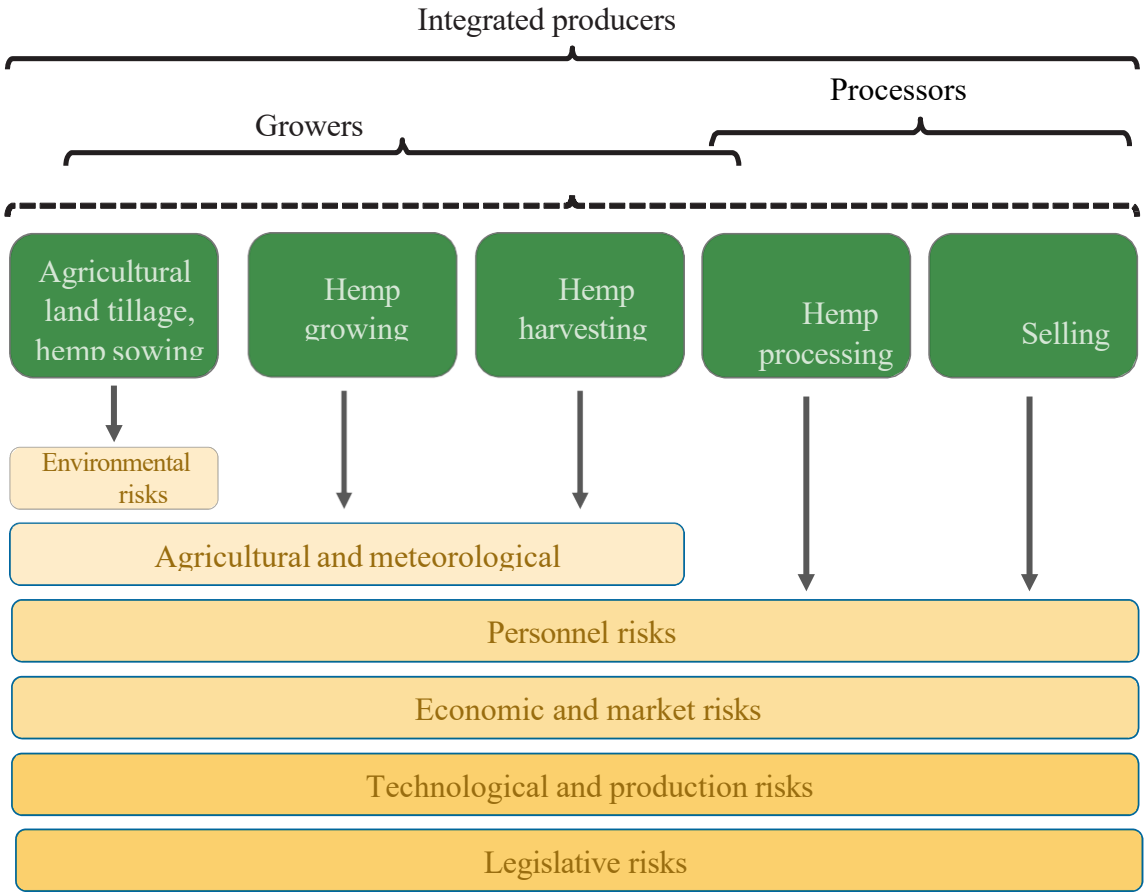


Figure 2.2: Risk faced by Some Hemp Industry Stakeholders.
Source: Zēverte-Rivža & Adamovičs (2015)

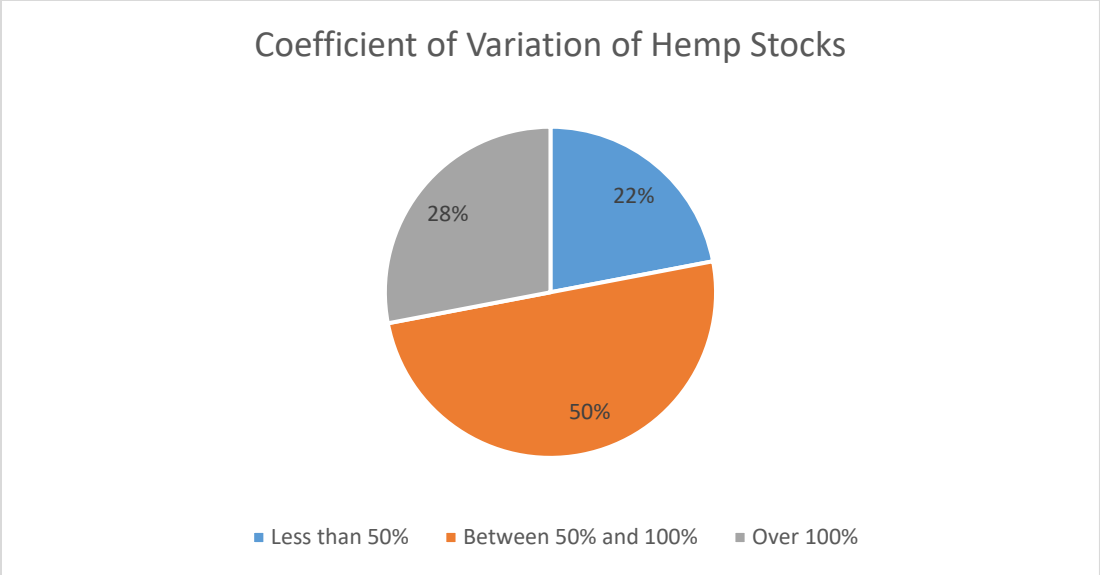


Figure 2.3: Distribution of the Coefficient of Variation of US Hemp Stocks
Source: Author Calculation

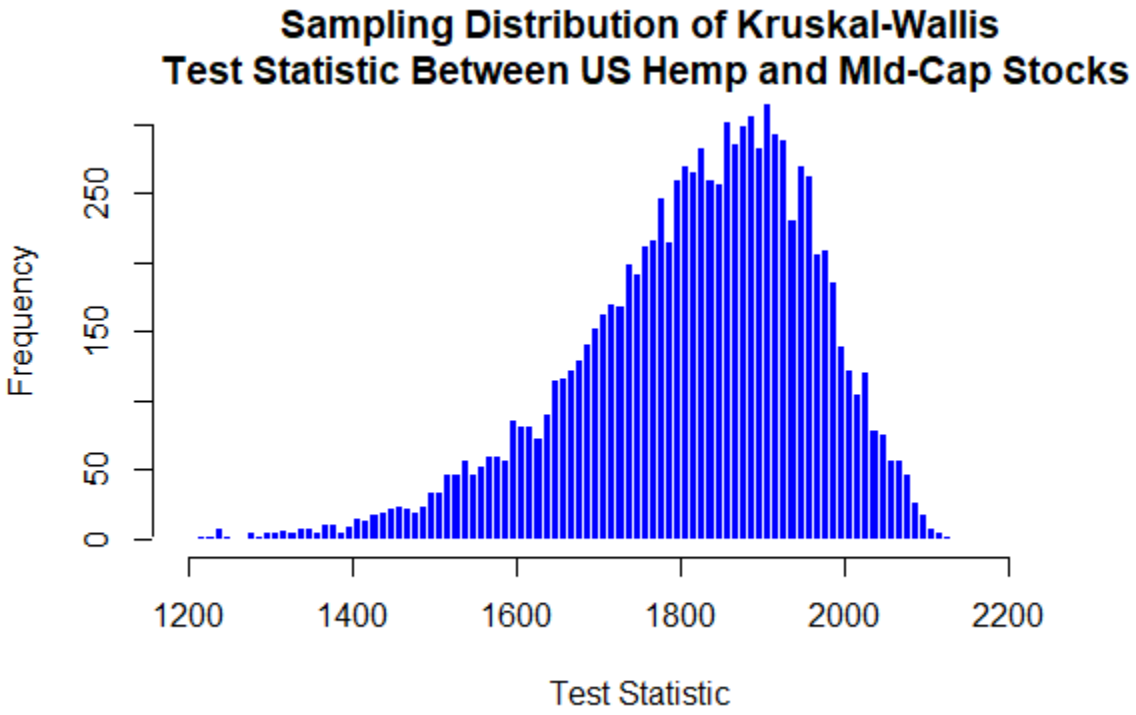


Figure 2.4: Kruskal-Wallis Test Distribution for US Hemp and Mid-Cap Stocks
Source: Author Calculation

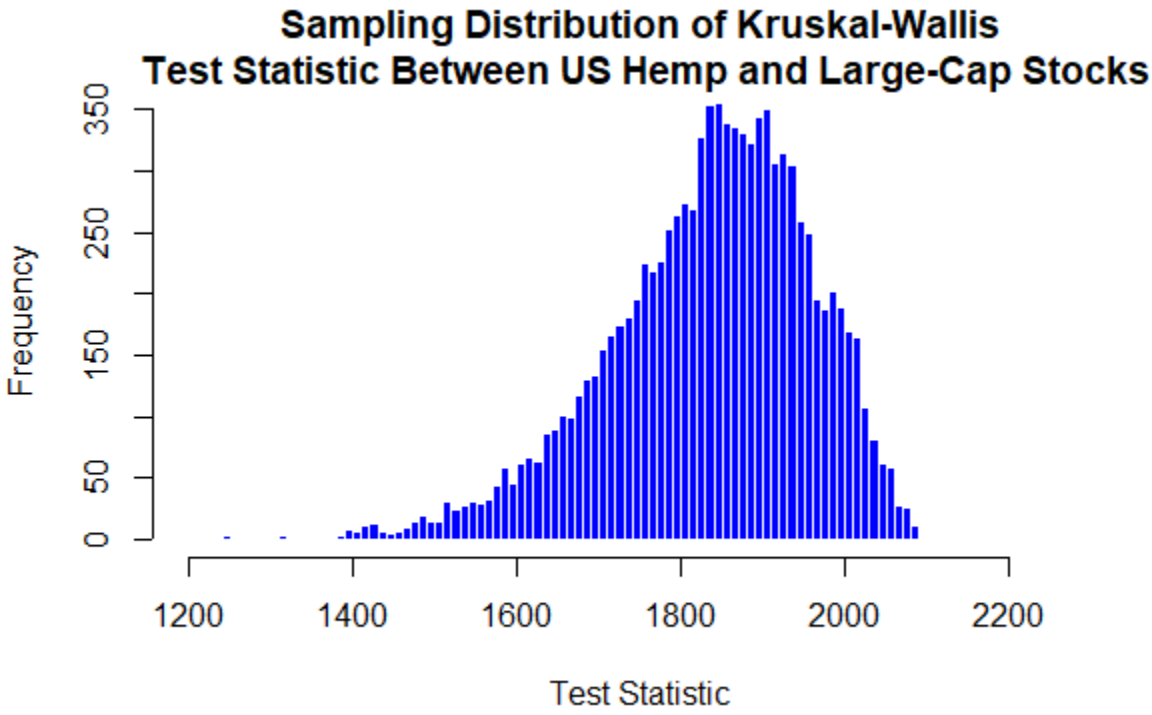


Figure 2.5: Kruskal-Wallis Test Distribution for US Hemp and Large-Cap Stocks
Source: Author Calculation

CHAPTER 3. MACROECONOMIC DETERMINANTS OF THE STOCK PRICES OF INDUSTRIAL HEMP FIRMS IN THE UNITED STATES

3.1. Abstract

This study examines the macroeconomic determinants of the stock prices of industrial hemp firms in the US using the nonlinear autoregressive distributed lag (NARDL) model developed by Shin, *et al*., (2014). This paper assesses the impact of four major macroeconomic indicators (Interest Rates, Industrial Production, S&P 500 Index, and Global Oil Prices) on the stock prices of 32 US industrial hemp firms, over a four-year period, from January 2019 to December 2022. The results show that asymmetrical relationships exist in both the short run and long run between US hemp stock prices and the selected macroeconomic indicators. The results also suggest that positive movements in these macroeconomic indicators have larger impacts on the stock prices of US industrial hemp firms than negative movements, suggesting that the stock prices of US industrial hemp firms respond more to positive movements in macroeconomic indicators than they do to negative movements in macroeconomic indicators. The findings are of importance to potential investors and policymakers in the US hemp industry as they bring to light a better understanding of how macroeconomic indicators influence the stock prices of publicly traded industrial hemp firms. Using these findings, stakeholders in the hemp industry get valuable knowledge in making investment decisions, ass*et al*location, resource hedging and policy design.

3.2. Introduction

Industrial hemp (*Cannabis Sativa* L.) is a versatile plant that can be grown for its fiber, seed, or oil. Hemp fields were once a common sight in the United States (US) with

states such as Kentucky, Illinois, Nebraska, Michigan, Minnesota, Iowa, Arkansas, California, and Wisconsin being the leading producers (Rogers, 2012; Kaiser, Cassady & Ernst, 2015).

The industrial hemp industry in the United States is a young but burgeoning industry (referred to as the "hemp industry" in this study). The hemp sector suffered a severe downturn after the Controlled Substances Act (CSA) restricted the legal cultivation and growth of hemp plants in the 1970s. As a result, the United States finally had to rely on imports of hemp goods, primarily from China and Canada (Rogers, 2012; Johnson, 2014). The 2014 Farm Bill allowed for the reintroduction of the crop into fields as part of state pilot initiatives managed by state departments of agriculture. A few years later, the 2018 Farm Bill, which legalized the commercial production of hemp once more in the US, was passed. (Mark, *et al*., 2020).

Current research on the hemp industry predicts that, despite being relatively less established in comparison to other well-established industries like dairy, corn, and soybeans, the hemp industry will be worth $16.7 billion globally by 2030, with a Compound Annual Growth Rate (CAGR) of roughly 21% (Research and Markets, 2022). Given that the demand for products made from hemp is increasing, figures like these would suggest that the industry is poised to expand at a rapid rate, coupled with rising demand for hemp products such as seeds and CBD oil (Malone and Gomez, 2019). Yet, for the US hemp industry to grow to its full potential as predicted by industry experts and researchers, investment is required. Without investments, the expansion and growth objectives of a developing sector or economy cannot be met; here is where the stock market comes in (Sharif, Purohit & Pillai, 2015; Enow & Brijlal, 2016). According to Malone and Gomez

(2019), the supply chain of the hemp industry needs to be improved if the US would compete with nations such as China and Canada in the global hemp industry. Investments directed at making US hemp supply chains more efficient is a win for the industry as the hemp industry is saddled with supply chain and market infrastructure problems (Dhoubhadel, 2021). The US hemp industry has an underdeveloped supply chain and about 25-33% of hemp output make it to the market (Allen and Whitney, 2019). Investing in the US hemp industry through the supply chain makes the link between hemp producers, processors, wholesalers, and retailers much more efficient.

The ability of the stock market to offer enterprises access to cash and rewards for investors with an accompanying level of risk has historically made it extremely important to business founders and managers. The stock market and its movements/fluctuations show how well companies and countries perform economically, especially when it comes to raising funds to support investment projects and economic growth (Enow & Brijlal, 2016; Shahzad, *et al*., 2020).

To acquire funds and capital needed for growth, the stock market is a viable option for many of the hemp firms in the US, especially when the firms are not owned and run privately. The stock market helps to raise much-needed funds for capital and would prove useful to industrial hemp firms in the US as they can access the capital they need to expand their business and at the same time, share risk with investors (Ding & Hou, 2015; Singh, 2016). There is a positive link between the setup of financial systems and economic growth of firms, industries or countries and by selling ownership stakes to interested investors, emerging industries and firms are able to access funds they need to operate and expand their businesses without having to take on debt (Levine, 1996; Duisenberg, 2001). For

investors, they earn benefits on their investments as capital gains which accrue as the firms put these funds to work (Forbes, 2023). Several industries have relied on the stock market to grow. From the technology industry to tourism to banking industries. The stock market has always been a source of funds for emerging firms, industries or countries. The technology industry is an industry that benefited greatly from the stock market. From speculation about its potential to legal troubles regarding regulation, the industry found a way to gain investors and has been able to grow rapidly in the US and globally, especially through the late 1999–early 2000 dot-com boom that drove investors to invest in the stocks of these technology firms (Corr, 2006; Forbes, 2006). Similar to the technology industry, the hemp industry could be up for an influx of investors if all prevailing conditions are adequate.

A considerable number of firms in the industrial hemp industry are listed on major stock exchanges or found in Over the Counter (OTC). Through these trading platforms, firms involved in the hemp industry can get the much-needed funds to expand their operations and the industry at large. While some firms are large enough to be listed on the major stock exchanges, other smaller firms cannot and are listed on OTC market. Hemp firms in the United States are small sized and are regarded as small-cap stocks, with a few mid-cap and large-cap stocks, since the industry is only re-emerging and not as developed as the industry in China, Europe and Canada (Moran, 2014; Alovisetti, 2016).

Besides the several social and legal issues facing the US hemp industry (Falkner, *et al.*, 2023; Malone and Gomez, 2019; Dhoubhadel, 2021), dynamic changes in the economy could also affect how the industry grows. As shown by prior research, economic indicators such as GDP, money supply, inflation, unemployment, consumer price index,

interest rate, global oil prices, etc., always affect how industries/sectors perform in an economy (Fama, 1981; Chen, *et al*., 1986; Bhargava, 2014; Rjoub, *et al*., 2017; Shahzad, *et al*., 2020). It is imperative to plan and make investments based on these macroeconomic factors.

Fama (1981), Chen, *et al*. (1986), Bhargava (2014), Rjoub, *et al*.(2017), and Shahzad, *et al*.(2020) all studied the effects of macroeconomic variables on stock prices and returns in several countries and industries, but there is no study akin to explaining how these indicators affect the US hemp industry. This study aims to fill that gap in the existing literature by assessing the macroeconomic factors that affect the stock prices of US hemp firms as well as give an idea of the short-term and long-term effects of these macroeconomic variables on the stock prices of US firms.

With the results, potential investors can objectively weigh the short and long-term effects of various factors on their investments in US hemp firms and the US hemp industry as a sound understanding of the influence of macroeconomic variables on the stock market provides a sound basis for more optimal asset allocation and hedging strategies. Also, the results would help firm managers to adopt appropriate policies and allocate their assets such that their firms would trend in the direction of financial stability (Shahzad, *et al*., 2020). A plethora of work has been done on the macroeconomic determinants of stock prices using conventional linear econometric methods. These traditional econometric methods assume stock prices and macroeconomic data have a linear relationship.

More recent studies in this area of research have shown that stock prices and macroeconomic data could have a non-linear and asymmetric relationship due to market fluctuations, trade speculation, or prevailing market conditions (Khan, *et al*., 2019;

Shahzad, *et al*., 2020). This study adds to the growing literature on asymmetrical stock price determinants by estimating how macroeconomic indicators could impact the stock prices of publicly traded hemp firms in the US. This study employs a dynamic econometric model to assess the impact of four major macroeconomic indicators (Interest Rates, Industrial Production, S& P Index, and Global Oil Prices) on the stock prices of US hemp firms over a four-year period. This study employs a dynamic econometric model – the nonlinear autoregressive distributed lag (NARDL) model presented by Shin, *et al*., (2014). The NARDL model has found recent use in macroeconomic stock price determinant research with researchers such as Sheikh, *et al*. (2020), Allen and McAleer (2020), and Alqaralleh (2020) using the model to estimate asymmetrical macroeconomic associations with stock prices.

The hemp firms employed in this study are all publicly traded companies, listed on major or minor exchanges. Privately held firms are not included in this study as they do not have their data for public access. 31 of the 32 firms in this study are small-cap stocks, indicating that they have market capitalizations below US$ 2 Billion, while just one of the stocks (Curaleaf Holdings Inc. - US$ 2.4 Billion) is a mid-cap stock, indicating that the firm has a market capitalizations between US$ 2 Billion and US$ 10 Billion.

Since it is difficult to model the effects of macroeconomic variables on daily stock prices due to the frequency of availability of the data, this study employs monthly stock prices and monthly macroeconomic variables. Four macroeconomic indicators are identified to be used in this study - Interest Rates, Industrial Production, S & P 500 Index, and Global Oil Prices; and these indicators are found in prior literature (Fama, 1981; Chen, *et al*., 1986; Rjoub, *et al*., 2017; Shahzad, *et al*., 2020). The macroeconomic variables

selected can be grouped into domestic and global determinants of stock prices. The Interest Rates, Industrial Production, and S& P Index represent domestic determinants while the Global Oil Prices represent the global determinants. The use of both domestic and global stock price determinants in research was proposed by Khan, *et al*. (2015).

3.3. Background (The Misconception with Marijuana)

Before industrial hemp returned to US fields after the 2014 and 2018 Farm Bills were passed into law, the commercial production of industrial hemp faced several challenges. First, hemp farmers were restricted through the 1937 Marijuana Tax Act. Also, as a part of the war on drugs in the 1970s, the legal growth and cultivation of industrial hemp was outlawed in the United States through the 1970 Controlled Substance Act (CSA).

Both laws targeted cannabis, but the hemp industry adversely affected by the legislation and that marked the decline and eventually, the disappearance of industrial hemp from US fields. (Moran, 2014; Johnson, 2014). The legislations that either restricted or outlawed hemp production failed to make the distinction between hemp and marijuana because both belong to the same species, *Cannabis Sativa*, L.

However, through the passing of the 2014 and 2018 Farm Bills, the USDA gives a clear distinction between industrial hemp and marijuana, based on the content of the intoxicating compound, delta 9 – tetrahydrocannabinol, also called THC.

According to Section 297A of the Agricultural Marketing Act of 1946 (AMA, 7 USC. 1621 et seq.), hemp refers to the whole plant or any part of such a plant (including seeds, extracts, isomers, acids), whether growing or not, with the federally defined THC concentration of not more than 0.3 percent on a dry weight basis. (Schluttenhofer & Yuan,

2017; Mark, *et al*., 2020). This guideline points out the fact that for a cannabis plant to be classified as industrial hemp, the intoxicating compound THC must be less than or at 0.3% on dry weight basis. Industrial hemp can be regarded as a low-THC variant of the cannabis plant and the level of THC in industrial hemp is insufficient to induce intoxication.

On the other hand, marijuana does not follow this basic definition as THC levels in marijuana reportedly average about 10%, with a high of 30% concentration and is deemed illegal and is considered drug trafficking under U.S federal laws. Deviating from federal laws, some US states have passed legislation to allow marijuana to be used in some form or under some circumstance – medicinal, recreational, or industrial. In these states, the cultivation and distribution of marijuana (medical and/or recreational) is allowed under state law and is regulated by state authorities (Lehrecke, 2019; Johnson, 2019; Sacco, 2022).

3.4. Literature Review

In this section, empirical evidence from prior research on the macroeconomic determinants of stock prices will be reviewed along with a progression of the models employed to give a timeline of research in the area of stock price determinants. Studies on the determinants of stock prices are not new in today's literature. Bhargava (2014) , Khan, *et al*. (2015), Rjoub, *et al*. (2017), Shahzad, *et al*. (2020), Humpe & Macmillan (2007) and Narayan, *et al*. (2014) have all undertaken studies to identify the factors influencing stock prices in different stock markets in different industries and countries. From firm-specific factors such as dividends, dividend yield, debt-equity ratio, book value, and firm assets to macroeconomic factors such as consumer price index, producer price index, inflation,

global oil prices, and interest rates, the response of stock prices to these variables has been widely researched in literature (Bhargava, 2014; Rjoub, *et al*., 2017).

Some of the earliest studies on macroeconomic stock price determinants were done by Fama (1981) and Chen, *et al*. (1986). Following their groundbreaking work in this area, more research has been done over the last four decades in the area of stock price determinants, across countries and industries, both developed and developing (Shahzad, *et al*., 2020; Khan, *et al*., 2015). The research on the US stock market by Fama (1981) and Chen, *et al*. (1986) laid a strong foundation for subsequent studies in the area of stock price determinant research. These researchers - Fama (1981), Chen, *et al*. (1986), Bhargava (2014) , Khan, *et al*. (2015), Rjoub, *et al*. (2017), Shahzad, *et al*. (2020), Humpe & Macmillan (2007) and Narayan, *et al*. (2014) have all selected macroeconomic indicators that are still relevant in literature today. Their research revealed that macroeconomic indicators such as interest rates, inflation rate, exchange rate, bond yield and industrial production have major impacts on the stock market. Recent research on macroeconomic stock price determinants have used interest rates, industrial production, inflation rates, stock market indexes, and global oil prices in their estimations. Their extensive use in research indicates that these macroeconomic indicators significantly influence stock prices.

It is intuitive to think that stock prices react to the state of the economy. A nation's GDP and industrial production usually gives a reflection of a nation's real output level. A nation's output level has been shown in economic theory and research to impact how stock markets perform. Increases in output level leads to a higher expected future cash flow, implying higher dividends and earnings for firms in stock markets (Humpe & Macmillan 2007; Narayan, *et al*., 2014). A reliable measure of a nation's production level and

economic activity is captured in the industrial production index. Unlike other macroeconomic indicators, industrial production has a somewhat consistent place in literature on how it affects stock prices. A positive association between industrial output and stock prices has been documented across different industries, sectors and nations (Chen, *et al*., 1986; Abugri, 2008; Humpe & Macmillan, 2009; Pramod-Kumar & Puja, 2012; Shahzad, *et al*., 2020; Peiro, 2016; Tiryaki, Ceylan, & Erdoğan, 2019).

One of the key variables in the study of how macroeconomic factors affect stock prices is the interest rate. It has direct links to economic growth and provides insight into the opportunity cost of investing in equity markets. The interest rate has different implications for different individuals in an economy. For a borrower, the interest rate reflects the cost of borrowing funds while for a lender, it reflects the benefits associated with lending out money. In times of rising interest rates in the economy, investors who own funds move their capital away from the stock market and toward the bank when the interest rate paid by the latter to depositors rises, leading to a decline in demand for stocks and ultimately, stock prices fall. Conversely, falling interest rates in the economy cause investors who own funds to move their capital out of the bank and to the stock market, leading to a rise in demand for stocks and ultimately, stock prices rise (Alam and Uddin, 2009; Narayan, *et al*., 2014; Shahzad, *et al*., 2020). The literature on the interest rate as a macroeconomic determinant of stock prices has been mixed over the years. Bhargava, (2014), Humpe & Macmillan (2009), Eita (2012) , Fama (1981), Abugri, (2008) and Ajaz, *et al*. (2017) all report a negative effect of interest rates on stock prices, while Asprem (1989), Shiller & Beltratti (1992) and Apergis & Eleftheriou (2002) reported that interest rates had a positive influence on stock prices. They argued that a rise in interest rates may

cause investors to expect future fundamentals, like dividend returns, to rise, which will raise stock prices. Alam & Uddin (2009) go on to attribute the mixed results to differences in stock market conditions, industries, or countries.

The use of oil prices in stock price research is growing. Research by Yun & Yoon (2018), Pooja (2017) and Ciner (2013) have been able to establish how global oil prices can impact stock prices in industries, sectors, and countries. Changes in global oil prices can affect expected cash flows and discount rates, since they could directly impact the cost of doing business (Hamilton, 2009). Similar to interest rates, the relationship between global oil prices and stock prices is not fixed in the literature. Some researchers argue that global oil prices positively impact stock prices (Basher & Sadorsky, 2006; Choi & Hammoudeh, 2010; Ciner, 2013), while some suggest the relationship is inverse (Yun & Yoon, 2018; Pooja, 2017). Chen, *et al*.(1986) suggest that oil prices have no impact on stock prices. de Jesus (2020) argue that the type of relationship depends on the country where the research is carried out, suggesting a positive long-term relationship between global oil prices and stock prices in oil-exporting countries and a negative long-term relationship between global oil prices and stock prices in oil-importing countries. Other researchers attribute this inconsistency to the nonlinear and asymmetric nature of the relationship as well as the nature of the market at the time of the analysis (Ciner, 2013; Shahzad, *et al*., 2020).

Inflation, in simple terms, is a measure of change in the general price level of an economy. Inflation gives a description of the purchasing power of income. Inflation has several measures and four of the most common are Consumer Price Index (CPI), Producer Price Index (PPI), Personal Consumption Expenditure (PCE), and GDP-Deflator (De

Gaetano, 2021). Any one of these could be used as proxies for inflation rates in research and of these four proxies, however, the consumer price index is the most used in research as a proxy for inflation rates (Eita, 2012). Inflation rates have been used conventionally in stock price determinant research since it was first described in the work of Fisher (1930). Since then, there have been conflicting perspectives on how it affects stock prices and returns. Choudhry (2001) , Kyriacou (2006) and Alagidede (2009) argue that inflation rates and stock prices have a positive association, while Fama (1981), Eita (2012) and Alqaralleh (2020) suggest that inflation rates and stock prices have a negative association. These contradictory views are a testament to how different market and country conditions reflect the effect of inflation.

Stock indexes like the S&P 500 Index have been used in research, mostly as dependent variables (Bhargava, 2014; Mgammal, 2018; Bahmani-Oskooee & Saha, 2015). However, the literature also shows that stock indexes can be used as independent variables on other dependent factors (Na & Shon, 2011). In the case of stock price research, the idea assumes that leading markets/industries affect emerging markets/industries. The S&P 500 Index is included in this study as an independent variable to serve as the alternative equity investment destination for investors. The response of investors in the hemp industry to movements in the S&P 500 Index could give some insight into how the boom or decline of alternative investment destinations on the stock prices of U.S hemp firms.

The estimation methods have also evolved in the area of macroeconomic stock price determinant research. From the use of linear methods of estimation to dynamic methods of estimation. Methods such as the Ordinary Least Square Regression method (Sharif, Purohit & Pillai, 2015; Milošević-Avdalović, 2018), Arbitrage Pricing Theory

(Chen, *et al*., 1986; Habib and Islam, 2017), Markov Switching Vector Autoregression (Bahloul, Mroua, & Naifar, 2017; Cevik & Bugan, 2018), and Vector Error Correction Model with causality tests (Pramod-Kumar & Puja, 2012; Eita, 2012; Pooja, 2017) have been used in macroeconomic stock price determinant research. However, more recent models such as the Autoregressive Distributed Lag Model (Alqaralleh, 2020; Shahzad, *et al*., 2020) and its variants are gaining prominence in this area of research. The use of dynamic estimation models like the ARDL, NARDL and QARDL models have a growing popularity in more recent studies on stock price determinants and other areas of research.

Prior to the use of more dynamic econometric models, traditional linear models were used to estimate macroeconomic stock price determinants. These linear econometric models fail to consider the asymmetrical and nonlinear relationships that could exist between stock prices and their macroeconomic determinants. They also ignore the possible differences in how stock prices respond to changes in macroeconomic indicators under different stock market conditions. Chen, *et al*. (1986), Habib and Islam (2017), Sharif, Purohit & Pillai (2015) and Milošević-Avdalović (2018) all assumed that a linear and symmetric relationships exists between stock prices and macroeconomic variables, failing to account for the possibility of asymmetry in the relationship. In a broader view, the conflicting results in the literature of macroeconomic stock price determinants comes down to the use of models that do not account for the nonlinear and asymmetrical relationships that exist between these macroeconomic indicators and stock prices. More recent dynamic models used by researchers such as Bahmani-Oskooee and Saha (2015), Ajaz *et al*., (2017), Alqaralleh (2020), and Shahzad, *et al*., (2020) account for these nonlinearities and asymmetries in the variables.

While more recent studies have employed dynamic models, a plethora of studies in the area of macroeconomic stock determinants have produced some results that seem to conflict with one another. This may be because the linear models employed in their do not perform well when nonlinearity is present. Many variables used in macroeconomic stock price determinant research, including interest rates, stock prices, and inflation, do in fact have nonlinear characteristics. In essence, using linear models to examine the relationship between stock returns and these macroeconomic stock price determinants may not be appropriate and may result in false conclusions (Madadpour and Asgari, 2019; Alqaralleh, 2020).

With the large amount of work done on the macroeconomic determinants of stock prices, there are several macroeconomic indicators that have been used by researchers overtime – Interest Rates, GDP, Industrial Production, Consumer Price Index, Inflation Rates, Unemployment Rates, Production Price Index, etc., because economies, sectors and industries differ in how they respond to these macroeconomic indicators at different points in time, but the two most-used macroeconomic indicators are production level and interest rates (Peiro, 2016). This paper adds to the existing literature in macroeconomic stock price determinants by estimating how four macroeconomic indicators impact the stock prices of hemp firms in the US. Also, nonlinear and asymmetric relationships that may exist are accounted for in the model estimation. As stated previously, the macroeconomic variables selected can be grouped into domestic and global determinants of stock prices. The Interest Rates, Industrial Production, and S&P Index represent domestic determinants while the Global Oil Prices represent the global determinants (Khan, *et al*., 2015). The definition,

symbols, units of measurements, expected signs, and sources of the study variables is presented in Table 3.1.

3.5. Data and Empirical Methodology

3..5.1. Data

With hundreds of studies carried out in the field of macroeconomic stock price determinants, the study variables used in this paper have been used by researchers such as in this area of study. Based on a thorough review of prior literature by researchers such as Fama(1981), Chen, *et al*. (1986), Paul & Mallik (2003), Habib and Islam (2017), Sharif, Purohit & Pillai (2015), Choudhry (2001) , Kyriacou (2006) and Alagidede (2009), Milošević-Avdalović (2018) and Huy, Loan & Pham (2020), four macroeconomic variables are selected. Data on the four selected macroeconomic variables - Industrial Production Index, Interest Rates, Global Oil Prices and the S&P Index is collected over a 4-year from period January 2019 to December 2022. Monthly data on stock prices (for 32 hemp firms) is also collected. The data sources are presented as part of Table 3.1.

The Industrial Production Index serves as a proxy for economic activity, the West Texas Intermediate (WTI) crude price is used as a proxy for the global oil prices. The WTI price is preferred as it is generally considered as the primary benchmark spot oil price for North America. The S&P Index is included to serve as proxy for the US aggregate equity markets, which serve as an alternative for investors. Also, the 10-year Treasury Bills Rate is used as proxy for interest rate. Long-term interest rates are chosen over short-term interest rates. Unlike short-term interest rates that show more volatile behavior and

are primarily influenced by monetary policy, long-term interest rates (Humpe & Macmillan, 2009; Shahzad, *et al*., 2020).

Monthly data on the S&P 500 is also collected as part of the study. We include the S&P 500 index to represent an alternative avenue of investments for potential investors. The S&P 500 is used as a proxy for the US large cap market in financial research. It accounts for about 75 percent of the US equity market since the index represents the 500 most successful publicly held businesses in the US economy**.**

Table 3.2 provides the descriptive statistics, expected relationships, and normality test results for the dependent (monthly stock prices of 32 US hemp firms) and independent study variables (the four macroeconomic indicators) for the entire panel over the study period. The table shows that the study variables are all non-normal, as shown by the Jarque–Bera test and statistics which reject the normal distribution of data series at 1% significance level. This suggests that the use of conventional econometric models like the OLS regression would yield problematic results since the requirement of normality is not fulfilled in the data. All variables are presented in their natural logarithms. Figure 3.1 shows the movement of all four macroeconomic variables, while Figure 3.2 shows the movement of US hemp stock prices over the study period. The US Industrial Production Index and S&P 500 Index show upward and steady trends, with slight downturns in late 2019 and early 2020, when the COVID-19 pandemic was in its early days. Oil prices and Interest rates show a mixed pattern, falling before the COVID-19 outbreak and later trending upwards after. US hemp stock prices show an erratic up and down pattern, suggesting the volatility of these stocks.

3..5.2. Empirical Method

Bahmani-Oskooee and Saha (2015); Ajaz *et al*., (2017); Alqaralleh, (2020), and Shahzad, *et al*., (2020) show that the relationship between stock price and its macroeconomic determinants are not always linear and symmetric. This implies that the degree of impact of these macroeconomic variables on stock prices vary in magnitude when they either increase or decrease, i.e., the response of stock prices to these macroeconomic indicators in one condition of the financial cycle is different from the response in another condition (Canepa, *et al*., 2019).

To account for the nonlinearities and asymmetries between the dependent and the independent variables, this study employs the nonlinear autoregressive distributed lag (NARDL) model to estimate the effects of the selected macroeconomic variables on the stock prices of US hemp firms. This model allows for asymmetries to be captured in the movement of macroeconomic indicators and stock hemp prices.

The NARDL model goes beyond the traditional ARDL model by capturing the effects of asymmetry. This is captured in the model by the decomposition of the independent variables into two parts:

(1) The partial sum of the positive change in the independent variable, denoted by X^+

(2) The partial sum of the negative change in the independent variable, denoted by X^-

These two partial sums are then used as separate regressors in the model estimation.

The NARDL model was developed by Shin, *et al*. (2014) and has gained widespread use among researchers (Sheikh, *et al*., 2017; Phong, *et al*., 2019; Allen & McAleer, 2020; Alqaralleh, 2020; Asadullah, *et al*., 2021) since it was developed.

The general form of the ARDL model is presented below in equation 3.1:

$$\Delta Y_{it} = \alpha_{0i} + \alpha_1 Y_{it-1} + \beta_i X_{t-1} + \theta_1 \sum_{j=0}^{p} \Delta Y_{it-1} + \gamma_i \sum_{j=0}^{q} X_{t-1} + \epsilon_{it} \qquad (3.1)$$

where the long-run coefficient for both dependent and independent variables are represented by α_1 and β_i respectively. The short-run coefficients for the dependent and independent variables are represented by γ_i and θ_1 respectively; Y_{it} represents the dependent variable; X_t represents the independent variables and ε_{it} represents the disturbance term The variables are used in the model as lags, lags of first differences, and differences.

However, the NARDL introduces a correction for asymmetry by breaking down the independent variables into partial sums to account for negative and positive fluctuations. X_{it} represents the independent variables decomposed into their negative and positive fluctuations (X^- and X^+). The decomposition is presented in equations 3.2 to 3.4 below:

$$X_t = X_t^- + X_t^+ \qquad (3.2)$$

$$X_t^- = \sum_{j=1}^{t} X_t^- = \sum_{j=1}^{t} min(\Delta X_t^-, 0) \qquad (3.3)$$

$$X_t^+ = \sum_{j=1}^{t} X_t^+ = \sum_{j=1}^{t} max(\Delta X_t^+, 0) \qquad (3.4)$$

The fully decomposed form of the NARDL model estimation for the effects of four macroeconomic variables on U.S hemp stock prices is presented in equation 3.5 below:

$$\Delta SPC_{it} = \phi_{0i} + \sum_{i=1}^{p-1} \lambda_{ij}\, \Delta SPC_{it-1} + \sum_{j=1}^{q-1} \psi_1^{+}\, \Delta INP_{t-1}^{+} + \sum_{j=1}^{q-1} \psi_1^{-}\, \Delta \mathrm{INP}_{t-1}^{-}$$

$$+ \sum_{j=1}^{q-1} \psi_2^{+}\, \Delta \mathrm{RINT}_{t-1}^{+} + \sum_{j=1}^{q-1} \psi_2^{-}\, \Delta \mathrm{RINT}_{t-1}^{-} + \sum_{j=1}^{q-1} \psi_3^{+}\, \Delta \mathrm{SP500}_{t-1}^{+}$$

$$+ \sum_{j=1}^{q-1} \psi_3^{-}\, \Delta \mathrm{SP500}_{t-1}^{-} + \sum_{j=1}^{q-1} \psi_4^{+}\, \Delta \mathrm{WTI}_{t-1}^{+} + \sum_{j=1}^{q-1} \psi_4^{-}\, \Delta \mathrm{WTI}_{t-1}^{-} + \varphi_{1i}\mathrm{SPC}_{it-1}$$

$$+ \delta_1^{+}\mathrm{INP}_{t-1}^{+} + \delta_1^{-}\mathrm{INP}_{t-1}^{-} + \delta_2^{+}\mathrm{RINT}_{t-1}^{+} + \delta_2^{-}\mathrm{RINT}_{t-1}^{-} + \delta_3^{+}\mathrm{SP500}_{t-1}^{+}$$

$$+ \delta_3^{-}\mathrm{SP500}_{t-1}^{-} + \delta_4^{+}\mathrm{WTI}_{t-1}^{+} + \delta_4^{-}\mathrm{WTI}_{t-1}^{-}$$

$$+ \epsilon_{it} \qquad (3.5)$$

where:

SPC_{it} represents the monthly stock price of US hemp firms; INP_t represents the monthly industrial production in the US (proxy for economic output/activity); $RINT_t$ represents the monthly treasury bill rate in the US (proxy for interest rate); $SP500_t$ represents the monthly value of the S&P 500 Index (used as a proxy for alternative investments); WTI_t represents the prices of the West Texas Intermediate (global oil price proxy). ψ_1^{+} to ψ_4^{+} and ψ_1^{-} to ψ_4^{-} represent the NARDL short run coefficients; δ_1^{+} to $\delta_4^{+}$and δ_1^{-} to δ_4^{-} represent the NARDL long run coefficients, and ϵ_{it} represents the disturbance term/white noise.

The NARDL model presented explains both long and short-run asymmetries and can also be estimated by OLS regression since the variables have been transformed into their linear forms (Allen & McAleer, 2020). The use of the NARDL model in this study has a few advantages over conventional cointegration models. First, the model can handle a mix of cointegration orders in its estimation, i.e., I (0) or I (1) or both can be included in

the model. Second, the model allows for small sample sizes to be estimated. Third, since the model takes lags of the variables used, the problem of endogeneity does not plague the model estimation. However, the model develops a bottleneck in its estimation if any of the variables become stationary at the second difference, i.e., the study variables are I (2). This makes the requirement for level or first difference stationarity an essential requirement for using the model (Pesaran, *et al*., 2001; Shin, *et al*., 2014; Phong, *et al*., 2019; Cho, *et al*., 2021; Leszczensky & Wolbring, 2022).

One of the distinctions of the NARDL from the traditional ARDL model is the asymmetry check incorporated in the model. The test of asymmetry is based on Wald tests of the partial sums in the model. Each set of partial sum coefficients will be tested to check for asymmetric impacts of the macroeconomic indicators on the stock prices of U.S hemp firms. The results of the Wald tests show if the partial sums are statistically different from one another, and a rejection of the null hypothesis leads to the conclusion that the selected macroeconomic variables have asymmetric effects in the short and long run on the stock prices of US hemp firms.

3.6 Estimation Results

3..6.1. Unit Root Test Results

The unit root test results give an indication of the integration property of the variables used in the model (Hsu, 2017). Carrying out the unit root tests paves the way for the application of the NARDL model and validates its use in the study (Phong, *et al*., 2019). Table 3.3 shows the results of the unit root test of the variables used in the study. The Fisher-type test is employed due to the unbalanced nature of the panel (Stata, 2005). For

the unit root test, the null hypothesis that all the panels contain a unit root and an alternative hypothesis state that the panels are stationary (Choi, 2001; Allen & McAleer, 2020; Asadullah, *et al*., 2021).

The Fisher-type test results show that industrial production is stationary at level while all other variables are stationary at first difference. Based on the results, we conclude that the study variables are all stationary at the first difference and are integrated of order zero and order one, i.e., I (0) and I (1). The results found none of the variables to integrated on I (2), implying that the NARDL model is an applicable model to estimate the effects of the selected macroeconomic determinants on the stock prices of U.S hemp firms.

3..6.2. NARDL Model Estimation Results

Table 3.4 shows the results of the NARDL model estimation of the effect of the four selected macroeconomic variables on the stock prices of U.S hemp firms. The results from Table 4.2 show the short-run and long-run effects of all four selected macroeconomic variables, by their positive and negative fluctuations. The table also includes the results of the Wald asymmetry tests of the decomposed form of the independent variables.

The results show that the stock prices of US hemp firms respond positively to positive fluctuations in industrial production in the US economy in the short run and in the long run. However, negative movements in industrial production fluctuations in the US economy are insignificant both in the short and long run. This suggests that US hemp firms could potentially reap the benefits of increased economic activity in the long run but gain even more in the short run. This could be of importance to potential investors who are more interested in making short-term investments in the hemp industry.

The results show that the stock prices of US hemp firms respond in an inverse manner to positive and negative fluctuations in the interest rate in the U.S economy in the short run and long run, in an asymmetric manner with the positive movements creating a larger impact than the negative movements. These results suggest that rising interest rates cause the stock prices of US hemp firms to fall, as investors are incentivized to move their investments to higher interest ventures that yield more for the risk of lending.

The results show that the stock prices of US hemp firms respond positively to positive and negative fluctuations in the S&P 500 Index in the short run but react negatively to positive and negative fluctuations in the S&P 500 Index in the long run. These results suggest that rises in the value of S&P 500 firms could incentivize investors to move their investments to firms in the S&P 500 as time passes, even if they could be unmoved initially. Potential investors could look to hemp stocks as a way of growing their financial portfolios in times of overall stock market declines but only in the short run. Long-run results could lure potential investors away from hemp stocks since the overall stock markets show a better level of returns over hemp stocks.

The results show that the stock prices of US hemp firms respond positively to positive fluctuations in global oil prices in the short run but react negatively to the same positive fluctuations in global oil prices in the long run. Negative fluctuations are insignificant in both the short run and long run. These results suggest that hemp firms could potentially reap the gains of rising oil prices in the short term as the rising prices could spur increased economic activity. However, the rise in costs could potentially catch up in the long term, leading to a decline in stock prices.

The results of the NARDL estimation shows the presence of asymmetries in the associations of the macroeconomic variables on U.S hemp stock prices, suggesting that the macroeconomic indicators, depending on the direction of the fluctuations, show significant impacts on stock prices of US hemp firms. Our results of the asymmetry tests agree with prior literature (Alqaralleh, 2020; Allen & McAleer, 2020; Sheikh, *et al*., 2020; Asadullah, *et al*., 2021) that shows that macroeconomic indicators usually associate with stock prices in an asymmetric manner and confirm an asymmetrical relationship between the selected macroeconomic variables and the stock prices of US hemp firms. The presence of asymmetry is a warning signal to potential investors and firm managers in the hemp industry to carefully examine movements in macroeconomic variables before making investment or ass*et al*location decisions since positive and negative effects do not usually yield the same effects on hemp stock prices in the US As part of the model diagnostics, the error correction term of the NARDL model estimated is both significant and negative, satisfying the requirements for long run cointegration of the independent variables. The error correction term of the NARDL model also estimates the speed at which the stock prices of US hemp firms attain stability and return to equilibrium after a change in the selected macroeconomic indicators (Narayan & Smyth, 2006; Chandio, *et al*., 2019). The value of the error correction term is -1.012, signifying a faster speed of adjustment when compared to the traditional ARDL estimation which had an error correction term of -0.0741 (presented in Table 3.5). Overall, the results indicate the presence of asymmetries in how macroeconomic factors affect the stock prices of US hemp firms.

As part of the analysis, the OLS results are included in the study to give an idea of the descriptive relationship between US hemp firms and macroeconomic factors. The

results of the OLS estimation of the study variables are presented in Table 3.6. The results indicate that US hemp firms have a positive relationship with Industrial Production and Global Oil Prices while a negative relationship is observed between US hemp firm stocks and long-term interest rates and the S&P 500 Index. And just like the NARDL results, Industrial Production and S&P 500 Index have the largest positive and negative effects of US hemp stocks.

The results agree with prior expectation and some prior literature like Humpe & Macmillan (2009), Bhargava (2014), Peiro (2016), Ajaz, et al. (2017) and Shahzad, et al. (2020) regarding the description of the relationship between these macroeconomic variables and US hemp stocks, except global oil prices which were expected to have a negative effect on US hemp stocks, in agreement with literature by Pooja (2017) and Yun & Yooh (2018) but the model estimated the relationship to be positive, in agreement with Basher & Sadorsky (2006) and Ciner (2013).

All three models used show that relationships exist between the selected macroeconomic variables and US hemp stocks. However, the OLS estimation gives an idea of the descriptive relationships that exist while the ARDL and NARDL model estimate what these relationships could be in the short-run and long-run. Furthermore, the NARDL results predict that these variables are associated with US hemp stocks in an asymmetrical manner. Besides the improvement in error correction and log likelihood values of the NARDL model over the ARDL model, the NARDL model captures asymmetry in the effects of the selected macroeconomic variables on the stock prices of US hemp firms.

When compared to the other macroeconomic factors employed in this study, the Industrial Production Index has the largest short-run effect while the S&P 500 Index has the largest long-run effects on US hemp stock prices.

3.6.3. Result Discussion

The Industrial Production Index affects the stock prices of US hemp firms in both the short run and long run. However, the short run effects are larger. Industrial production can be a reliable metric for measuring economic activity and health and have an impact on stock prices. Essentially, more economic activity causes stock prices to rise. The results indicate that hemp stock prices respond more to increased economic activity in the short-run, benefiting more in the short term when economic activity in the US economy surges than in the long-run. For investors, observing production levels through the Industrial Production Index could serves as a metric that quantifies how much stock prices could rise since increased industrial production translates to increased returns on stocks through dividends and other payouts to investors.

The US 10-year Treasury bond rate is proxy for interest rates, and they show an inverse relationship with US hemp stock prices. Since the effects of the rising interest rates are detrimental to stock prices, this study confirms that falling interest rates have a favorable influence on US hemp stock prices. For investors, rising interest rates puts them in a dilemma as they could invest in higher interest paying bonds over hemp stocks. Rising interest rates are particularly unfavorable for the US hemp industry since managers are faced with falling corporate earnings which in turn, affects returns on funds put in by investors, reflected in falling stock prices. For firm managers in the hemp industry, a falling

interest rate would be desirable and would spark investor sentiment to invest in stocks over bonds or treasury bills.

The WTI crude oil price also shows short-run and long run variation. While oil prices favor US hemp stock prices in the short run, the relationship turns inverse in the long run. The results suggest that the rising costs caused by rising oil prices is not immediately felt in the US hemp industry. However, these rising costs show up in the long run and cause stock prices to fall. Crude oil prices are a metric for describing the level of economic activity, but they also represent rising costs of economic activity. Investors could use oil prices as a metric for hemp stock returns in the short run but not in the long run since the rising oil prices are reflected in rising costs that slow down returns.

The S&P 500 Index as a macroeconomic variable has not been addressed in previous literature. The S&P 500 Index influences the stock prices of US hemp firms both in the short run and in the long run. The signs on the coefficients also lead to a few suggestions. The short-run results are positive, suggesting that hemp stock prices move together with the S&P 500 Index as it rises. However, the long-run movement is inverse, suggesting that the S&P 500 Index could take away investors from US hemp investors if it continues to rise in the long run. This evidence is of importance to potential investors as they can make decisions to either invest in hemp firms in the short run or assume more risk with a long-term investment in the industry. Investors could be drawn to the overall stock market – represented by the S&P 500 Index over hemp stocks if they value long term gains over short term earnings. For hemp firm managers, they must find ways to keep investors in their firms and avoid long-term loss of these investors to the larger and arguably more stable S&P 500 Index companies.

Based on the expectations for the study variables and the mix of coefficient signs observed in the study results, the variables in the study show asymmetric association with US hemp stock prices, with the positive fluctuations having a larger effect than the negative fluctuations.

Macroeconomic factors are mostly out of the control of most investors and could sometimes be erratic in how they trend. However, for potential investors, knowing how these macroeconomic factors could possibly affect investments in a certain aspect of an economy could prove invaluable while making decisions on whether or whether not to add certain stocks to their financial portfolios.

3.7 Conclusions

The global hemp industry has been touted to reach as high as $16.7 Billion by the end of the decade (Research and Markets, 2022). However, some industry experts and researchers put the global value of the hemp industry lower than this figure while some others think the value could exceed the figure above by 2030. These figures reflect the optimism on the growth and expansion potential of the hemp industry since more states in the US are beginning to legalize hemp production and the demand for hemp derived products have been on the rise in the last few years. The industry is in its resurgence in the US and to compete globally and gain a good share of the potential growth, as forecasted, investment in the hemp industry in the US is crucial. Stock price movements are affected by a variety of factors that must be considered by the investor while making investment decisions.

This paper examined the macroeconomic determinants of the stock prices of industrial hemp firms in the US using the NARDL model. Four major macroeconomic indicators (Interest Rates, Industrial Production, S&P 500 Index, and Global Oil Prices) were employed in this study over a four-year period, from January 2019 to December 2022. The start of the study period reflects the start of the legal production of hemp in the U.S after the passing of the 2018 Farm Bill. The results show that asymmetrical relationships exist in both the short run and long run between US hemp stock prices and the selected macroeconomic indicators. More specifically, the Industrial Production Index and the S&P 500 Index show the largest short-run and long run effects on US hemp stock prices respectively. Interest rates show an obvious negative relationship in both the short-run and long run, indicating that rising interest rates favors stock prices. Global oil prices produce a positive effect in the short run, but rising costs cause stock prices to fall in the long run.

The findings are important to potential investors, hemp firm managers, and policymakers in the U.S hemp industry as they bring to light a better understanding of how macroeconomic indicators influence the stock prices of publicly traded hemp firms in the US The study results suggest that both positive and negative movements in the selected macroeconomic variables influence the stock prices of US hemp firms. However, the positive fluctuations show a greater impact on the stock prices of US hemp firms.

A keen understanding of movements and their effects would be an invaluable tool for potential investors when they make decisions to invest in firms involved in the U.S hemp industry. This paper recommends that potential investors consider both positive and negative shocks in macroeconomic indicators before investing in firms in the US hemp industry. More specifically, potential investors can look at these macroeconomic indicators

as tools in making objective decisions regarding hemp stocks. From the perspective of firm managers and owners, this paper provides objective insights on how fluctuations in macroeconomic variables such as the long-term interest rates, industrial production index, oil prices, and the S&P 500 Index influences the movement of the stock process of their firms and would help in asset allocation to yield the best returns for investors. For policymakers, this study shows how changes in macroeconomic policies such as interest rates could affect the stock prices of US hemp firms. Based on this, policymakers could consider the results of this study in formulating policies that could foster growth in the US industrial hemp industry since policies that affect major stock exchanges influence the hemp industry.

Tables and Figures for Chapter 3

Table 3.1. Variable Definition, Symbols, Unit of Measurement, and Expected Signs

Variable Definition	Symbol	Unit of Measurement	Expected Sign	Data Source
Monthly stock price of US hemp firms	SPC	US $	NA	Yahoo Finance
Monthly industrial production in the US (proxy for economic output/activity)	INP	Index	+	Federal Reserve Bank of St. Louis
Monthly treasury bill rate in the US (proxy for interest rate)	RINT	percentage	-	Federal Reserve Bank of St. Louis
Monthly value of the S&P 500 Index; used as a proxy for alternative investments	SP500	Index	-	Federal Reserve Bank of St. Louis
Monthly prices of the West Texas Intermediate (global oil price proxy)	WTI	US $	-	Federal Reserve Bank of St. Louis

Table 3.2. Descriptive Statistics and Normality Tests of Study variables

Variable	SPC	INP	RINT	S&P 500 Index	WTI
Observations	1,325	1,325	1,325	1,325	1,325
Mean	0.7285	4.6093	0.4975	8.2072	4.1387
Standard Deviation	1.8626	0.0423	0.5245	0.1699	0.3772
Minimum	-5.0995	4.4422	-0.5978	7.8573	2.9565
Maximum	5.649	4.645	1.411	8.4693	4.7395
Skewness	-0.5207	-2.1532	-0.2276	-0.3033	-0.9122
Kurtosis	3.0169	8.3099	2.354	1.8029	4.2327
Jarque–Bera	59.9**	2580**	34.48**	94.44**	267.7**

**Significant at 1% level

Table 3.3. Fisher-type Unit Root Test Results

Variable	Level	p-value	First Difference	p-value
Hemp Stock Prices	7.15	0.5056	-28.77**	0.0000
Industrial Production Index	-6.10**	0.0000	-35.69**	0.0000
10-year Treasury Bond Yield	4.50	0.5647	-13.96**	0.0000
S&P 500 Index	0.55	0.7096	-42.17**	0.0000
West Texas Intermediate Price	-1.39	0.0832	-36.60**	0.0000

**Significant at 5%

Table 3.4. NARDL Model Estimation and Asymmetry Test Results

Variable	Short-Run Effect			Long-Run Effect		
	Positive	Negative	Wald Test	Positive	Negative	Wald Test
Industrial Production Index	2.27**	2.10	6.78**	1.64*	-0.38	3.65
10-year Treasury Bond Yield	-0.31**	-0.17*	23.89**	-0.99**	-0 .45**	52.04**
S&P 500 Index	1.48**	2.13**	6.45**	-3.35**	-2.13**	4.35**
West Texas Intermediate Price	0.60**	0.01	31.68**	-0.64**	-0.05	12.04**
Diagnostics						
Log Likelihood	411.13					
Error Correction	-1.01**					

**Significant at 5%

Table 3.5. ARDL Model Estimation Results

Variable	Short Run	p-value	Long Run	p-value
Industrial Production Index	0.50	0.3931	12.82**	0.0061
10-year Treasury Bond Yield	0.16	0.0574	-2.63**	0.0000
S&P 500 Index	1.49**	0.0000	-2.69**	0.0023
West Texas Intermediate Price	0.18**	0.0004	0.48	0.4156
Diagnostics				
Log Likelihood	249.47			
Error Correction	-0.07**	0.0000		

**Significant at 5%

Table 3.6. Ordinary Least Square (OLS) Model Estimation Results

Variable	Coefficient	p-value
Industrial Production Index	5.00	0.000
10-year Treasury Bond Yield	-0.97	0.000
S&P 500 Index	-1.23	0.000
West Texas Intermediate Price	0.56	0.002
Diagnostics		
R-Squared	0.02	
F-Value	171.56	0.0000

**Significant at 5%

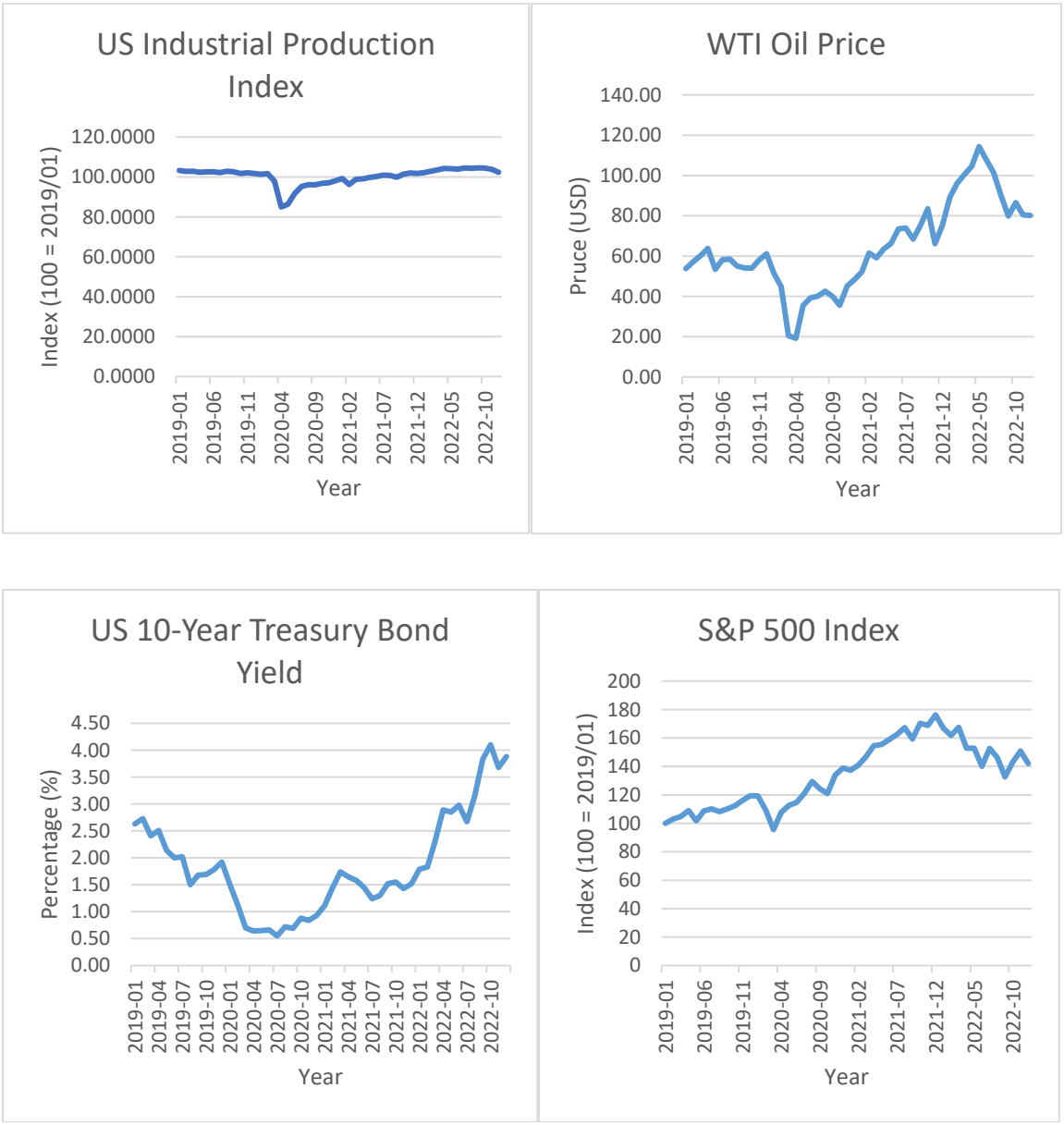


Figure 3.1: Movement of Macroeconomic Variables over the Study Period

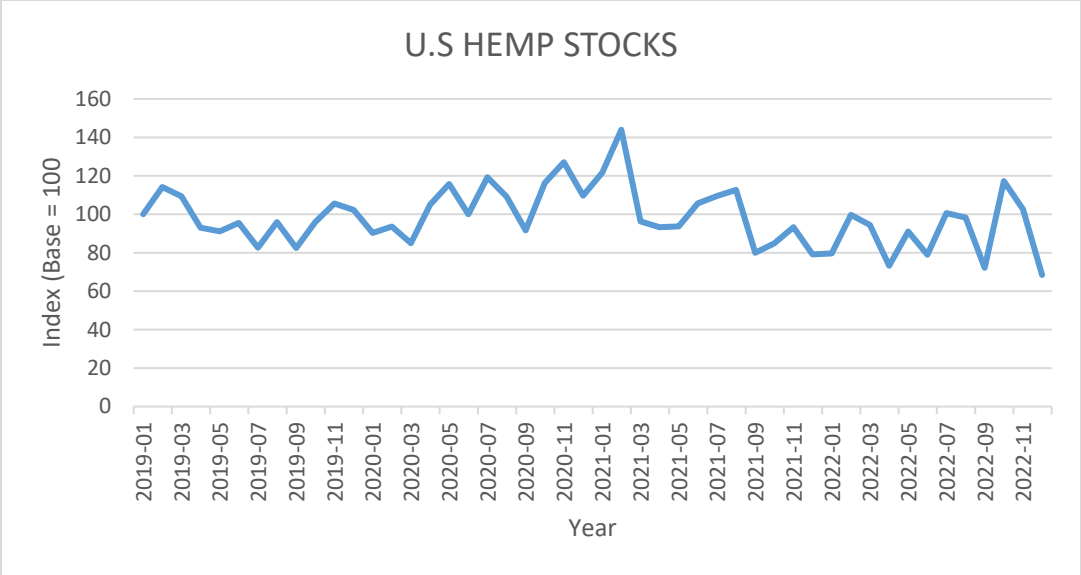


Figure 3.2: Movement of Selected US Hemp Stocks over the Study Period.

CHAPTER 4. SUMMARY

As a comeback crop in the US agricultural sector, industrial hemp has garnered the interest of investors who believe the industry would grow exponentially in the coming years. According to Research and Markets (2022), the hemp industry would be worth upwards of 20 billion dollars globally by 2030. Numbers like this could be suspect but are driven by the rising demand for hemp products. Despite the potential in the industry, investors do not have a whole lot of reliable peer-reviewed data to draw from as research on the hemp industry is very little and mostly non-peer reviewed. To contribute to the thin literature in the fledgling US hemp industry, this paper contributes two essays on US hemp stocks.

In the first essay, we investigate how US hemp stocks compare to mid-cap and large-cap stocks in the US economy using a mix of descriptive statistics, correlation analysis, and the Kruskal-Wallis Test. The results show that US hemp stocks come with a high degree of risk for investors, due to their high level of risk but they could be used to hedge against sliding losses in period of market declines since their returns are not as responsive when compared to the overall stock market. In terms of price movements, US hemp stocks show weak correlation with mid-cap and large-cap stocks, suggesting a low level of association. In addition, US hemp stocks are very different from mid-cap and large-cap stocks since the results suggest that US hemp stocks are not drawn from the same distribution as mid-cap and large-cap stocks.

The second essay investigates the macroeconomic determinants of the stock prices of 32 industrial hemp firms in the US in the short-run and long-run using the nonlinear autoregressive distributed lag model over a four-year period. Based on prior literature, four

major macroeconomic indicators - Interest Rates, Industrial Production, S&P 500 Index, and Global Oil Prices are employed in the study. The results suggest the presence of asymmetric relationships, both in the short run and long run between US industrial hemp stock prices and the selected macroeconomic indicators. The results also suggest that positive fluctuations in these macroeconomic indicators have larger impacts the stock prices of US industrial hemp firms than negative fluctuations, suggesting that the stock prices of US industrial hemp firms respond more to positive movements in macroeconomic indicators than they do to negative movements in macroeconomic indicators.

The findings shed light on how industrial hemp stocks compare to mid-cap and large-cap stocks, giving investors an idea of how to include or exclude industrial hemp and non-industrial hemp stocks in their investment portfolios, based on their trends and returns. The findings also bring to light a better understanding of how macroeconomic indicators influence the stock prices of publicly traded industrial hemp firms. Using these findings, stakeholders in the hemp industry get valuable knowledge in making investment decisions, ass*et al*location, resource hedging and policy design.

APPENDICES

APPENDIX 1. Abbreviations

ARDL: Autoregressive Distributed Lag

CAGR: Compound Annual Growth Rate

CSA: Controlled Substance Act

FRED: Federal Reserve Bank of St. Louis Economic Data

NARDL: Nonlinear Autoregressive Distributed Lag

OLS: Ordinary Least Squares

OTC: Over the Counter

QARDL: Quantile Autoregressive Distributed Lag

UNCTAD: United Nations: United Nations Conference on Trade and Development

USDA: United States Department of Agriculture

WTI: West Texas Intermediate

APPENDIX 2. U.S Hemp Firms Employed in the Study

Firm	Location	Market Capitalization	Cannabis Section
Curaleaf Holdings Inc.	New York, NY	2.44B	YES
Green Thumb Industries Inc.	Chicago, IL	1.917B	YES
Trulieve Cannabis Corp.	Quincy, FL	1.276B	YES
Verano Holdings Corp.	Chicago, IL	993.749M	YES
Cresco Labs Inc.	Chicago, IL	510.28M	YES
Turning Point Brands Inc.	Louisville, KY	355.999M	YES
Columbia Care Inc.	New York, NY	236.179M	YES
Ascend Wellness Holdings Inc.	New York, NY	222.534M	YES
Glass House Brands Inc.	Long Beach, CA	217.342M	YES
Grow Generation Corp.	Greenwood Village, CO	216.527M	YES
Planet 13 Holdings Inc.	Las Vegas, NV	179.793M	YES
WM Technology	Irvine, CA	162.855M	YES
4Front Ventures Corp.	Phoenix, AZ	160.34M	YES
MariMed Inc.	Norwood, MA	143.557M	YES
iAnthus Capital Holdings Inc.	New York, NY	130.252M	YES
Jushi Holdings Inc.	Boca Raton, FL	113.74M	YES
Medicine Man Inc.	Denver, CO	71.274M	YES
Acreage Holdings Inc.	New York, NY	66.875M	YES
Medical Marijuana Inc.	San Diego, CA	59.7M	YES
Ayr Wellness Inc.	Miami, FL	56.567M	YES
Homology Medicines Inc.	Belford, MA	55.948M	YES
Charlotte's Web	Boulder, CO	45.489M	NO
TPCO Holding Corp.	San Jose, CA	26.93M	YES
Tilt Holdings Inc.	Phoenix, AZ	23.641M	YES
Med Men Enterprises	Los Angeles, California	21.355M	YES
Goodness Growth Holdings Inc.	Minneapolis, MN	18.652M	YES
StateHouse Holdings Inc.	San Diego, CA	13.892M	YES
cbdMD Inc.	Charlotte, NC	13.086M	NO
Unrivaled Brands Inc.	Santa Ana, CA	10.70M	YES
Agrify Corporation	Billerica, MA	6.708M	YES
CV Sciences	San Diego, CA	6.006M	NO
Lowell Farms Inc.	Salinas, CA	3.018M	YES

APPENDIX 3. Study Terms and their Definitions

Asymmetry: This is a phenomenon observed when the effect an independent variable on a dependent variable has a different magnitude of effect when it is rising than when it is declining.

Industrial Hemp: Industrial hemp is derived from the plant *Cannabis Sativa* and by definition, contains a tetrahydrocannabinol level of 0.3 percent, or less. Tetrahydrocannabinol (THC) is the psychoactive ingredient in *Cannabis Sativa*.

Large Cap Stocks: A large cap stock in the US financial sector is a stock with a market capitalization above US$ 10 billion. Large cap stocks are among the largest in the stock market, in terms of their market capitalization.

Linear Relationship: This describes a relationship between variables that can be represented by a straight line, i.e., changes in any of the independent variables directly corresponds to changes in the dependent variable.

Marijuana: Just like industrial hemp, marijuana/cannabis is derived from the *Cannabis Sativa* plant. However, when compared to industrial hemp, the levels of tetrahydrocannabinol in marijuana is between 3 to 30 percent.

Market Capitalization: This describes the total market value of securities issued by a firm, industry, sector or market(s). The market capitalization of a firm, sector or industry is calculated by multiplying the market price per share by the number of shares issued.

Mid-Cap Stocks: A mid cap stock in the US financial sector is a stock with a market capitalization above US$ 2 billion and below US$ 10 billion. Mid-cap stocks are among the middle ranked in markets, in terms of their market capitalization.

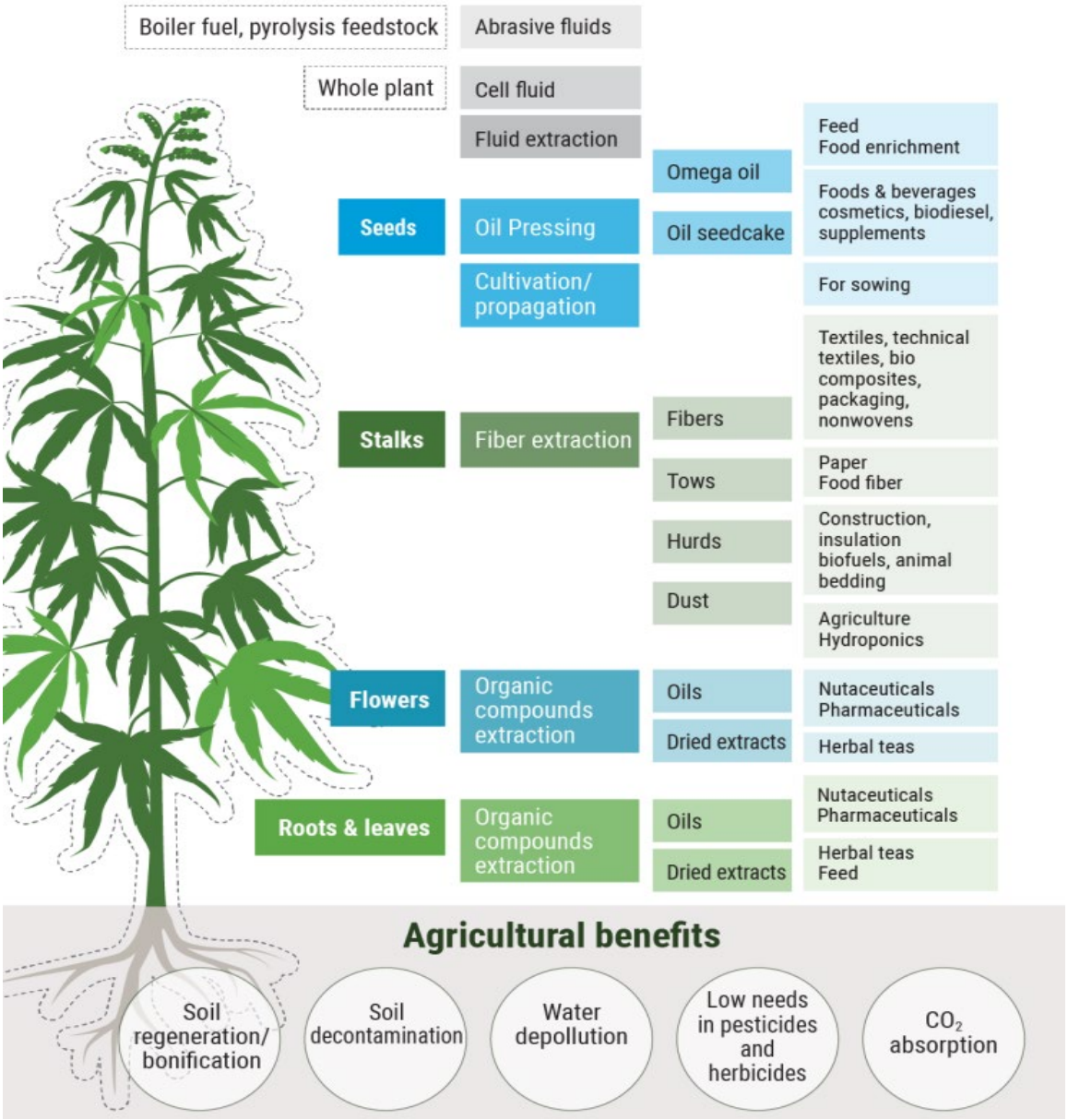
Nonlinear Relationship: This describes a relationship between dependent and independent variables such that connection that cannot be represented by a straight line, i.e., changes in any of the independent variables do not directly correspond to changes in the dependent variable.

Over-the Counter Markets (OTC): OTC markets trade securities using a broker-dealer network. Stocks and bonds are traded in OTC markets, but the majority of the financial contracts are based on an underlying commodity or asset. In this case, industrial hemp.

Small-Cap Stocks: A small cap stock in the US financial sector is a stock with a market capitalization below US$ 2 billion. Small cap stocks are among the small firms in markets, in terms of their market capitalization, even if they usually offer the most room for growth.

Speculative Stocks: Speculative stocks refer to stocks with high risk but with the potential for high returns. These stocks are purchased for the potential high returns that investors "feel" they can get from them. Speculative stocks are often found in industries that are subject to new trends or uncertainties, such as technology, emerging markets, rare materials or pharmaceuticals.

APPENDIX 4. Uses and Agricultural Benefits of the Hemp Plant



Source: UNCTAD (2021)

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VITA

Abraham Olakunle Ajibade

Education/Professional Development

Google Career Certificates (Coursera) — United States
Professional Certificate in Data Analytics — September 2022

University of Benin (Benin-City) — Edo State, Nigeria
Bachelor of Science in Agricultural Economics — October 2017
Advisor: Macson O. Ogieriakhi

Work Experience

University of Kentucky — Lexington, KY
Graduate Research Assistant (Dr. Tyler B. Mark Lab) — January 2021-July 2023

Gidi Mobile Ltd. — Lagos, Nigeria
Content and Learning Intern (Agricultural Science) — May 2018-September 2018

Publications

Ajibade, A., & Saghaian, S. (2022). US Almond Exports and Retaliatory Trade Tariffs. Sustainability, 14(11), 6409.

Ajibade, A., Ogieriakhi, M. O., and Emokpae, O. P. (2018). Technical Efficiency of Pig Producers in Benin Metropolis, Edo State, Nigeria. Nigerian Journal of Agriculture, Food, and Environment, 14(1): 25-30.

Presentations

Agricultural & Applied Economics Association (Poster Presentation) - "Macroeconomic Factors and the Stock Prices of US Hemp Firms" July 23-25, 2023, Washington D.C., USA.

Southern Agricultural Economics Association (Paper Presentation) - "Chinese Retaliatory Tariffs and the Export Demand for US Pistachios" February 12-15, 2022, New Orleans, Louisiana

USDA Hemp Advisory Board Meeting (Poster Presentation) - "What Firm-Specific and Macroeconomic Factors Determine the Prices of Hemp Firms Stocks" October 28, 2021, Lexington, Kentucky

Works in Progress

Thesis: Two Essays on Industrial Hemp Firms in the United States (With Tyler B. Mark)

Honors and Awards

Graduate Research Assistantship, University of Kentucky — January 2021 – July 2023
Department of Agricultural Economics
Best Graduating Student; Department of Agricultural Economics — October 2017
University of Benin, Nigeria
Shell-JV Scholarship — 2014 -2016