Hedging decreases in temperature: a comparison of the hedging effectiveness of frozen concentrated orange juice (FCOJ), natural gas and heating degree days (HDD) futures contracts

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ABSTRACT

Hedging decreases in temperature: a comparison of the hedging effectiveness of frozen concentrated orange juice (FCOJ), natural gas and heating degree days (HDD) futures contracts

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Weather is an important fundamental factor which affects almost every sector of the economy. Previous research on the effect of weather focused on temperature effects and the use of weather derivatives to hedge. This thesis provides an alternative view on hedging against decreases in temperature by comparing the hedging effectiveness of futures contracts on commodities whose prices are influenced by temperature, which are the frozen concentrated orange juice (FCOJ) and natural gas futures contracts, to that of a futures contract designed to hedge decreases in temperature, which is the heating degree days (HDD) futures contract. The results indicate that the HDD futures contract performs better than the FCOJ and natural gas futures contracts, in hedging against decreases in temperature in Orlando.

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1. INTRODUCTION

The objective of this thesis is to investigate the hedging effectiveness of frozen concentrated orange juice (FCOJ), natural gas and heating degree days (HDD) futures contracts in hedging against decreases in temperature in Orlando area. Since temperature affects the price of these three futures contracts, they can be hedge strategies to hedge against decreases in temperature. Hedging effectiveness is measured by comparing the variance of different hedge portfolios with that of an unhedged portfolio, and it determines which futures contract performs the best.

In the U. S., weather has a significant impact on the economy. Capacity and revenues have been affected in almost every industry, such as agriculture, energy, construction, transportation, entertainment, travel and others which are closely related to the vagaries of temperature. Weather changes can be as large as weather disasters, or as small as a degree change in temperature. The National Oceanic and Atmospheric Administration (NOAA)'s report on U.S. billion-dollar weather and climate disasters since 1980 includes 238 weather and climate disasters, with the total cost of these events exceeding $1.5 trillion. In March 2017, a severe freeze heavily damaged fruit crops across several southeastern states. Damage was most severe in Georgia and South Carolina. The total estimated costs were $1.0 billion. In March 2018, a northeaster winter storm brought extreme cold temperature and heavy snowfall to northeastern states, which caused economic losses which were estimated to be $2.2 billion.

The catastrophic impact of weather risk has been recognized, and the huge risk can be managed directly by insurance contracts. The research by Lazo et al (2011) shows that even minor changes in weather, the non-catastrophic weather risks, play a major role in the U.S. economy. For example, unexpected decreases in temperature may pose risks in many areas. A cold summer can leave hotel and airline seats empty, which causes a reduction in revenues. A comparatively cold winter may obstruct the progress of construction work and increase the costs to government over those budgeted for. For agriculture, a lower temperature than normal in winter affects the growth of crops. Since weather plays an important role in almost every sector and decreases in temperature may pose many risks. It is necessary to hedge against temperature decreases and find out the best strategy to hedge.

To control the risk, an individual or an organization can choose hedging or risk management techniques, to reduce substantial losses. A hedge can be constructed from many types of financial instruments, including stocks, futures contracts and so on. In this thesis I focus on the use of futures contracts to hedge against decreases in temperature.

Due to the increasing influence of weather on the economy, weather derivatives have emerged. Weather derivatives are designed to help participants to hedge against the risk associated with unexpected weather conditions. In the U.S., temperature futures contracts for the winter months, the heating degree days (HDD) futures contracts are associated with the HDD index. The index quantifies the demand for energy requirements for heating a home, or business. Each futures contract is based on an accumulation of heating degree days over a calendar month at a listed location. The HDD futures contract is used to hedge against decreases in temperature. When the temperature decreases, the price of HDD futures increases and along with the growth of the value of HDD index. Hedgers who are expected a colder winter will gain from the futures market.

Prices of agricultural commodities tend to be seasonal, because storage is expensive and there is a time limit for which a product can be stored. Weather plays a key role in determining the price of many agricultural products. The frozen concentrated orange juice (FCOJ) is an agricultural commodity, and FCOJ spot prices should be sensitive to decreases in temperature below freezing in the regions in which oranges are grown, since such decreases can hurt the orange crop. Natural gas is a widely used source of energy for heating buildings, as a result, demand for natural gas is seasonal and dependent on the weather. The natural gas spot prices should be sensitive to decreases in temperature, since such decreases in temperature would be accompanied by an increase in demand for heating. Summing up, temperature has a significant impact on both FCOJ and natural gas spot prices, and it should affect FCOJ and natural gas futures prices as well. Hence, the prices of futures contracts on FCOJ and natural gas should also be sensitive to decreases in temperature and as such, these contracts have the potential to be used as hedges against decreases in temperature. When the temperature drops, the prices of FCOJ and natural gas futures should increase due to the increases in FCOJ and natural gas spot prices. Thus, hedgers may gain from FCOJ and natural gas futures to offset the losses due to lower temperatures.

The traditional type of orange juice was fresh squeezed. In 1947, the frozen concentrated orange juice (FCOJ) was invented. This invention opened the possibility of global trade in orange juice. The FCOJ futures contract has been traded in New York since 1966, first on the New York Cotton Exchange, then on the successor New York Board of Trade and then on the Intercontinental Exchange (ICE) Futures U.S. since 2007. The ICE Futures U. S. is currently the exclusive global market for FCOJ futures and options. According to the data provided by ICE (2012), the U.S. is the second largest producer of orange juice in the world and Florida dominates U.S. production. Brazil occupies the first place.

The FCOJ futures contract is a contract for physical delivery of U.S. grade A juice with a Brix value[1] of not less than 62.5 degrees. The size of the contract is 15,000 pounds. The tick movement is based on a per pound basis. Each single tick move in the FCOJ futures contract's price is 0.0005. Every 0.0005 movement is the equivalent of $7.50 per contract. The delivery months are January, March, May, July, September and November. The FCOJ futures contract market consists of three contracts: 1) FCOJ-1 futures contracts; 2) FCOJ-A futures contracts and 3) FCOJ-B futures contracts. FCOJ-1 futures contracts are no longer listed for

[1] Brix is the sugar content of an aqueous solution. One-degree Brix is one gram of sucrose in 100 grams of solution.

trading since 2005 and FCOJ-B futures contracts are the substitute for FCOJ-1 futures contracts, which are not limited to any specific country of origin. They are traded only as a component of the spread between FCOJ-B and FCOJ-A contracts. FCOJ-A futures contracts were first introduced by NYBOT in 2004. FCOJ deliverable against the FCOJ-A contracts must be of U.S., Brazil, Costa Rice and Mexico. Since the sample period addressed in this thesis is from October 2009 to April 2019, I focus on FCOJ-A futures contracts traded on the ICE Futures U.S.

The FCOJ-A futures contract is the world benchmark contract for the global frozen concentrated orange juice market. In 2019, compared to other types of juice, the share of Florida's orange production has declined, but it is still very important to the research of price changes. Roll (1984) notes that "unlike other agricultural commodities, frozen concentrated orange juice (FCOJ) is a relatively good candidate for a study of the interaction between prices and a truly exogenous determinant of value, the weather." Roll (1984) found that there is a "statistically significant relationship between FCOJ futures returns and subsequent errors in temperature forecasts". Boudoukh et al. (2007) highlight that it is decreases in temperature below freezing which should be expected to impact the orange crop. The results of previous researches (Roll (1984) and Boudoukh et al. (2007)) imply that the FCOJ futures contract could be a good method to hedge against decreases in temperature during winter.

In the U.S., orange production for FCOJ is geographically concentrated in central Florida. From the publication Facts About Florida Oranges & Citrus by VISIT FLORIDA staff, Florida is a great place for planting citrus due to the unique sandy soil and subtropical climate. Today, FCOJ is a $9 billion industry nearly 76,000 employees. Florida ranks second in orange juice production and it provides more than 70% of supply in the U.S. Orange juice production is heavily influenced by the weather at one single region, namely the Orlando area in the central Florida. Since the prices of FCOJ are mainly affected by temperature changes in the central Florida Orlando area where orange crops are grown, I focus on the risk exposure due to decreases in temperature in Orlando.

The Energy Information Administration (EIA) at the Department of Energy classifies natural gas consumption into four sectors: residential, commercial, industrial, and electric power. The natural gas futures contract was first traded on the New York Mercantile Exchange (NYMEX), whose parent company is the CME Group, on April 3, 1990. The natural gas futures contract traded on the NYMEX is for all calendar months. The size of the contract is 10,000 million British thermal units (MMBtu) of natural gas delivered at Henry Hub, Louisiana. Henry Hub is the largest centralized natural gas trading hub in the U.S. The price of the natural gas futures contract fluctuates in $0.001 increments. Each single tick movement is the equivalent of $10 per contract. The Energy Information Administration reports that, in 2016, natural gas was the largest source of energy production in the U.S., accounting for 33 percent of all energy produced in the country.

The natural gas futures contract is the third-largest physical commodity futures contract in the world on the basis of trading volume. It is widely used as a national benchmark price for natural gas, which continues to grow as a global and U.S. energy source. Mu (2007) notes that about 50 percent of the U.S. natural gas demand, including space heating in residential and commercial sectors, is affected by weather. The futures price is based on delivery at the Henry Hub in Louisiana. This contract allows market participants to hedge price risk in the highly unstable natural gas market, which is driven by weather-related demand. Mu (2007) examines how weather shocks impact the price of natural gas futures in the U.S. The results of empirical tests indicate that there is a significant weather effect on both the conditional mean and the conditional volatility of natural gas futures returns. Nick and Thoenes (2014) indicate that the natural gas price is affected by temperature, storage and supply shortfalls in the short term. This implies that weather shock may cause high volatilities in both natural gas spot and futures markets.

The HDD futures contract was first listed in September 1999 on the Chicago Mercantile Exchange (CME) for 10 locations in the U.S. It is traded exclusively on the CME Globex electronic trading platform for the fall and winter months of October through April. As of December 2018, the CME offers weather futures and options contracts for 24 cities in the U. S., including Atlanta, Chicago, Cincinnati, New York, Dallas, Philadelphia, Portland, Tucson, Des Moines, Las Vegas, Boston, Houston, Kansas City, Minneapolis, Sacramento, Detroit, Salt Lake City, Baltimore, Colorado Springs, Jacksonville, Little Rock, Los Angeles, Raleigh Durham and Washington D.C. The HDD index is computed each calendar day for each city upon which contracts trade and equals the number of degrees that the day's average temperature is lower than the benchmark of 65° Fahrenheit. The day's average temperature is based on the maximum and minimum temperature from midday to midnight. Many contracts trade based upon the accumulation of HDD. Thus, the CME provides monthly and seasonal accumulated HDD. HDD seasonal strips include strip from November to March and strip from December to February. The monthly HDD index is simply the sum of the values of the daily HDD values for that particular month. The futures contract’s value is obtained by multiplying the cumulative HDD value by $20. For example, an average temperature of 40° F would give you an HDD value of 25 (65 - 40) for the day. If the cumulative HDD is 25, the nominal settlement value of the contract would be $500 ($20*25). If the temperature exceeded 65° F on a particular day, the value of the HDD would be zero. This is because, in theory, there typically would be no need for heating on a day in which the temperature is higher than 65° F. HDDs are extremely localized. Heating (and cooling) requirements vary widely by the geographic region. Current users of weather futures are primarily energy companies in energy-related businesses, such as heating oil distributors who use weather derivatives to help them smooth their profits from fluctuations in demand for heating in winter. However, a growing number of agricultural companies and companies in the travel industry recognize the potential growth in the trading of weather futures.

According to data collected from ICE, the FCOJ futures contract's trading volume from January 2, 2018 to December 31, 2018 was 356,854 contracts. From data provided by the CME group, the annual total trading volume of the natural gas futures contract in 2018 was 185,292,259 contracts. In comparison to the FCOJ and natural gas futures contracts, the HDD futures contract has very little liquidity, with the smallest annual trading volume being only a few thousand contracts.

In terms of these three futures contracts' history, the HDD futures contract is a relatively new financial instrument with a shorter history of use in hedging. The comparison of annual trading volumes shows that the liquidity of the HDD futures contract is not as high as those of the FCOJ and natural gas futures contracts. This implies that the FCOJ and natural gas futures contracts may perform better than the HDD futures contract as hedges against decreases in temperature. My analysis focuses on the period 2009 through 2019. On account of unreliable price data of HDD futures contract, I use HDD index as a proxy. I estimate the hedging effectiveness of FCOJ, natural gas and HDD futures contracts in hedging against decreases in temperature in Orlando which is the HDD index in Orlando. The results of my empirical tests show that the HDD futures contract performs better than FCOJ and natural gas futures contracts. However, the performances of FCOJ and natural gas futures contracts cannot be ignored.

The remainder of this thesis proceeds as follows. Chapter 2 reviews relevant literature on the three futures contracts: FCOJ, natural gas and HDD and the methods used to evaluate hedging effectiveness. In chapter 3, I explain the theoretical background behind the model of hedging and measure of hedging effectiveness. Chapter 4 describes the data, the methodology and the results of the empirical tests. Chapter 5 provides the conclusion.

2. LITERATURE REVIEW

In this section, I review past research on FCOJ, natural gas and HDD futures contracts, focusing on a fundamental factor----how temperature affects futures prices, as well as on measures of hedging effectiveness.

2.1. FCOJ futures contract

Previous researchers have studied the relationship between FCOJ futures prices and fundamental factors that would affect prices. Decreases in temperature is one of these fundamental factors. Even though studies have shown that temperature does not fully explain the variability in daily FCOJ futures prices, it is the most relevant factor, since the orange crop would be severely affected when the temperature drops below zero.

Roll (1984) notes that weather is the major influence on orange juice production. "Unlike other commodities such as corn and oats, whose production is distributed over wide geographical areas, orange juice production is influenced primarily by the weather at a single location." Decreases in temperature below freezing will cause serious damage to orange trees. From a comparison of the actual minimum temperature in Orlando with FCOJ futures prices, using data from October 1975 to December 1981, Roll finds that periods with freezing temperatures are accompanied by significant increases in FCOJ futures contract prices. He argues that only weather surprises should be correlated with the volatility of FCOJ futures prices. Weather surprises have been measured by the percentage difference between the actual temperature and the forecast of temperature, namely, the temperature forecast error. The result of a linear regression shows that although the R-squared of the regression is small, there is a statistically significant correlation between the temperature forecast errors and FCOJ futures returns.

Boudoukh et al. (2007) identify two problems in Roll's paper. First, Roll uses daily data including both winter seasons and non-winter seasons. But there is no significant relationship between temperature surprises and the production of oranges in non-winter seasons. Second, Roll uses linear regressions to test the relationship, but Boudoukh et al. argue that there should be a nonlinear relationship between decreases in temperature and FCOJ futures returns. Boudoukh et al. improve upon Roll's empirical tests by using data from winter, a pre-freeze period, which includes days in December, January and February, and a period which includes all the days in which a freeze occurs. Boudoukh et al. use two non-linear regressions: 1) the quadratic function and; 2) non-parametric regression. They use realized temperature instead of temperature surprises, because given a nonlinear relationship, futures prices will move even if a freeze is correctly forecast and actually occurs. Using data from September 1967 to June 1998, their empirical results and an enhanced R squared indicate that decreases in temperature close to or below freezing is a single fundamental factor that explains almost 50 percent of FCOJ futures price variability. In non-winter seasons, temperature is not an important factor affecting the production of oranges.

Jiang and Shanker (2009) investigate the effect of freezing temperatures in the central Florida region, as well as an implicit quality delivery option, under which the delivered FCOJ could originate either from Florida or Brazil, on the FCOJ futures contract price. The authors use the Freezing Degree Days (FDD) as the temperature variable of interest. Using data from December 1997 through October 2000, their empirical results provide support that FCOJ futures prices are largely responsive to fundamental factors, which include the implicit quality delivery option and temperatures below freezing.

2.2. Natural Gas futures contract

Mu (2007) uses historical data from January 1997 to December 2000 on monthly natural gas production and consumption in the U. S., and shows that although the natural gas production and industrial use are relatively stable over time, the total consumption of natural gas is highly seasonal because of the seasonal demand from residential, commercial, and electric power sectors. In winter, especially in December and January, the rise in consumption is mainly from residential and commercial customers' space heating demand. Since natural gas is widely used for heating purposes, it seems obvious that temperature is an important driver of natural gas demand.

Mu (2007) draws on evidence from the U.S. natural gas market that market fundamentals affect the volatility of returns. He uses "the deviation of temperatures from normal (weather shocks) as a proxy for demand shocks and a determinant of the conditional volatility of natural gas futures returns". He estimates a GARCH model on short-term price dynamics. His empirical results indicate that the weather shocks variable has a significant effect on the conditional volatility of natural gas futures returns over the period of January 1997 through December 2000.

Nick and Thoenes (2014) focus on the German natural gas market. They note that natural gas prices rise in reaction to supply interruptions and due to extraordinarily cold temperatures increasing the demand for heating. For the weather factor, they construct the historical average seasonal series of heating degree days (HDD) temperature data and calculate the deviations of observed HDD from their historical averages in order to estimate the effects of unexpected temperature conditions on gas prices. They evolve a structural vector autoregressive model (VAR) and the results indicate that in the short term, the natural gas price is influenced by three factors: temperature, storage and supply shortfalls.

Ji et al. (2018) note that as the natural gas market in North America is completely deregulated and market-oriented, there are many fundamental factors which may affect natural gas prices. They focus on factors that affect natural gas prices in the U.S. Two seasonality factors are HDD and CDD. The results of their empirical tests based on data from 1999 to 2017 indicate that an additional 11 percent of natural gas volatility is explained by HDD deviation. The HDD deviation was measured as the difference between HDD in a given week and the average for that week over the past five years. The result that HDD deviation is a significant factor supports the conclusion that seasonality factors are important when analyzing natural gas prices.

2.3. HDD futures contract

Jones (2007) notes that HDD futures contracts have many uses in agricultural risk management. A company can use HDD and CDD futures contracts traded on the CME to hedge its weather risk exposure. A winter wheat farmer can buy an HDD futures contract to hedge the effect of an extremely cold winter, because this cold winter can hurt crops and lead to decreased revenues. If the winter is unusually cold, he/she will receive a payoff on the futures position, because the value of the HDD futures contract will increase and offset the loss of revenue from a bad crop.

Barth et al (2011) examine the problem facing an electricity retailer. The demand for electricity is dependent on the average temperature over the area in which the retailer's customers are located. If the customers are using electricity for cooling, say, the profit of the company will increase with increasing average temperatures. But decreases in temperature may seriously harm the income of the retailer, and he/she may want to hedge this risk using temperature futures, such as the cooling degree days (CDD) futures contract. Chincarini (2011) provides an example of the use of HDD futures to hedge. On February 28, 2006, the monthly HDD contract for Atlanta closed at 305. This indicated that the market's fair value for the sum of HDD daily values in Atlanta was 305. For March 2006, the market underestimated the actual final value of the monthly cumulative HDD, which turned out to be 349 on the first business day of the following month. Someone who purchased the HDD contract on February 28, 2006 would have paid $6,100 ($20*305) for one contract and had they held it until expiration would have made $880 ($20*349-$6,100). Using the HDD futures contract as a hedge against decreases in temperature would have provided a $880 payoff.

Yang et al. (2009) test both basis risk and hedging efficiency of weather derivatives in the U.S. energy industry. They estimate the power load due to the weather-related variable and analyze both linear and nonlinear hedging strategies with the temperature data. Their results indicate that basis risk is sufficiently low for some power producers. Štulec (2017) tests the effectiveness of weather derivatives in food retailing companies. The results of a multiple linear regression show that there is a significant relationship between sales of non-alcoholic beverages and temperature.

2.4. Hedging effectiveness

The existing literature on hedging performance and effectiveness of futures contracts is vast. According to Hull (2003), "The hedge effectiveness can be defined as the proportion of the variance that is eliminated by hedging."

Pelka and Musshoff (2013) compare the hedging effectiveness of three weather derivatives, which are a temperature-based weather derivative, a precipitation-based weather derivative and a derivative based on a mixed index of these two weather variables. The method for measuring hedging effectiveness is to compare the relative reduction of the standard deviation of the winter wheat revenue in 32 farms located in Germany, with and without these three weather derivatives. The risk addressed in Pelka and Musshoff (2013) is fluctuation in income from winter wheat. The effectiveness of hedging or the potential to reduce risk is measured by the degree of income stability.

Figlewski (1984) studies hedging performance and basis risk in U.S. stock index futures and finds that compared to other hedging strategies, the minimum variance hedge ratio provides the most effective measure of hedging, because the minimum variance hedge ratio is in all cases smaller than the beta of the portfolio being hedged. Beta is a measure of a stock's volatility in relation to the market.

Misund and Asche (2016) address the Atlantic salmon futures market. They test the hedging effectiveness of three types of strategies, no hedge, which is used as a benchmark, fully hedged and hedging using the optimal hedging ratio. The optimal hedging ratio is calculated by four ways: 1) a constant hedging ratio based on the full sample of data using Ordinary Least Squares (OLS); 2) a 20-week rolling OLS; 3) a 52-week rolling OLS; and 4) bivariate GARCH. They compare the return variance of these strategies as the method for evaluating hedging effectiveness. They find that the fully hedged strategy has the highest hedging effectiveness. The second-best hedging effectiveness is achieved with the use of a constant hedge ratio based on the full sample of data. The bivariate GARCH approach performs well, ranking below the use of the constant hedging ratio.

3. THEORETICAL BACKGROUND

In this thesis, I investigate the hedging effectiveness of three futures contracts in hedging against to the risk of decreases in temperature. The aim of hedging is to insure against a negative event. The negative event cannot be prevented from happening. But if people properly hedge, the bad impact of this event can be reduced. In futures markets, participants use futures contracts to hedge risk, to reduce their exposure to various risks. Decreases in temperature could cause many risks in many industries. These risks include but are not limited to the volatility of an asset's spot prices, the decreases in revenues due to reduced crop yields, postponement of entertainment events and reduced attendance at these events. The prices of FCOJ futures contracts are affected by the temperature of the Central Florida-Orlando area, in which orange crops are mainly grown. Therefore, I investigate the temperature risk due to temperature decreases in the Orlando area.

For hedgers, the objective of hedging is not to gain profit, which is different from that of speculators and arbitrageurs. Their aim is to offset their loss and stabilize return. For example, an energy company plans to purchase natural gas in three months. If the temperature decreases, the price of natural gas will be expected to rise. Thus, if the company wants to lock in the price of natural gas at the current date, it could take a long position in a hedging financial asset. A long futures position leads to a gain if the price of natural gas increases and a loss if it decreases. On the other hand, if the company plans to sell natural gas in the future, it could take a short position in the futures contract which would benefit if the price of natural gas drops.

A perfect hedge completely eliminates the risk, but it may not be possible to execute a perfect hedge. In the example of a company which uses natural gas futures to reduce the risk that natural gas spot prices will rise, the asset underlying the futures contract is the same as the asset whose price is being hedged. When the two assets are different, cross hedging occurs. The hedge ratio is the ratio of the size of the position taken in the futures contracts to the size of the exposure. It is a measure of the number of futures contracts one needs to buy or sell in order to hedge the price risk. When the two assets are the same, or the hedge termination date is the same as the futures contract's delivery date, a hedge ratio of 1.0 will completely eliminate risk. When the two assets are different and the hedge termination date is different from the delivery date of the futures contract, of the hedge ratio could be different from 1.0 and should be chosen so as to minimize the variance of the value of the hedged position.

In the application of hedge accounting, hedge effectiveness is the extent to which the changes in the fair value or cash flow of the hedging instrument offset the changes in the value of the hedged item. There are two methods used to measure the effectiveness of the hedge, the qualitative method and the quantitative method. The critical term match and the short-cut are two qualitative methods. The critical term match method is that as long as the derivative instrument matches the hedged item on all critical terms, this hedging strategy will be highly effective. Under the short-cut method, if a hedging strategy meets a set of specific criteria, the company could say it is highly effective. The dollar offset and regression analysis are two quantitative methods. The dollar offset method compares the ratio of value changes in the hedging instrument with value changes in hedged item. If the dollar offset ratio is in the range of 80% to 125%, it can be treated as highly effective. Otherwise, it is not effective. Regression analysis regresses the changes in value of the hedged item on corresponding changes in value of the derivative instrument. If the slope parameter is between 80% to 125%, and the R-Squared parameter is no less than 80%, the derivative instrument is considered highly effective as a hedge.

Each hedging strategy creates a hedge portfolio. In recent studies (e.g., Martinez-Garmendia and Anderson (1999), Pelka and Mussoff (2013), Misund and Asche (2016)), the hedging effectiveness is evaluated by comparing the relative change in the variance of return, income or revenue from the industry with and without the hedging strategy. The degree of a hedge portfolio's return stabilization is also referred to as hedging effectiveness or as a potential risk reduction.

3.1. Model of hedging and the measure of hedging effectiveness

According to Hull (2003), "the minimum variance hedge ratio depends on the relationship between changes in the spot price and changes in the futures prices." Defining ΔS as the change in the spot price, ΔF as the change in the futures price, then h* the minimum variance hedge ratio is given by:

$$h^* = \rho \frac{\sigma_s}{\sigma_f} \quad (1)$$

Where σ_s and σ_f are the standard deviation of ΔS and ΔF, respectively, and ρ is the coefficient of correlation between the two variables ΔS and ΔF. The optimal hedge ratio h* may also be written as:

$$h^* = \frac{cov(\Delta S, \Delta F)}{var(\Delta F)} \quad (2)$$

Then the hedge effectiveness can be defined as the proportion of the variance that is eliminated by hedging. This is the R^2 from the regression of ΔS on ΔF and equals ρ^2.

In accordance with Misund and Asche (2016), the relationship between changes in the spot price and futures price can be defined as follows:

$$r_{s,t} = \alpha + \beta r_{f,t} \quad (3)$$

Where α and β are coefficients, $r_{s,t}$, and $r_{f,t}$, are changes in the natural logarithm of the spot and futures prices from time t-1 to time t, respectively, given by:

$$r_{s,t} = lnS_t - lnS_{t-1} \quad (4)$$

$$r_{f,t} = lnF_t - lnF_{t-1} \quad (5)$$

The parameter β describes the relationship between changes in the futures and spot prices. If β=0, there is no relationship between the futures and spot prices. Consequently, the β parameter can be used to determine how to hedge the risk as the spot price changes,

Hence, another method used to calculate the optimal hedging ratio is to apply ordinary least squares by solving a linear regression, as follows:

$$r_{s,t} = \gamma_0 + \gamma_1 r_{f,t} + \varepsilon_t \qquad (6)$$

Where ε_t is the error term, γ_0 is the intercept, and γ_1 is the slope coefficient calculated by ordinary least squares. The estimate of the optimal hedge ratio is γ_1.

Then hedging effectiveness is estimated by comparing the variances of the returns of the hedged portfolios and the unhedged portfolio. The returns of the hedged portfolio $r_{p,t}$is:

$$r_{p,t} = r_{s,t} - h^* r_{f,t} \qquad (7)$$

Where $r_{s,t}$ is the return on the spot asset, $r_{f,t}$ is the return on the futures contract and h^* is the estimated optimal hedge ratio used. Eq. (7) indicates that a long position in the spot asset is hedged by a short position in the futures contract. The size of the futures position is determined by the hedge ratio. For the unhedged portfolio, h^*=0 and for hedged portfolio, h^* is the estimated optimal hedge ratio calculated by Eq. (6). The hedging effectiveness is then measured by the difference between the variance of the return on the unhedged portfolio var_s and the variance of the return on the hedged portfolio var_p as a percentage of the variance of the return on the unhedged portfolio.

$$\text{Hedging effectiveness} = \frac{var_s - var_p}{var_s} \qquad (8)$$

4. METHODOLOGY OF EMPIRICAL TESTS AND RESULTS

My raw data includes daily futures prices of the FCOJ-A, natural gas (NG), and HDD futures contracts. I also collect daily temperature data in Orlando. The sample period for futures prices and temperature is from October 2009 to April 2019.

In the futures market, the symbols for each delivery month from January to December are F, G, H, J, K, M, N, Q, U, V, X, Z. For example, F20 represents the delivery month of January 2020. On each business day, several futures contracts with different delivery months trade on the futures exchange. For example, on Oct 1, 2018 in the NYMEX natural gas futures market, there are NGX18, NGZ18, NGF19 and so on. Considering the trading volume and open interest for each contract, previous researchers discard the futures contracts with longer maturities and remove the nearest to maturity futures contract, because open interest declines and price volatility increases substantially in the delivery month (Roll 1984). According to Hull (2003), the prices of futures contracts are very erratic during the delivery month. So, we usually choose a contract with a later delivery month. “A good rule of thumb is to choose a delivery month that is as close as possible to, but later than, the expiration of the hedge.” Which contract I choose will be described in detail in following sections.

4.1. Temperature in Orlando

In this thesis, I focus on hedging decreases in temperature in the central Florida region--Orlando area in which oranges used to produce orange juice are mainly grown. Decreases in temperature causes temperature risk. Since temperature is not a physical good, there is no spot market for the underlying asset. Therefore, the temperature risk needs to be quantified. Since I investigate decreases in temperature, a lower temperature is associated with a higher HDD index. This HDD index could be a representative of temperature. Thus, the HDD index value in Orlando is the independent variables in my research and it is a proxy for the price in spot market. That is to say, the temperature risk is the fluctuation of the HDD index value.

For the temperature data I follow Boudoukh et al's (2007) work to choose realized temperature instead of temperature forecast. Following Jiang and Shanker (2009), historical realized daily temperature data of Orlando are collected from the website of the Florida Automated Weather Network (FAWN), including daily average, minimum and maximum temperatures at 2 meters in the air at five weather stations in the central Florida region around Orlando. The select stations are Umatilla, Okahumpka, Avalon, Apopka and Lake Alfred. Data period is from October 1, 2009 to April 30, 2019. First, I calculate the daily HDD= Max (0, 65-W_t), where W_t is the observed average temperature at a station in degrees Fahrenheit. Then monthly Cumulative HDD is calculated by summing the average HDD of all five weather stations including all days in a month. The reason I do not choose daily HDD is that not every day in Orlando has an HDD value different from 0. Especially in the months of April and October, only a few days have an HDD value different from 0. Data in the cumulative HDD index value for Orlando extends from October 2009 to April 2019. Whereas I only extract those months with actively trading the HDD futures contracts as my data of HDD index value in Orlando, for a total of 70 monthly observations.

4.2. Daily FCOJ futures contract prices

The FCOJ futures contract is traded on the ICE Futures U.S. with delivery months January, March, May, July, September and November. The last trading day of the FCOJ futures contract is the 14th business day prior to the last business day of the month. For example, for the futures contract OJH19, the delivery month is March 2019, and the last trading day is March 11, 2019. Trading volume in the FCOJ futures contract is concentrated in the near-maturity contracts, thus after discarding the fourth and longer maturities, Roll chooses 2-6 months to maturity. He sets maturity months between 2-4 as contract 1 and sets maturity months between 4-6 as contract 2. Boudoukh et al. first collect daily closing prices for the three closest to maturity FCOJ futures contracts. After removing the nearest maturity contracts, they average the price changes in the two closest to maturity contracts but switch out of the closest to maturity contract in the expiration month. Jiang and Shanker (2009), choose the first, second and third closest to delivery contracts in non-contract months and the second, third and fourth closest to delivery contracts in contract months.

Daily FCOJ futures contract prices are collected from the ICE for the period October 1st, 2009 to April 30, 2019. The ICE provides historical daily open, high, low and close prices of FCOJ futures contracts, grouped in the first nearby to the fifth nearby contract from June 1st, 1999 to the current date, as well as the open interest and trading volume. In this thesis, after discarding the nearest maturity and longer maturities contracts, I use the second nearest to maturity futures contracts.

I first calculate daily returns, and then accumulate daily returns to generate monthly returns. In calculating the daily return, to address the effect of the price limit, I use the procedure of aggregating daily futures returns until the limits no longer bind, as in Roll (1984), Boudoukh et al (2007) and Jiang and Shanker (2009). For example, if the price hit the upper limit for three consecutive days, I use the fourth day's future price and the first no-limit day's future price to calculate the one-day return. The sample period extends from October 2009 to April 2019, including every month for a total of 115 observations.

4.3. Daily natural gas futures prices

The natural gas futures contract is traded on the NYMEX with delivery in every month of the year. Natural gas futures contracts expire three business days prior to the first calendar day of the delivery month. For example, if the delivery month is December 2018, the contract NGZ18 will expire on Nov 28, 2018. Thus, the delivery month for the nearest contract, namely contract 1 on the EIA, is the calendar month following the trade date. For time period Oct 30, 2018 to Nov 28, 2018, the nearest contract is NGZ18. Contracts 2-4 represent the successive delivery months following Contract 1. So, the second nearest contract is NGF19. Mu (2007) complies two return series from the nearest contract and the second nearest contract. To avoid the "thin market" problem, he uses the second nearest contract to replace the nearest contract at the last trading day to calculate the return. There is no significant autocorrelation and seasonality in the mean and return. But there is a strong autocorrelation in the squared return, which implies temperature and natural gas futures prices have a linear relationship.

Daily natural gas futures prices are obtained from the EIA, which also provides weekly, monthly and annual data on contract months 1-4 back to January 1994. Discarding the nearest and longer maturity contracts, I choose the second nearest natural gas futures contracts. Following the same procedure as for FCOJ futures contracts, I calculate daily returns and use these to determine monthly returns. Natural gas futures daily close prices are collected from October 2009 to April 2019 yielding 115 observations of monthly prices.

4.4. Daily HDD futures prices and the HDD index for Atlanta

The HDD futures contract is traded on the CME with delivery months October, November, December, January, February, March and April, and for temperature based on 24 locations in the U.S. The last trading date is the second business day of the following calendar month. For example, if the delivery month is December 2018, then the last trading date of this contract is January 3, 2019. Although HDD futures contracts based on temperature recorded at 24 locations in the U.S. are listed on the CME, not all locations' HDD futures prices are available. This is the limitation of using temperature-based weather derivatives. While there are many cities in the U.S., HDD futures contracts are only available for 24 locations, giving rise to basis risk, if decreases in temperature at a different city is to be hedged. Charles et al (2009) indicate "In hedging using standardized weather derivatives, hedgers must bear basis risk and the risk due to a weather contract being written in a different location than the area the hedger wishes to cover." Since I focus on temperature in Orlando, it is appropriate to choose HDD futures on temperature in Orlando. But Orlando is not one of the cities with HDD futures listed on the CME. Geographically, in Florida, the nearest location to Orlando is Jacksonville, Florida, with symbol VF, and the second nearest location is Atlanta, Georgia with symbol H1. But data on HDD Jacksonville futures contacts are not available. Therefore, I choose the location Atlanta, Georgia, which was one of the first cities for which HDD futures were introduced and which has available data. The symbol for Atlanta HDD futures is MH1. MH1F16 represents Atlanta HDD futures contracts with delivery in January 2016.

Daily close prices for the Atlanta HDD futures contract are collected from the website barchart.com. Data period is from October 2009 to April 2019. Previous researchers pay more attention on pricing weather derivatives, and empirical tests usually use the value of HDD or CDD, not the prices of HDD futures contracts. By looking at the prices data, I find some unusual facts. First, the prices of HDD futures only change near to and in delivery months. For example, M1J10 represents contracts with delivery in April 2010. The futures prices of this contract were unchanged until March 18, 2010. MH1V12 represents contracts with delivery in Oct 2012. Prices stay stable until the mid of September 2012, and there is little change over May through August, which are non-contract months. Even in September and October 2012, on some consecutive days, the price does not change at all. Since I focus on a liquid contract, I first choose the first closest to delivery contract in my empirical analysis. For instance, in January 2010, I choose contracts which mature in January 2010. In other words, in contract months, I choose contracts with delivery in that month, while in non-contracts months, from May to September, no data is collected. Second, except for the first year of my data period, almost every year, prices of some days increased or decreased sharply. For example, in

2011, from January 19 to January 20, prices changed from 27.9 to 1661.0, and on January 22, price declined from 1670.0 to 40.1. This happened several times in the overall period. The sharpest change is on November 5, 2018, when the futures price increased from 322 to 32,200 and dropped back to 322 on the following day. Third, excluding the year 2010, contracts with delivery in March had prices as high as the thousands, while the prices of contracts with delivery in April were usually in the tens or hundreds. This caused the changes in prices of the first trading day in April to be extremely high. Fourth, there are two gaps in the time period in which I cannot access historical price data, from December 16, 2010 to January 17, 2011, and from February 2015 to November 2015.

After a simple checking of the data of HDD futures contracts, I understand why previous researchers do not use close prices of weather derivatives but use the HDD index calculated by realized temperature data at one location, as a proxy for the futures price. In this thesis, I follow the previous studies by using the HDD index from Atlanta. Data on the monthly HDD index value for Atlanta are collected from the website iweathernet.com. It also provides daily maximum, minimum and average temperatures. In general, my raw data on the HDD index for Atlanta consists of 70 observations based on HDD futures delivery months of October 2009 through April 2019. This is my sample of HDD Atlanta futures prices.

4.5. Data summary

The sample period extends from October 2009 to April 2019. Since I focus on decreases in temperature and use the HDD index, only data in HDD futures delivery months is used. Therefore, the data on monthly prices of FCOJ and natural gas futures, the proxy for HDD futures in Atlanta and the HDD index value in Orlando consist of 70 observations. Since the return of a month is calculated by Eq. (4) and Eq. (5), in the natural logarithm, the price must be larger than zero. Therefore, returns for every October, April 2015 and November

2015 are not valid. To maintain data consistency, these 70 monthly prices generate 58 monthly returns, which are used in the regression analysis.

Figure 1. shows how HDD index values in Orlando and FCOJ futures prices vary over time. The graph of the HDD index value indicates that the temperature in Orlando is highly seasonal and varies greatly from month to month. In Orlando, HDD index values peak in December and January. In April and October, the values of the HDD index are small, sometimes single digit and close to zero. As can be seen from the graph, the futures price of FCOJ does not always coincide with the HDD index value in Orlando. However, we can see that during December 2011 to March 2013, and October 2016 to December 2017, the FCOJ futures contract prices and the HDD index values in Orlando were both going up and going down at almost the same time.

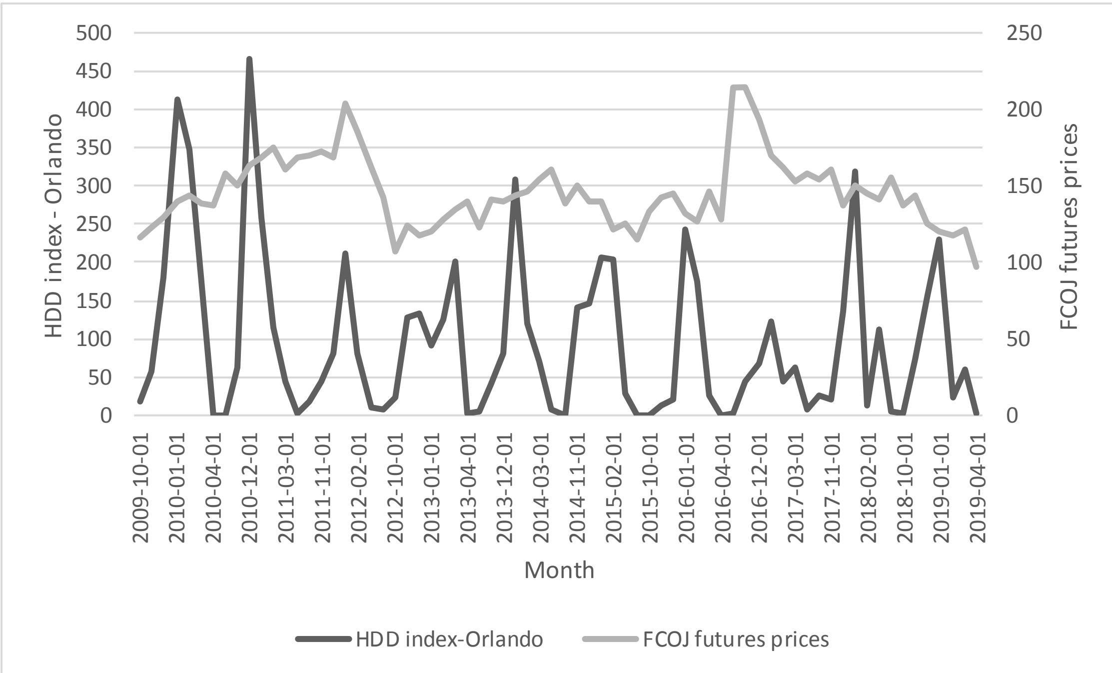

Figure 1. FCOJ futures prices and HDD index value in Orlando over time.

Figure 2. shows how HDD index values in Orlando and natural gas futures prices vary over time. Over January 2012 to March 2013, the two prices move together in the same direction, but in other periods, (e.g., March 2014 to February 2015), they move in opposite directions. The reason is that apart from

temperature, one fundamental factor, there are many other factors that affect natural gas futures prices. According to Bopp (2000), the Henry Hub natural gas price is more closely related to Chicago's temperature than any other cities including New York, Boston, St. Louis, and Atlanta. Although there is a significant relationship between temperature in these two locations, we cannot expect the same correlation between natural gas prices and the HDD index value in Orlando.

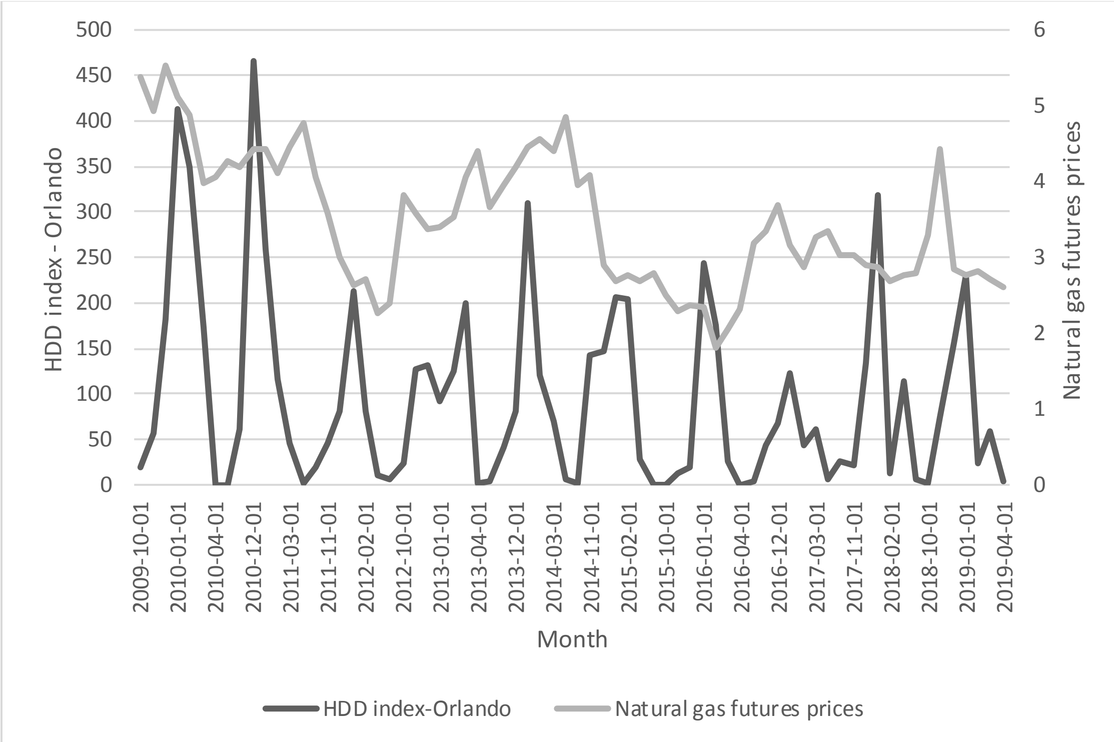

Figure 2. Natural gas futures prices and HDD index value in Orlando over time.

Figure 3. presents the HDD index value in Orlando and the HDD index value in Atlanta over time. The figure shows that HDD index values in Orlando and Atlanta move closely together. This close relationship may be explained by the fact that the two cities are both located in the U.S. and relatively closely, that the HDD index values are based on realized temperatures and there is a high correlation between temperature in these cities. However, Atlanta is further north than Orlando, and is colder in winter, which yields higher monthly HDD index values.

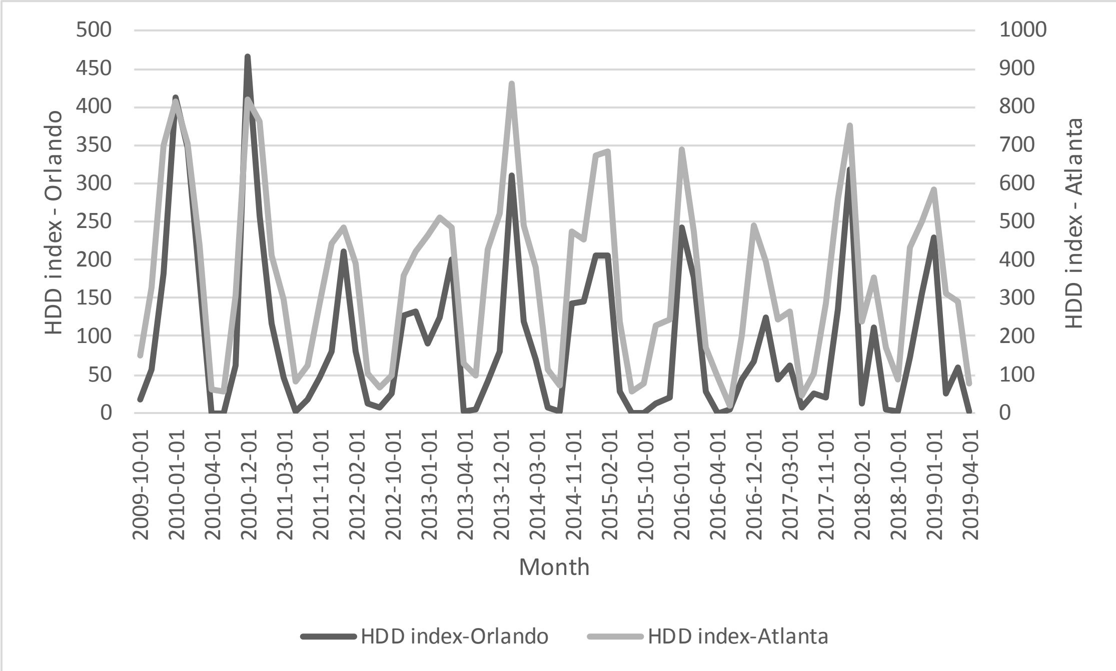

Figure 3. HDD index value in Atlanta and HDD index value in Orlando over time.

4.6. Empirical tests and results

In this thesis, to measure hedging effectiveness, I evaluate the performance of the three hedging strategies, by using the FCOJ and natural gas futures contracts, and the HDD futures contract based on temperature in Atlanta separately to hedge the HDD index value in Orlando. Each strategy creates a hedging portfolio by combining positions in the HDD index in Orlando with each futures contract. Hedgers holding this portfolio will have revenues on the futures position to offset the loss due to decreases in temperature in Orlando. The hedging effectiveness of each futures contract is estimated by the proportion of the variance that is eliminated by hedging.

First, I use Eq. (4) and Eq. (5) to calculate monthly returns for the HDD index value in Orlando, and the HDD Atlanta futures contract. Then I use Eq. (5) to calculate daily returns for the FCOJ and natural gas futures contracts. Next, I accumulate daily returns to generate monthly returns for the FCOJ and natural gas futures. For the benchmark, the unhedged strategy consists of full exposure to the HDD index value in Orlando. Table 1 presents descriptive statistics for the monthly returns on the HDD index value in Orlando, and for the FCOJ, natural gas and HDD Atlanta futures contracts, over the period October 2009 to April 2019. It shows that the HDD index value in Orlando is more volatile than the other variables. It has the highest standard deviation, which means the temperature in Orlando fluctuates more from month to month than the other variables. The volatilities in the returns of the FCOJ and natural gas futures contracts are small, while the volatility in returns of the HDD Atlanta futures contract is relatively large. This is because the price of the HDD Atlanta futures contract is estimated based on realized temperature in Atlanta. Overall, the volatilities of the three futures contracts are small in relationship to the volatility of the HDD index values in Orlando.

Table 1. Descriptive statistics for the monthly return on the HDD index value in Orlando, and for the FCOJ, natural gas and HDD Atlanta futures contracts over the period October 2009 to April 2019.

Monthly return on	Mean	Standard Deviation	Variance	Minimum	Maximum
HDD index value in Orlando	-0.05868	2.1751	4.7310	-6.1744	6.5022
FCOJ futures contract	-0.00402	0.08456	0.00715	-0.2206	0.1853
Natural gas futures contract	-0.01585	0.1190	0.0142	-0.4382	0.2914
HDD Atlanta futures contract	0.01525	0.9100	0.8280	-1.9668	2.3638

Next, I use the returns on the HDD index value in Orlando for the spot market returns, and each of the three futures contracts' returns for the futures returns in Eq. (6). The coefficient γ_1, is the estimated optimal hedge ratio for each of the three hedging strategies. Table 2 presents the corresponding estimated optimal hedge ratios for the sample period October 2009 to April 2019.

The first row within the table provides the results for the full sample, with 58 monthly observations of returns. The optimal hedge ratio for the HDD Atlanta futures contract is statistically significant at the 1% level. For both the FCOJ and natural gas futures contracts, the slope coefficient is not statistically significant, indicating that these contracts cannot be used to effectively hedge decreases in temperature as estimated by the HDD index value in Orlando.

The results are not significant for FCOJ and natural gas futures contracts by using the full sample. Since the HDD index values in Orlando peak in December and January, I break down the whole period into two sub-samples. Sub-Sample 1 with observations from November through January and Sub-Sample 2, with observations from February through April. The average HDD index values in Orlando for the full sample and the sub-samples, Sub-Sample 1 and Sub-Sample 2 are presented in the first column in Table 2. We can see a big difference in average values of HDD index in Orlando between Sub-Sample 1 and Sub-Sample 2. The average HDD index value of Sub-Sample 1 is more than twice as much as that of Sub-Sample 2. The results of optimal hedge ratios for the sub-samples are shown in the second and the third rows in Table 2. The optimal hedge ratios for the HDD Atlanta futures contract are statistically significant at the 1% level in both sub-samples. For the FCOJ futures contract, the slope coefficient is not statistically significant in both sub-samples, indicating that the FCOJ futures contract cannot be used to effectively hedge decreases in temperature. And for the natural gas futures contract, the slope coefficient is statistically significant at the 10% level in Sub-Sample 1, indicating that the natural gas futures contract has the potential to hedge decreases in temperature in Orlando in every November to January.

Table 2. Optimal hedge ratios for the FCOJ, natural gas and HDD Atlanta futures contracts in hedging the HDD index value in Orlando

		Optimal hedge ratio γ_1/ p value			
	Average HDD index value	FCOJ futures contract	Natural gas futures contract	HDD Atlanta futures contract	Observations
Full sample	113.1449	3.5134 (0.3066)	-0.0903 (0.9706)	2.1306 (<0.001)	58
Sub-Sample 1	154.6121	1.7890 (0.6172)	3.6611 (0.09513)	1.8273 (<0.001)	29
Sub-Sample 2	71.6777	0.1535 (0.9704)	-1.9684 (0.5738)	2.5867 (<0.001)	29

To investigate hedging effectiveness, I build three hedge portfolios with the estimated optimal hedge ratios for the overall sample, and for the sub-samples, Sub-Sample 1 and Sub-Sample 2. For the unhedged portfolio, the variance is estimated using the returns of the HDD index value in Orlando. I also conduct a fully hedged strategy with the optimal hedge ratio set equal to 1.0 for each of the hedging instruments. Using Eq. (7), I calculate the returns of the different hedged portfolios and the variances of their returns. Finally, the hedging effectiveness is calculated by using Eq. (8). The effectiveness of the hedging strategies is presented in Table 3.

Results show that all optimal hedges perform better than the simple one to one full hedge. The HDD Atlanta futures contract based on temperature in Atlanta perform the best in full sample and sub-samples. The optimal hedge yields the highest hedging effectiveness of 74.159% in Sub-Sample 2. The performances of the FCOJ and natural gas futures contracts are poor in full sample and in Sub-Sample 2. Which means in these two samples, the FCOJ and natural gas futures contracts cannot be used to effectively hedge decreases in temperature in Orlando. However, in Sub-Sample 1, the natural gas futures contract performs better than the FCOJ futures contract, yielding a statistically significant hedging effectiveness of 9.974%, which indicates that the natural gas futures contract has the potential to hedge temperature decreases through November to January, when it is the coldest season in Orlando.

Table 3. Variance of returns and hedging effectiveness of various strategies for the full sample, Sub-sample 1 and Sub-sample 2

	Overall sample		**Sub-Sample 1**		**Sub-Sample 2**	
Portfolio	**Variance of returns**	**Hedging effectiveness**	**Variance of returns**	**Hedging effectiveness**	**Variance of returns**	**Hedging effectiveness**
Unhedged–HDD index value in Orlando	4.731037	N.A.	2.496343	N.A.	3.137026	N.A.
Portfolio of HDD index value in Orlando and FCOJ futures contract						
Full hedge	4.687943	0.911%	2.477482	0.756%	3.141805	0%
Optimal hedge	4.642772	1.866%	2.472928	0.938%	3.136863	<0.1%
Portfolio of HDD index value in Orlando and natural gas futures contract						
Full hedge	4.747769	0%	2.378903	4.704%	3.184445	0%
Optimal hedge	4.730921	<0.1%	2.247360	9.974%	3.099809	1.186%
Portfolio of HDD index value in Orlando and HDD Atlanta futures contract						
Full hedge	2.030708	57.077%	1.351143	45.875%	1.685978	46.256%
Optimal hedge	1.708398	63.890%	1.055878	57.703%	0.810640	74.159%

5. CONLUSION

Weather plays an important role in today's economy. Not only can severe weather events impact the economy, but small changes in temperature may have a significant effect on almost every industry. Unexpected decreases in temperature may pose risks in many areas, such as a decrease in crop yields, a tourism slump and a sharp increase in energy demand for heating. To control the risk, an individual or an organization can choose a risk management technique, to reduce possible substantial losses. A hedge can be constructed from many types of financial instruments, including stocks, futures contracts and so on. In this thesis I focus on futures markets, using futures contracts to reduce a temperature change risk. Frozen concentrated orange juice (FCOJ) is an agricultural commodity, spot prices are sensitive to decreases in temperature below freezing in the regions in which oranges are grown, since such decreases can hurt the orange crop. Natural gas spot prices are also sensitive to decreases in temperature, since such decreases in temperature would be accompanied by an increase in demand for heating. Hence, the prices of futures contracts on FCOJ and natural gas should be sensitive to decreases in temperature and as such, these contracts have the potential to be used as hedges against decreases in temperature. The heating degree days (HDD) futures contract is designed to be used to hedge against decreases in temperature. The objective of this thesis is to investigate the hedging effectiveness of futures contracts on FCOJ, natural gas and HDD futures contracts, in hedging against decreases in temperature.

To investigate the hedging effectiveness of these three hedging strategies, I determine the relationship between changes in the HDD index value in Orlando and the three futures contracts' price changes, estimate the optimal hedge ratios, and determine their hedging effectiveness. The hedging effectiveness is the proportion of the variance that is eliminated by hedging. The effectiveness of the hedging strategy is evaluated by comparing the minimum variance of the return on the hedging portfolio to the variance of an unhedged position in the spot market. The empirical analysis indicates that the HDD Atlanta futures hedging strategy always performs the best. Especially in Sub-Sample 2, the HDD Atlanta futures contract can reduce 74.159% of the variance of returns in HDD index value in Orlando. This means by using the HDD Atlanta futures contract as one hedging strategy to hedge against decreases in temperature, the hedging effectiveness is 74.159%. Hedging strategy with natural gas futures contract does not perform well in full sample and in Sub-Sample 2. However, in Sub-Sample 1, the natural gas futures contract can effectively reduce 9.974% of the risk due to decreases in temperature in Orlando during the time which includes every November through January in every year. As for the hedging strategy with the FCOJ futures contract, it does not achieve any significant result. According to previous researches, one possible reason why the FCOJ futures contract does not perform well is that the price of FCOJ futures contract only has a nonlinear relationship with freezing temperature in Orlando. When people expect a freezing temperature to occur, hedging strategy with the FCOJ futures contract may achieve a higher hedging effectiveness.

The reason why HDD Atlanta futures perform the best is that I do not apply actual trading prices of HDD Atlanta futures contract due to the unreliable nature of the data. I estimate the price of HDD Atlanta futures contract based on the realized daily temperature in Atlanta. There is a high correlation between the temperature in Atlanta and in Orlando, which results in a high correlation between the estimated price of HDD Atlanta futures contract and the HDD index value in Orlando. This explains why the hedging effectiveness of HDD Atlanta futures contract is the best. In practice, when a participant plans to hedge by using traded weather derivatives—such as the HDD futures contract, the return is based on the actual futures price, which is established by trading. HDD futures contracts are not very liquid, which may lead to their hedging effectiveness being poor in practice. Hence, though the empirical results indicate that the HDD Atlanta futures contracts perform best as hedges in theory, in practice, the FCOJ and natural gas futures contracts have the potential to be used as hedge instruments.

The method used to estimate the optimal hedge ratio can be improved by using other approaches, such as a GARCH model which optimizes the weights applied to recent and earlier observations of returns, while the OLS approach allocates an equal weight to all observations in the estimation window. This research is constrained by a short sample period and monthly returns. Future research could extend the sample period and investigate the data with a higher frequency such as weekly or daily data on spot prices and futures prices, if these become available.

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