FROZEN CONCENTRATED ORANGE JUICE FUTURES PRICES, THE QUALITY OPTION AND TEMPERATURE

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A Thesis
In
The John Molson School of Business

Presented in Partial Fulfillment of the Requirements
For the Degree of Master of Science in Administration at
Concordia University
Montreal, Quebec, Canada

June 2009

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Your file Votre référence
ISBN: 978-0-494-63060-0
Our file Notre référence
ISBN: 978-0-494-63060-0

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ABSTRACT

Frozen Concentrated Orange Juice Futures Prices, the Quality Option and Temperature

Haibo Jiang

Previous research on the effect of fundamental factors upon FCOJ futures prices focused on the effect of decreases in temperature below freezing. However, a large proportion of FCOJ futures price variability remains unexplained. We recognize that the FCOJ futures contract provides an implicit quality option to the seller, by allowing delivery of the cheaper of FCOJ from Florida and FCOJ from Brazil. We value this option and show that it is a substantial percentage (14.7%) of FCOJ futures prices, on average. Our regression of FCOJ futures returns upon changes in the value of the option indicates that futures returns are significantly related to the option value in winter and in spring. Our results also show that the quality option provides substantial incremental (7-10%) explanatory power over that provided by decreases in temperature below freezing. Our research supports the view that futures prices are largely responsive to fundamental factors.

ACKNOWLEDGEMENT

I would like first to thank my thesis supervisor, Dr. Latha Shanker, for directing my thesis and helping me on so many things through my master's study at JMSB. Her expertise on derivatives is very helpful to my thesis. I also want to thank Dr. Nilanjan Basu and Dr. Gregory J. Lypny for serving on my thesis committee. I appreciated their encouragement while conducting this research and valuable comments on my thesis.

To my parents and particularly my wife, Xiuli, I dedicate my thesis. Without their unconditional love, trust and patience over years, I would not be able to finish this work.

And last, I would like to express my gratitude to the Institut de Finance Mathématique de Montréal for awarding me the Master's Fellowship to help facilitate my study and this research.

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1. INTRODUCTION

Previous researchers have studied the relationship between frozen concentrated orange juice (FCOJ) futures prices and fundamental factors that would be expected to affect these prices. Of these factors, the greatest attention has been paid to the effect of decreases in temperature, which should have the greatest influence upon the orange harvest. Roll (1984) addresses the effect of temperature in the central Florida region in which the U.S. production of oranges is concentrated and finds that temperature surprises are unable to explain more than a small fraction of the variability in daily FCOJ futures prices. Specifically, the adjusted R^2 of regressions of temperature surprises on FCOJ futures returns were between 1% and 3%. Roll's sample period extends from October 1975 through December 1981. Boudoukh et al. (2007) emphasize that it is not decreases in temperature per se but decreases in temperature below freezing which should be expected to impact the orange crop. Further, the relationship between temperature decreases and futures returns should be nonlinear, since substantial decreases in temperature below freezing should have an accelerated adverse effect. A drop in temperature from 0°C to -5°C causes more severe damage to the orange crop than a drop from 0°C to -1°C. Boudoukh et al. demonstrate that when these effects are taken into account, the R^2 of a regression of FCOJ futures returns upon decreases in temperature below freezing is around 50%. The regression uses a sample of 77 observations of daily returns in winter (December, January and February) from 1967 through 1998, in which the daily temperature is below 35°F.

Both of the above papers also address the effect of other factors upon FCOJ futures returns. Roll regresses daily FCOJ futures returns squared on temperature, on other variables which could be expected to influence the demand and supply of FCOJ such as general economic activity, as well as on dummy variables for days with relevant news releases such as crop forecasts. The R^2 of this regression is close to 27%. Boudoukh et al. show that the volatility of FCOJ futures returns is higher on days with relevant news releases.

Specifically, Roll and Boudoukh et al. address the effect of news releases about Brazil upon FCOJ futures returns variability. Boudoukh et al. and the U. S. International Trade Commission[1] note that Brazil is the world's largest exporter of oranges and that FCOJ from Brazil is a good substitute for FCOJ from Florida. When the supply of oranges from Florida falls, the shortfall is primarily made up by imports from Brazil Between 1989 and 2008, the volume of U.S. imports of FCOJ from Brazil averaged 72.2% of total U. S. imports of FCOJ, ranging from a low of 46.5% in 2008 to a high of 93.4% in 1992. Shefrin (2002) recognizes that fundamental news releases that should affect FCOJ futures prices are weather and the supply of oranges from Brazil. Jiang and Shanker (2009) explicitly consider the effect of the supply of FCOJ from Brazil upon FCOJ futures returns by addressing the quality option implicit in the FCOJ futures contract.

The New York Cotton Exchange (NYCE) first introduced a FCOJ futures contract, termed the FCOJ-1 contract, in 1966. The FCOJ delivered against the contract

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[1]U. S. International Trade Commission, March 2005, Frozen concentrated orange juice from Brazil, Investigation No. 731-TA-326 (Second review), Washington DC.

was not limited to any specific country of origin. The last traded delivery month for the FCOJ-1 contract was March 2005[2]. The contract size was 15,000 pounds of orange juice solids. Delivery months were January, March, May, July, September and November[3]. The FCOJ-1 contract provided the seller of the contract an implicit quality option to deliver FCOJ of any origin. Since FCOJ from Brazil forms the greater proportion of U. S. imports of FCOJ, sellers of these futures contracts would be more likely to deliver FCOJ from Florida or from Brazil. Hence, the futures price should reflect the value of the implicit quality option, which is the right of the seller to deliver the commodity (FCOJ from Florida or from Brazil) with the lower spot price on delivery.

Jiang and Shanker show that the quality option is a substantial percentage of FCOJ futures prices. However, their research is constrained by estimated spot prices of FCOJ from Brazil based on the total Brazilian FCOJ exports, which do not directly reflect actual costs for U.S. FCOJ importers. In this thesis, we estimate spot prices for FCOJ from Brazil based on monthly U.S. FCOJ import data, which provide direct, precise measures of costs for the U.S. FCOJ importers. Our analysis focuses on the period 1994 through 2000. We estimate the value of the quality option following the methodology of Gay and Manaster (1984). On average the quality option constitutes

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[2] In 1998, the New York Board of Trade (NYBOT) became the parent company of the NYCE and the Coffee, Sugar and Cocoa Exchange. In 2004, the NYBOT introduced: 1) the FCOJ-B contract, which does not specify the country of origin of the FCOJ delivered, as a substitute for the old FCOJ-1 contract; 2) the FCOJ-A contract which specifies that juice deliverable against the contract must be of Florida and/or Brazil origin. In January 2007, the Intercontinental Exchange (ICE) acquired the NYBOT, which became the ICE Futures U. S. In March 2008, the ICE Futures U. S. announced that FCOJ deliverable against the FCOJ-A contract could originate from Florida, Brazil, Costa Rica and Mexico, effective with the July 2009 expiration.

[3] Qualified orange juice is U. S. Grade A with a Brix value of not less than 62.5 degrees and the FCOJ-1 futures contract required physical delivery.

14.7% of the FCOJ futures price. Using a no-arbitrage pricing model as in Gay and Manaster, we regress monthly futures returns upon the change in the value of the quality option and other relevant variables for different seasons. Our adjusted R^2 s range from a low of 66.17% in summer (June, July, and August) to a high of 90.84% in fall (September, October, and November) and the coefficient of the quality option is statistically significant in winter and spring. Following Boudoukh et al., we use a nonlinear regression to determine the effect of the quality option and a temperature variable that accounts for the effect of temperature drops below freezing upon the FCOJ futures prices. We find that the quality option provides substantial incremental (7-10%) explanatory power over that provided by the temperature variable.

The thesis is organized as follows. Chapter 2 reviews related literature on the FCOJ. In Chapter 3, we describe the FCOJ spot market. In Chapter 4, we examine the FCOJ futures market. Chapter 5 describes the data that we use in our analysis. In Chapter 6, we discuss our empirical methodology and present results. We conclude in Chapter 7.

2. LITERATURE REVIEW

Orange juice futures market participants and researchers have tried to explain the variability of FCOJ futures prices by examining fundamental factors. Previous research has investigated a series of factors, which could affect FCOJ futures prices. Freezing temperature in the Orlando area has been identified as a fundamental factor. But more than half of the variability of FCOJ future prices cannot be explained, especially in non-winter seasons.

This chapter reviews previous research on frozen concentrated orange juice futures, especially the pricing of FCOJ futures. In the rest of this chapter, we will discuss the uniqueness of orange juice production in the U.S. and then briefly go over factors that have been investigated by previous research.

2.1 Oranges in Florida

In the U.S. the production of oranges used to process FCOJ is geographically concentrated in the central Florida region around Orlando[4]. Orange juice production for frozen concentrates is mainly a Florida industry. Unlike other agriculture commodities, orange juice production is affected largely by the weather at one single region, namely the Orlando area in the central Florida. Thus, Roll considers FCOJ "a relatively good candidate for a study of the interaction between prices and a truly exogenous determinant of value, the weather." Furthermore, he points out that non-weather factors will not affect short-term supply of and demand for orange juice. For instance, the carry over in

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[4] California is also a large region producing oranges in the U.S. However, California oranges are mainly consumed as table oranges.

inventory is small because of high storage costs; short-term shift in demand is trivial as well since consumers' tastes and national incomes change gradually over time. In addition, because orange trees need to grow five to fifteen years to produce oranges, farmers' planting decisions are not oriented towards the short-term. In short, it seems that only the weather in Orlando should influence the short-term supply of oranges and in turn, orange juice futures prices.

Roll implicitly assumes that price increases of orange juice in Florida will lead one-to-one increases in FCOJ futures prices. This assumption was probably true when his paper was published in 1984. The sample period of his data extends from October 1975 to December 1981. At that time, Florida was the largest orange juice producer in the world. However, this assumption is less appropriate now since Florida is now the second largest orange juice producer while Brazil has become the largest. A decrease in the supply of orange juice from Florida should not necessarily cause a one-to-one increase in FCOJ futures prices. Boudoukh et al. recognize that orange juice futures prices are influenced by global supply and demand. We will discuss the impact of the supply of orange juice from Brazil on FCOJ futures prices in Section 2.5 which follows.

2.2 Orlando Weather

The rising influence of the supply of FCOJ from Brazil does not mean that the weather in the Orlando area is not important any more. In fact, Boudoukh et al. confirm Roll's finding and further show that freezing temperatures can explain almost 50% of the variance of FCOJ futures returns.

Daily weather data, used by both Roll and Boudoukh et al., are reported by the National Weather Service of the Department of Commerce. Relevant weather information for oranges includes temperature and rainfall. Roll uses three different forecasts of temperature and rainfall, actual maximum and minimum temperature, and actual rainfall.

Although rainfall is important for orange groves, the relationship between rainfall and the orange crop is less obvious than that between temperature and the orange crop. Roll finds that forecasts of rainfall provide less useful information than forecasts of temperature for FCOJ futures returns. In other words, temperature is the more important weather variable that explains FCOJ futures prices.

2.3 Temperature

In this section, we focus on relevant temperature observations on winter evenings because freezes do not occur at other times. Winter freezes are detrimental to orange production. Orange trees could be severely damaged by freezing temperatures that last for several hours. Even a moderate freeze will cause pre-harvest fruit drop. The magnitude of damage is determined by level of the freezing temperature and the duration of this temperature level. Empirical results also prove that freezes have an influence on U.S.-based production of oranges. By plotting actual minimum temperature in Orlando along with FCOJ futures prices, Roll finds that periods with freezing temperatures are associated with significant futures price increases. Boudoukh et al. find that orange production decreased 12.7% more than forecast by the USDA in 11 freeze years in the period 1967 - 1998[5].

Assuming that the FCOJ futures market is efficient in processing information, futures prices should incorporate all publicly available long-term and short-term forecasts of temperature. Given the publicly available forecasts of freezing temperature in the winter that is available to orange juice market participants, future prices may rise before the day that a freeze occurs. In the long-term, prices of FCOJ futures in fall are usually high enough to reflect market participants' expectation that severe freezes could occur during the winter season.

Roll argues that only weather surprises, which have not been forecast, should be concurrently correlated with price movements. Roll measures the temperature forecast error (i.e., temperature surprise) by the percentage difference between the actual temperature and the forecast of temperature that is provided by the National Weather Service. He conducts a regression of the temperature forecast errors on the same day's futures returns plus the returns on two leading and two lagged days. The regression results indicate that the temperature forecast error is a statistically significant predictor of FCOJ futures returns. Given that the adjusted R^2s of regressions are between 1% and 4%, however, temperature surprises can explain only a small proportion of the variability of FCOJ futures returns.

Boudoukh et al. point out two problems with Roll's regressions. First, the regressions use observations on all days including non-winter seasons. In non-winter

[5] Freeze years are classified by Attaway (1997).

seasons, there is no clear link between temperature surprises and orange production. Boukoukh et al. argue that the impact of temperature surprise is state dependent. Temperature surprises really matter only when they provide new information about the change in the probability and severity of a freeze. Thus, Boudoukh et al. select a sample of futures prices from the winter, pre-freeze period, which includes days in December, January, and February, up to and including the first freeze of the season, if a freeze occurs, and all the days in the season. Second, Boudoukh et al. claim that Roll's assumption of a linear relationship between futures returns and temperature surprises is problematic. These authors argue that the relationship between temperature decreases and futures returns should be nonlinear because substantial decreases in temperature below freezing should have an accelerated adverse effect upon the orange crop. In addition, given a nonlinear relationship between futures returns and temperature surprises, futures prices will move even if a freeze is correctly forecast and actually occurs. If a freeze occurs, the temperature level actually provides information on the severity of the freeze. Thus, Boudoukh et al. use realized temperature instead of temperature surprises in their regressions. They also show that forecasts of freezing temperature and temperature surprises have a relatively small additional explanatory power.

Boudoukh et al. test two nonlinear models. In their first model, FCOJ futures returns are assumed to be a quadratic function of the independent variable $\text{Max}[0, W^* - W_t]$, where W^* is the critical temperature threshold (i.e., 32°F) and W_t is the actual minimum temperature measured in Fahrenheit degrees on day t. The variable $(\text{Max}[0, W^* - W_t])^2$ is included in the regression to measure the nonlinear effect of freezing temperature. Roll uses the variable $\text{Max}[0, W^* - W_t]$ in regressions along with a series of other variables, but does not account for a nonlinear effect of freezing temperature. In their second model, Boudoukh et al. use an unspecified functional form, which is estimated by the methodology of kernel estimations. This conducts a nonparametric regression of futures returns on realized minimum temperature. Regression results indicate that these two models are appropriate models of the relation between FCOJ futures returns and temperature. The R^2s for the nonlinear model and the nonparametric model using all observations for the winter, pre-freeze sample are 33.3% and 33.6%, respectively. On days with temperatures of 35°F and below, the R^2s for the two models rise to 47.8% and 48.0%, respectively. However, these two models have very little explanatory power for temperature ranges above 35°F.

Boudoukh et al. showed that realized temperature close to or below freezing is a single fundamental factor that explains approximately 50% of FCOJ futures price variability. However, a large proportion of this variability remains unexplained even in the winter season. In non-winter seasons in which temperature is not a critical variable affecting the output of oranges, other factors should be responsible for the variability of FCOJ prices.

2.4 Other Factors

Based on the small predictive power for temperature and rainfall in his paper, Roll infers that influences other than weather affect FCOJ futures returns. Roll first examines news stories related to orange production that appeared in the Wall Street Journal. News stories are classified into categories, such as on weather, crop forecasts, international conditions, and miscellaneous. By analyzing the variability of futures returns on days with news about orange production in the Wall Street Journal, Roll finds that weather is the most important identifiable factor influencing FCOJ futures returns. Even though crop forecasts and other events influence FCOJ futures returns, these factors failed to explain a significant portion of the variability in returns that is not explained by weather.

Roll also tries to measure other influences on supply of and demand for orange juice. Two regressions are tested. The independent variables include freezing temperature and variables that represent changes in supply and demand of orange juice. As mentioned in Section 2.3, freezing temperature is measured by Max[0, $32 - W_t$], where W_t is the minimum temperature at Orlando on day t. Stock market returns are used as the proxy for consumer demand. The Canadian dollar/U.S. dollar exchange rate is used as the proxy for Canadian demand. Energy prices, measured by oil stock returns, are also considered because they influence the cost of operating farm equipment and the costs of processing and distributing the orange juice product. The first regression uses the futures return as the dependent variable. The results of the first regression show that freezing temperatures do affect FCOJ futures returns, but that stock market returns, changes in the Canadian dollar exchange rate, and oil stock returns have no significant influence. The adjusted R^2 is 6.68%. The second regression uses the squared FCOJ futures return as the dependent variable. All independent variables except for freezing temperature are squared as well. The reason for using the squared FCOJ futures returns is to determine the sources of price movements in either direction, rather than the direction of influence of particular variables. In this second regression, cold weather remains significant and news stories related to weather and crop forecasts are significant as well. The adjusted R^2 is 26.8%. Roll comments that most of the variability in FCOJ futures returns remains unexplained.

By studying shifts in the demand for orange juice caused by changes in the prices of substitute products, such as apple juice, tomato juice, and soft drinks, Roll investigates the relative importance of other shocks to demand. The results support the conclusion that most of the FCOJ price volatility is caused by supply shocks rather than by demand shocks.

Following Roll's paper, Boudoukh et al. also examine futures price volatility on days on which articles about FCOJ futures were published in the Wall Street Journal (WSJ) from 1984 to 1998. They find that particularly high volatility is associated with USDA's first official government forecast of orange production in October for the forthcoming season. However, the government's subsequent crop forecasts are less important than the first one. Bauer and Orazem (1994) provide a detailed analysis of USDA forecast and FCOJ returns, and they find a strong negative relationship between production surprises and FCOJ futures returns. Given that 70% of news about production comes out in non-winter months, this type of news seems to help explain seasonal volatility of FCOJ futures returns. Unlike Roll, these authors focus on news about Brazil. The importance of news about Brazil will be addressed shortly.

2.5 Brazil

Brazil has been the largest producer of orange juice in the world since 1984[6]. Brazilian orange juice is as good as that produced in Florida. Brazil and the U.S. together

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[6] An article entitled "Florida – The King of Citrus No More" which appeared in the Miami Herald on October 1, 1984 provides more information on Brazil's rise to the position of the largest producer of oranges.

produce 85% of the worldwide production of orange juice. The U.S. is a net importer of orange juice to meet its larger domestic demand, while Brazil exports most of its production of orange juice. When orange production in Florida decreases, especially in freeze years, FCOJ imported from Brazil makes up for about 80% of the lost production. In other words, FCOJ imported from Brazil is very important to deal with the shock to production, and its magnitude is significant. Therefore, information about Brazil's FCOJ production and prices should be reflected in FCOJ futures prices.

Because supply of and demand for orange juice are global, news about Brazil should affect FCOJ futures prices. Shefrin (2002) recognizes that fundamental news releases that should affect FCOJ futures prices are weather and the supply of oranges from Brazil. Boudoukh et al. find that stories about Brazil production were associated with return volatilities close to those of weather-related stories. Because the harvest season in Brazil is June to December, 74% of these stories about Brazil appear in non-winter months.

Boudoukh et al. highlight the importance of the effect of Brazil's FCOJ production on FCOJ futures prices variation. But they do not explicitly examine the direct link between futures returns and FCOJ from Brazil. Jiang and Shanker recognize that the FCOJ futures contract contains an implicit delivery option, which belongs to the seller, to deliver the cheaper of FCOJ from Florida or FCOJ from Brazil against the contract. They show that the quality option is a substantial percentage of FCOJ futures prices. However, their research is constrained by estimated spot prices of FCOJ from Brazil based on the total Brazilian FCOJ exports. The estimated spot prices of FCOJ from Brazil are used to calculate the value of the quality option. Although U.S FCOJ imports are mainly from

Brazil, Brazil exports most of its FCOJ to Europe and Japan. Therefore, estimated spot prices of FCOJ from Brazil based on the total Brazilian exports are not a good proxy of direct costs for U.S. FCOJ importers. In this thesis, we will estimate spot prices for FCOJ from Brazil based on monthly U.S. FCOJ import data, which provide direct, precise measures of costs for the U.S. FCOJ importers. In addition, we analyze the interaction between orange production in Florida and Brazilian FCOJ exports and examine the explanatory power of the quality option.

3. THE SPOT MARKET FOR FROZEN CONCENTRATED ORANGE JUICE

3.1 FCOJ Producers

Manufacture of FCOJ has been a major industry in Florida since the manufacturing process was invented in 1947. The FCOJ market has rapidly developed in the U.S. along with technological developments in storage, packaging and bulk transport. Matthews (1994) attributes the demand for FCOJ to convenience and time saving compared to squeezing juice by hand at home.

Since the middle of the 1980s, Brazil has become the world's largest exporter of orange juice. Interestingly, most of the oranges processed to produce FCOJ in Brazil are also produced in one area, Sao Paolo. FCOJ from Brazil is a good substitute for FCOJ from Florida. Orange juice from Florida and Brazil are priced at a premium by market participants. When the supply of oranges from Florida falls, the shortfall is primarily made up by imports from Brazil. Brazil and the U.S. together are the two largest FCOJ producing countries. Figure 1 shows the annual volume of U.S. FCOJ imports from Brazil and the corresponding proportion of imports from Brazil to all imports. Between 1989 and 2008, the volume of U.S. imports of FCOJ from Brazil averaged 72.2% of total U.S. imports of FCOJ, ranging from a low of 46.5% in 2008 to a high of 93.4% in 1992.

[Please insert Figure 1 about here.]

[Please insert Figure 2 about here.]

Besides Brazil, Mexico and Costa Rica are the second- and third-largest FCOJ exporters to the U.S. Figure 2 illustrates that Brazil, Mexico and Costa Rica together supplied more than 93% of U.S. FCOJ imports, on average, from 1989 to 2008. While Brazil's share of the total U.S. orange juice imports declined from 93% in 1992 to 47% in 2008, shares for Mexico and Costa Rica increased dramatically over the same period. Because of the North American Free Trade Agreement (NAFTA), Mexican FCOJ exporters face fewer, decreasing tariffs on orange juice after 1994. Under the Caribbean Basin Initiative (CBI), Costa Rica is able to export orange juice duty-free to the U.S. Although Mexico, Costa Rica, and other countries produce orange juice, Florida and Brazil are the dominant players in the world trade in FCOJ. Thus, in this thesis, we focus on FCOJ from Florida and Brazil alone.

3.2 Competition between Florida and Brazil

The Florida orange industry considers the Brazilian orange industry as a strong competitor, both in the U.S. and in the global market[7]. While Florida orange growers harvest their oranges from November to June, Brazil orange growers harvest from June to December. Orange groves in Brazil are more likely to be affected by drought in summer, whereas orange groves in Florida are threatened by freezing temperatures in winter. Brazilian orange growers enjoy the advantages of lower labor costs but face a high U. S. FCOJ tariff, Florida Department of Citrus (FDOC) equalization tax, and transportation costs, when exporting FCOJ to the U.S. Muraro, Spreen, and Pozzan (2003) estimate that the total 2000-2001 Freight on Board (FOB) costs for bulk FCOJ delivered at a

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[7] Carter and Mohapatra (2006) study the trade war between Florida and Brazil and evaluate the impact of monthly FCOJ imports from Brazil on U. S. prices.

processing facility in Florida was $0.9882 per pound solids[8] for FCOJ from Florida and $1.0640 for FCOJ from Brazil. After the Brazilian Central Bank stopped pegging the Brazilian Real to the U.S. dollar in January 1999, the exchange rate between the Brazilian Real and the U.S. Dollar also influences the price of U.S. FCOJ imports from Brazil. Figure 3, which graphs the exchange rate between the Brazilian Real and the U.S. Dollar for the period January 1995 through December 2008[9], shows that the exchange rate has been fairly stable up to 1998 and volatile from 1999 onwards.

[Please insert Figure 3 about here.]

[Please insert Figure 4 about here.]

The Florida orange industry uses tariffs and the FDOC equalization tax to protect itself against imports, especially imports from Brazil. The U.S. tariffs on orange juice are charged on all imports into the U.S. However, the FDOC equalization tax is charged only on orange juice imported into Florida. The U.S. FCOJ tariff forms the bulk of the cost of Brazilian FCOJ imports, although it declined over the years from 34.04 cents per pounds solids in 1994, to 28.89 cents in 2000 and after. The history of the U.S. orange juice tariff is presented in Table 1. As shown in Figure 4, if the U.S. FCOJ tariff is not considered, then orange juice from Brazil is much cheaper than orange juice locally produced in Florida most of the time. The FDOC equalization tax is much smaller, 2.99 cents per pounds solids in the period 2000/2001. Nevertheless, orange juice importers are

[8] A pound solids is a basic and standardized measurement of the amount of dissolved citrus sugar found in juice.
[9] Data are from the website of the Federal Reserve Bank of St. Louis. http://www.stlouisfed.org/default.cfm.

motivated to use non-Florida ports. Figure 5 shows that the proportion of FCOJ imported through ports in Florida declined over time. Beilock et al. (1988) find that the U.S. tariff provided considerable protection against FCOJ imports and that the Florida equalization tax placed Florida orange juice importers at a marked disadvantage compared to importers in other areas of the U.S.

[Please insert Figure 5 about here.]

[Please insert Table 1 about here.]

3.3 U.S. FCOJ Imports from Brazil

[Please insert Table 2 about here.]

We examine the dynamic between oranges production in Florida and Brazilian FCOJ exports, in spirit of Boudoukh et al. (2003). Table 2, Panel A provides annual FCOJ data and summary statistics of Florida production, Brazil exports, and U.S. imports from Brazil, all measured in millions SSE liters. Annual changes in production, exports, and imports are also reported. For the period of 1989-2002, the average level of Brazil exports is 27% more than the average level of Florida production, consistent with the fact that Brazil is the largest exporter of FCOJ worldwide. The U.S. FCOJ imports from Brazil are about 22% of average Florida production. The mean of changes in U.S. imports from Brazil is –22 millions SSE liters, indicating a downtrend of imports from Brazil. However, larger positive means of changes in Florida production and Brazil exports indicate the level of production in both countries have increased. As discussed in Section 3.1, when the supply of oranges from Florida falls (rises), we expect that imports from Brazil will increase (decrease). In addition, we expect that changes in U.S. imports from Brazil are affected by changes in Brazilian production. As predicted, correlations between changes in import of FCOJ and changes in Florida production and Brazil exports are –0.58 and 0.44, respectively.

Table 2, Panel B examines the interaction between changes in U.S. imports and changes in Florida production and changes in Brazil exports. Whenever there is a negative production shock in Florida, imports from Brazil increase at a similar magnitude to lost production; the average drop in Florida production is 289 millions SSE liters while the increase in FCOJ imports from Brazil are 323 millions SSE liters. If there is a production drop in Brazil, total Brazilian exports fall and U.S. imports also decrease. We also observe a similar pattern for positive production shocks.

To conclude, the magnitude of U.S. imports of Brazilian FCOJ is a significant, 22% of orange production in Florida, and these imports are used to replace a drop in orange production in Florida. The above analyses further illustrate that production and prices of Brazilian FCOJ provide important information and should be incorporated into FCOJ futures prices.

4. FROZEN CONCENTRATED ORANGE JUICE FUTURES MARKET

The expansion of the FCOJ market led to the introduction of FCOJ futures, to enable hedging of price risks associated with the citrus industry. The New York Cotton Exchange (NYCE), which was founded in 1870, first introduced the FCOJ-1 futures contract in 1966. The FCOJ delivered against the contract was not limited to any specific country of origin. The last traded delivery month for the FCOJ-1 contract was March 2005. Since the sample period in this thesis is from January 1994 to October 2000, we focus on the FCOJ-1 contract.

The size of the FCOJ-1 contract is 15,000 pounds solids of orange juice. The price quotation is in cents and hundredths of a cent to two decimal places. Contract listings are January, March, May, July, September and November with at least two January months listed at all times. The orange juice eligible for delivery is U.S. Grade A with a Brix[10] value of not less than 62.5 degrees. It must be pointed out that the FCOJ futures contract requires physical delivery of exchange-grade product, upon settlement, in store in exchange-licensed warehouses in the U. S.

The FCOJ-1 contract provides the seller of the contract an implicit delivery option to deliver FCOJ of any origin. Since FCOJ from Brazil forms the greater part of U. S. imports of FCOJ, sellers of this futures contract would be more likely to deliver FCOJ from Florida or from Brazil. Hence, the futures price should reflect the value of the implicit quality option, which is the right of the seller to deliver the commodity (FCOJ from Florida or from Brazil) with the lower spot price on delivery. Cox, Ingersoll and

[10] Brix is a measurement of the percent of weight of soluble solids (sugars and acids) in a solution.

Ross (1981) first define the rights of short futures traders to determine what assets will be delivered, as the quality option. In this context, it should be clarified that the product quality of FCOJ from Brazil is as good as that of FCOJ from Florida.

5. DATA

Our raw data include daily FCOJ-1 futures prices, daily spot prices of FCOJ from Florida, monthly data on U. S. imports of FCOJ from Brazil, and daily minimum temperatures in the central Florida region. The sample period for futures and spot prices is from January 1994 to October 2000, and the sample period for daily minimum temperatures is from December 1997 to October 2000.

5.1 Daily FCOJ-1 Futures Prices

Daily open, high, low and close prices, as well as trading volume and open interest, for the FCOJ-1 futures contract, are downloaded from the website of Turtle Trader[11]. This provides historical FCOJ-1 futures prices from February 1, 1967 to October 1, 2002. For each contract, observations of daily futures prices are used in the analysis, if the open interest for the day is 100 contracts or more.

While estimating the value of the quality option embedded in the futures contract, we focus on liquid contracts. In non-contract months, we choose the first, second, and third closest to delivery contracts, and in contract months, we choose the second, third, and fourth closest to delivery contracts. In addition, we exclude a futures contract in its delivery month. For instance, in March 1997, we choose futures contracts expiring in May, July, and September 1997, and exclude the futures contract maturing in March 1997. In general, the time to delivery for these selected futures contracts range between

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[11] http://www.turtletrader.com/hpd.html

30 and 200 days, and open interests for these contracts exceed 2,000.

Previous research has documented that daily price limits imposed by the exchange delay the incorporation of information into prices. The exchange does not provide the history of price limit hits for FCOJ futures. Following the rules of price limits, we manually check whether a contract hits its price limit. If a price limit hit occurs, we use the standard procedure of aggregating returns until the limits no longer bind, as in Roll. For FCOJ-1 futures contracts, the size of the price limits was 5 cents above or below the previous day's settlement price[12]. The price limit was 10 cents for the nearest maturity contract in its expiration month. On and after the first notice day of the nearest maturity contract, the price limit for the second nearest maturity contract becomes 10 cents.

5.2 Daily Spot Prices of FCOJ from Florida

In order to estimate the value of the quality option embedded in the FCOJ-1 futures contract, we need spot prices for FCOJ originating from Florida and from Brazil.

Although almost forty years (i.e., 1967-2008) of daily historical FCOJ futures prices are available, only about seven years (i.e., 1994-2000) of daily historical spot prices of FCOJ from Florida can be obtained. Daily spot prices for FCOJ from Florida are collected from Bloomberg (Ticker: ORNGSUNS Index). The underlying commodity of the ORNGSUNS index is the New York Cotton Exchange (NYCE) Frozen Concentrated Orange Juice Grade A from Florida with a Brix value of not less than 62.5 degrees, and the index is quoted in U. S. cents per pounds solid. The sample period is from January 3,

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[12] Currently, the ICE sets the size of the daily price limit as 10 cents for FCOJ-A futures contracts.

1994 to November 13, 2000.

5.3 Estimated Spot Prices of FCOJ from Brazil

Although we have conducted an exhaustive search, we cannot directly obtain spot prices for FCOJ from Brazil. Therefore, we estimate monthly spot prices for FCOJ from Brazil, by using three series of data collected from the United States International Trade Commission (USITC) Interactive Tariff and Trade DataWeb[13]. The USITC Interactive Tariff and Trade DataWeb provides U.S. imports/exports statistics and U.S. tariffs information. International trade data are available for years 1989 and thereafter on a monthly, quarterly, and annual basis. The Harmonized Tariff Schedule (HTS) code, a classification system used by the USITC, of Frozen Orange Juice is 2009.11.00. We retrieve monthly U.S. general import data of FCOJ from Brazil for the period of 1989 to 2008. Specifically, we collect three series of monthly data: CIF (Cost, Insurance, and Freight) import value, first units of quantity, and U. S. FCOJ tariff.

We use the following formula to estimate the spot prices for FCOJ from Brazil:

Estimated spot price = (CIF Import Value) / (Equivalent Pounds Solids) + U. S. FCOJ Tariff + USDA Inspection and Other Costs + FDOC Equalization Tax (if applicable).

The CIF import value represents the landed value of the FCOJ at the first port of arrival. In other words, the CIF import value includes FOB costs, insurance, and transportation costs, and import charges, but it does not include U.S. import duties. The

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[13] http://dataweb.usitc.gov/

CIF import value is measured in U.S. dollars and is directly provided by the USITC DataWeb database.

The equivalent pounds solids are the total weight of corresponding FCOJ imported from Brazil each month. We calculate the equivalent pounds solids from the total volume of FCOJ imported from Brazil, namely the "First Units of Quantity", a term used by the USITC DataWeb database. The first units of quantity (i.e., the total volume) are quoted in equivalent liters, on a single strength equivalent (SSE) basis[14]. The single-strength orange juice is a ready-to-drink concentration level of 11.8 degrees Brix. Converting the volume to the equivalent weight involves two steps: from SSE liter to SSE gallon and then from SSE gallon to pounds solids. First, given that one liter of SSE orange juice of 11.8 degrees Brix is equivalent to 0.2641 gallons of SSE orange juice, we convert the first units of quantity to equivalent gallons of SSE orange juice. Second, because one gallon of SSE orange juice is equivalent to 1.029 pounds solids[15], we finally transform the volume of SSE gallons to the weight of pounds. In short, one liter of SSE orange juice is equivalent to 0.2718 pounds solids.

Using the above two series of data, we calculate the CIF spot price for FCOJ from Brazil as the CIF import value divided by the equivalent pounds solids. Besides the CIF spot price, we consider additional costs for FCOJ from Brazil that is deliverable in the

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[14] http://hotdocs.usitc.gov/docs/pubs/701_731/pub3930.pdf. As stated in footnote 1 on Page I-1, in the HTS, the volume (i.e., liter) of frozen concentrated orange juice for further manufacturing ("FCOJM"), is on a single strength equivalent ("SSE") basis. Note, however, that most FCOJ is traded at different values of degrees Brix, such as 65 degrees and 42 degrees. SSE liters are used as a standard measure when aggregating orange juices with different Brix values.

[15] http://www.floridajuice.com/pdfs/RB2005.pdf. International Marketing Conversion Tables on Page 48.

U.S. against the futures contract. Following Muraro, Spreen, and Pozzan, we estimate three additional costs: the U.S. FCOJ tariff, the United States Department of Agriculture (USDA) inspection and other costs, and the Florida Department of Citrus (FDOC) Equalization Tax. The data on the U.S. FCOJ tariff is straightforward and obtained from the website of the Florida Department of Citrus, University of Florida[16]. The United States Department of Agriculture (USDA) inspection and other costs and the FDOC equalization tax are 2.85 cents and 2.99 cents per pounds solids, respectively, both estimated by Muraro et al. However, the FDOC equalization tax is special because it is charged only on orange juice imported into Florida. As we have separate monthly quantities data of FCOJ imports from Brazil through all ports in the U.S., we do not include the FDOC equalization tax for FCOJ imports into ports other than Tampa, Florida and Miami, Florida.

5.4 Temperature in the Central Florida Region

We collect daily temperature data from the website of the Florida Automated Weather Network (FAWN)[17]. FAWN provides several series of daily temperature across Florida starting in December 1997. Oranges used to produce orange juice in the U. S. are grown mainly in the central Florida area. We use the daily minimum temperature measured at 2 meters in the air at five weather stations in Orange County, Polk County, and Lake County in the central Florida region around Orlando. FAWN IDs of these five weather stations are 302 (Umatilla in the Golden Gem Farm in Lake County), 303

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[16] http://www.floridajuice.ifas.ufl.edu/data/ojtariff.pdf
[17] http://fawn.ifas.ufl.edu

(Okahumpka in the USDA Whitmore Foundation Farm in Lake County), 304 (Avalon in the Mid-Florida Citrus Foundation Farm at Orange County), 320 (Apopka in the Mid-Florida REC at Orange County), and 330 (Lake Alfred in the Citrus REC in Polk County).

As pointed out by Boudoukh et al., a change in temperature matters only around freezing temperatures. We focus on temperatures below freezing by calculating a variable that we term the Freezing Degree Day $FDD = Max(0, 0 - W)$, where W is the observed minimum temperature at a weather station, measured in degrees Celsius. We calculate the average FDD using data from all five weather stations, and calculate the Cumulative Freezing Degree Day $CFDD$ for each month by summing the average FDD over all days in the month.

5.5 Other Data

Other data that we use in this thesis include U.S. Treasury bill rates and estimates of storage costs for FCOJ. The U.S. Treasury bill rates are obtained from the website of the Federal Reserve Bank of St. Louis[18]. There are four series of monthly Treasury bill rates: 30-day, 3-month, 6-month, and 1-year. Appropriate risk-free interest rates for different maturities of futures contracts are estimated by interpolating from the rates of the two nearest Treasury bills with maturities on either side of the maturity of interest. For instance, we estimate a 4-month risk-free rate by interpolating from 3-month and 6-month Treasury bill rates.

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[18] http://www.stlouisfed.org/default.cfm

Handling, storage, and re-inspection costs for FCOJ are estimated using list prices of the ICE Futures U.S. licensed FCOJ tank facilities[19]. Handling In/Out and Re-Inspection fees are $500 and $100 per contract of 15,000 pounds of orange juice solids, respectively. Storage costs are $300 per month. The storage costs are adjusted over the years by the Producer Price Index: Fuels & Related Products & Power Index[20].

5.6 Summary of Data

[Please insert Table 3 about here.]

[Please insert Table 4 about here.]

Table 3 shows the mean and standard deviation of the monthly futures price, the spot price of FCOJ from Brazil and from Florida, and the minimum temperature for the different seasons. From the table, we note that the average spot price of FCOJ from Brazil is higher than that of FCOJ from Florida. Average futures prices are lower than average spot prices from either Florida or Brazil. This price inversion is consistent with Malick and Ward (1987)'s finding that commercial users of FCOJ carry over inventories because of the convenience yield. We also observe that the average of futures returns in the winter is –4.06% and the corresponding volatility of 10.01% is the largest of the volatilities of all seasons, as would be expected. The prices of FCOJ futures in the fall usually have risen high enough to reflect market participants' expectation that severe freezes could happen during the winter season. A slight price decline occurs each day

[19] https://www.theice.com/publicdocs/futures_us_reports/oj/FCOJ_Tank_Facilities.pdf
[20] http://research.stlouisfed.org/fred2/series/PPIENG?cid=31

when no freeze occurs. In addition, inventories begin to accumulate given that harvesting of oranges begins in the fall and last until early summer. Unrealized freezes and increased inventories lead to a downtrend in futures prices during a typical nonfreezing winter. However, occasional sharp price increases caused by severe freezing can cause positive returns to FCOJ futures. We examine a subsample of five freezing months in which freezes occurred. These freezing months are January-February 1996, January 1999, and January-February 2000. The average futures return is 1.32% for the freezing months. Table 4 summarizes the data for different years. The results are similar to those of Table 3.

6. FCOJ FUTURES PRICES, THE QUALITY OPTION AND TEMPERATURE: MODEL AND RESULTS

6.1 Estimation of the Value of the Quality Option

As noted in the introduction, the FCOJ-1 futures contract, which was traded till the March 2005 delivery month, did not specify the origin of FCOJ deliverable under the contract. However, orange juice from Florida and Brazil dominate the orange juice market, and Florida and Brazil orange juice are priced at a premium by market participants. Thus, we focus on FCOJ from Florida and Brazil only in valuing the quality option.

[Please insert Figure 6 about here.]

Although the quality of the orange juice from Florida and Brazil is the same, the cost of the juice from these two places is different over different seasons and years. Figure 6 compares the monthly spot prices of FCOJ from Florida and from Brazil, which takes into account the tariff, equalization tax and transportation costs, for the years 1994 through 2000. We note that the spot price of FCOJ from Brazil is close to, but more expensive than that from Florida over the period from 1994 to 1996. In 1997, FCOJ from Brazil is far more expensive than that from Florida. Figure 1 shows that the volume of FCOJ imported from Brazil in 1997 is lower than the volume imported in 1996 by 23%. However, from 1998 to 2000, the prices of FCOJ from Brazil and from Florida fluctuate around each other.

If there is uncertainty as to whether FCOJ from Florida or from Brazil will be cheapest to deliver on the maturity of the futures contract, the quality option will have value. The greater the value of this option, the lower will be the futures prices.

Following Gay and Manaster, we use the model of an exchange option that was initially developed by Margrabe (1978) to estimate the value of the quality option. The exchange option is to exchange FCOJ from Florida (asset 1 with spot price X_{1t} at time t) for FCOJ from Brazil (asset 2 with spot price X_{2t} at time t) at time T, the delivery date of the futures contract. The value of the quality option at time t is given below:

$$W_t(T, X_{1t}, X_{2t}) = X_{1t}N(d_1) - X_{2t}N(d_2)$$

where $N()$ is the cumulative standard normal probability function,

$$d_1 = \frac{\ln(X_{1t}) - \ln(X_{2t}) + 0.5\sigma^2(T-t)}{\sigma(T-t)^{1/2}}$$

$$d_2 = d_1 - \sigma(T-t)^{1/2}$$

and σ is the standard deviation of the difference between the rates of return on assets 1 and 2. We estimate σ for each month based on the sample standard deviation of changes in $\ln\left(\frac{X_{1t}}{X_{2t}}\right)$ for the preceding twelve months. Table 3 shows the mean and standard deviation of the monthly value of the quality option for each season. On average, the quality option constitutes 14.70% of the futures price, which is a substantial amount. For the freezing months, the average value of the quality option and the percentage of corresponding future price are the highest, \$0.2352 and 24.23%, respectively. This means that the exchange option of substituting FCOJ from Brazil for FCOJ from Florida becomes more valuable when freezes occur. Table 4 shows that the average value of the quality option in 1997 is 6.07 cents, the lowest in all years and that the average value of the quality option from 1998 onwards ranges from 14.70 cents to 27.59 cents.

6.2 Relationship between the Futures Price and the Quality Option

Using arbitrage pricing methods, Gay and Manaster propose that the futures price in the presence of a quality option should be given by:

$$F_t(T) = e^{r(T-t)}[X_{1t} + S_t(T) - W_t(T, X_{1t}, X_{2t})]$$

where $S_t(T)$ is the present value at time t of the storage costs associated with delivering asset 1 on the delivery date T and r is the risk free rate of interest. Gay and Manaster further convert the above in the form of a regression equation as:

$$\Delta \ln\{F_t(T)\} - r\Delta t = \gamma_1 \Delta \ln\{X_{1t} + S_t(T)\} + \gamma_2 \Delta \ln\{Z_t(T)\} + \varepsilon_t$$

where γ_1 and γ_2 are coefficients of the regression, ε_t is the error term of the regression and

$$Z_t(T) = \{1 - [\frac{W_t(T, X_{1t}, X_{2t})}{X_{1t} + S_t(T)}]\}.$$

We use $Z_t(T)$ as a proxy for the importance of the quality option. The higher the value of the quality option, the lower the value of $Z_t(T)$. In theory, γ_1 and γ_2 should equal +1. The futures price should increase with an increase in the sum of the spot price and storage costs. The futures price should decrease with an increase in the value of the quality option (decrease in value of $Z_t(T)$).

[Please insert Table 5 about here.]

We run the above regression for different seasons. Table 5 shows the results. We see that the adjusted R^2 ranges from a high of 90.84% for fall to a low of 66.17% in summer. The coefficient γ_1 is positive, as expected, and is statistically significant at the 1% level for all seasons. However, the results on the coefficient γ_2 are mixed. For summer and fall, the coefficient γ_2 is negative but not statistically significant. In these two seasons, the quality option does not have a significant influence on the FCOJ-1 futures price. For spring, the coefficient γ_2 is positive and statistically significant at the 5% level. We would expect that the winter season would be the one with the greatest uncertainty as to the condition of the orange crop in Florida and the need to substitute FCOJ from Brazil for that from Florida. Consequently, we would expect γ_2 to be positive and statistically significant in winter. Contrary to our expectations, however, in winter, the coefficient γ_2 is negative and statistically significant at the 5% level. This indicates that the FCOJ-1 futures price rises as the value of the quality option increases. This unexpected relationship could be partially explained by abnormal high futures prices bid up by speculative long positions in the winter. Malick and Ward find that FCOJ futures prices increase relatively more than spot prices because of the potential for freezes. Potentially, speculative gains could be realized by a long position in the futures contract if a freeze occurs later. In the winter, as the quality option becomes more valuable in the winter, futures prices are also simultaneously pushed up by the market, accounting for the positive relationship. In Section 6.3, we will examine the influence of the quality option while controlling for the influence of freezing temperatures.

6.3 Relationship between the Futures price, the Quality option and Temperature

We next determine the explanatory power of freezing temperatures upon futures prices and the incremental explanatory power of the quality option by conducting two regressions. We first determine the effect of freezing temperatures upon FCOJ futures prices by regressing monthly futures returns $FRET_t$ on monthly changes in freezing temperature, $\Delta CFDD_t$, and its squared term $\Delta CFDD\, squared_t$. Then, we regress monthly futures returns on monthly changes in the value of the quality option as represented by $\Delta Z_t(T)$ and on $\Delta CFDD_t$ and $\Delta CFDD\, squared_t$, for the winter season. Nonlinear effects are addressed by including $\Delta CFDD\, squared_t$ as an independent variable in the regressions. The following two regressions are analyzed.

$$FRET_t = \alpha + \beta_1 \Delta CFDD_t + \beta_2 \Delta CFDDsquared_t + \varepsilon_t$$

$$FRET_t = \alpha + \beta_1 \Delta Z_t(T) + \beta_2 \Delta CFDD_t + \beta_3 \Delta CFDD\, squared_t + \varepsilon_t$$

ε_t represents the error term.

[Please insert Table 6 about here.]

Table 6 presents the results. The first two regressions, labeled (1) and (2), are for winter months, while the last two regressions, labeled (3) and (4), are for months with freezing temperatures. Regressions (1) and (3) only include the temperature variables, while regressions (2) and (4) include the quality option in addition to the temperature variables. The results for regression (2) show that the coefficients of both $\Delta Z_t(T)$ and

$\Delta CFDD_t$ are statistically significant and have the desired sign. The adjusted R^2 of regression (2) is 28.79%, 10% more than that of the regression (1). The adjusted R^2 of regressions (3) and (4) are over 90%. The quality option variable $\Delta Z_t(T)$ provides an additional 7% explanatory power for months with freezing temperatures. Significantly, positive coefficients for $\Delta Z_t(T)$ in regressions (2) and (4) indicate that futures returns actually decrease as the value of the quality option increases. In other words, with the availability of substitutable orange juice from Brazil, futures prices respond by a lower magnitude to the supply shock in Florida caused by the occurrence of freezes. To conclude, the quality option is a significant factor that explains an additional 7-10% variation of FCOJ futures returns in the winter.

7. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

We have investigated the effect of two fundamental factors, the supply of orange juice from Brazil and freezing temperatures in the central Florida region, upon FCOJ futures prices. We explicitly consider the effect of the supply of FCOJ from Brazil upon FCOJ futures returns, by addressing the quality option implicit in the FCOJ futures contract. We value this option and show that, on average, it is a substantial percentage (14.7%) of FCOJ futures prices. A regression of FCOJ futures returns upon changes in the value of the quality option indicate that futures prices are significantly related to the value of the option for winter and spring. We also find that a greater proportion of the variability of FCOJ futures prices (more than 90%) are explained than has been found in previous research (50%), which focused only on freezing temperatures. Besides changes in temperature below freezing, the quality option provides substantial incremental (7-10%) explanatory power. Our research supports the view that futures prices are largely responsive to fundamental factors.

Our research is constrained by a short sample period and monthly estimated data of spot prices for FCOJ from Brazil. In future research, we will extend the sample period and investigate the availability of data with a higher frequency such as weekly or daily data on spot prices, and use it if available. Our results show that the variability of futures prices in the summer and fall seasons cannot be explained by the quality option. Future research can investigate other factors or trading activities to explain the variation of futures returns in these seasons.

REFERENCES

Attaway, J., 1997. A History of Florida Citrus Freezes. Florida Science Source Inc., Lake Alfred, FL.

Bauer, R., Orazem, P., 1994. The rationality and price effects of U.S. Department of Agriculture forecast of oranges. Journal of Finance, 49, 681-695.

Beilock, R., Crandall, P., Hooks, C., 1988. The influence of tariffs, import taxes, and fuel costs on the US orange juice market. Agribusiness 4, 385-401.

Boudoukh, J., Richardson, M., Shen, Y., Whitelaw, R.F., 2003. Do asset prices reflect fundamentals? Freshly squeezed evidence from the OJ market. NBER Working Paper 9515. National Bureau of Economic Research, Cambridge, MA.

Boudoukh, J., Richardson, M., Shen, Y., Whitelaw, R.F., 2007. Do asset prices reflect fundamentals? Freshly squeezed evidence from the OJ market. Journal of Financial Economics 83, 397-412.

Carter, C., Mohapatra, S., 2006. The Sunshine State versus Brazil: Economics of the Orange Juice Trade. Working Paper, University of California, Davis.

Cox, J., Ingersoll, J., Ross, S., 1981. The relation between forward prices and futures prices. Journal of Financial Economics 9, 321-346.

Florida Department of Citrus, 2004. Citrus Reference Book. Economic and Market Research Department, University of Florida, Gainesville, FL.

Florida Department of Citrus, 2005. Citrus Reference Book. Economic and Market Research Department, University of Florida, Gainesville, FL.

Gay, G., Manaster, S., 1984. The quality option implicit in futures contracts. Journal of

Financial Economics 13, 353-370.

Jiang, H., Shanker, L., 2009. Frozen concentrated orange juice futures prices, the quality option and temperature. Presented at the Eastern Finance Association (EFA) 2009 meetings and the Southwestern Finance Association (SWFA) 2009 meetings.

Margrabe, W., 1978. The value of an option to exchange one asset for another. Journal of Finance 32, 177-186.

Matthews, R.F., 1994. Frozen concentrated orange juice from Florida oranges. Fact Sheet FS 8. Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Malick, W., Ward, R., 1987. Stock Effects and Seasonality in the FCOJ Futures Basis. The Journal of Futures Markets 7, 157-167.

Muraro, R., Spreen, T., Pozzan, M., 2003. Comparative Costs of Growing Citrus in Florida and Sao Paulo (Brazil) for the 2000-2001 Season. Extension Digital Information Source (EDIS) FE364, Department of Food and Resource Economics, University of Florida, Gainesville, FL.

Roll, R., 1984. Orange juice and weather. American Economic Review 74, 861-880.

Shefrin, H., 2002. Beyond greed and fear. Oxford University Press, New York.

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Figure 1. Percentage of U.S. FCOJ imports from Brazil

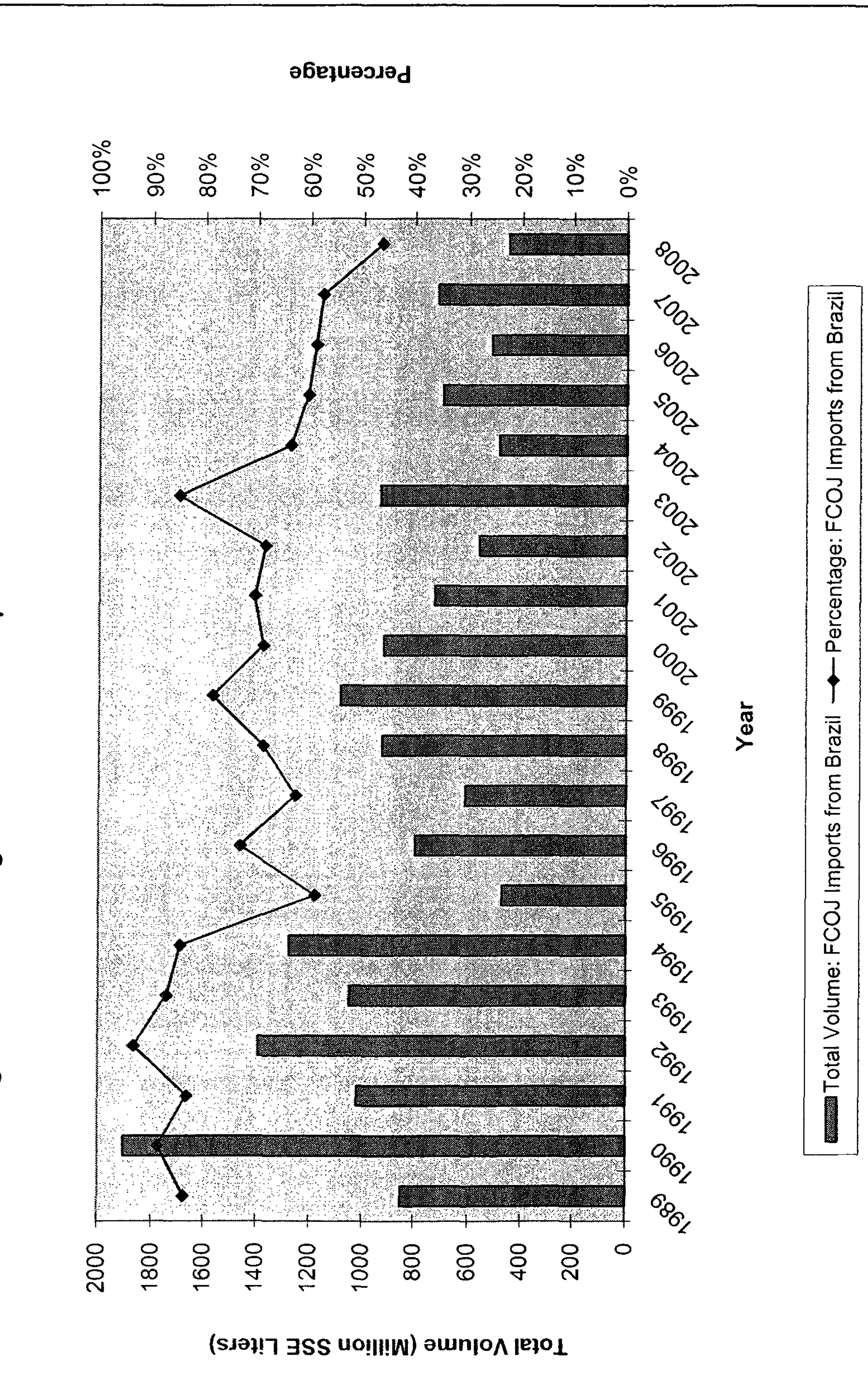

Figure 2. Proportion of FCOJ imported from Brazil, Mexico, and Costa Rica

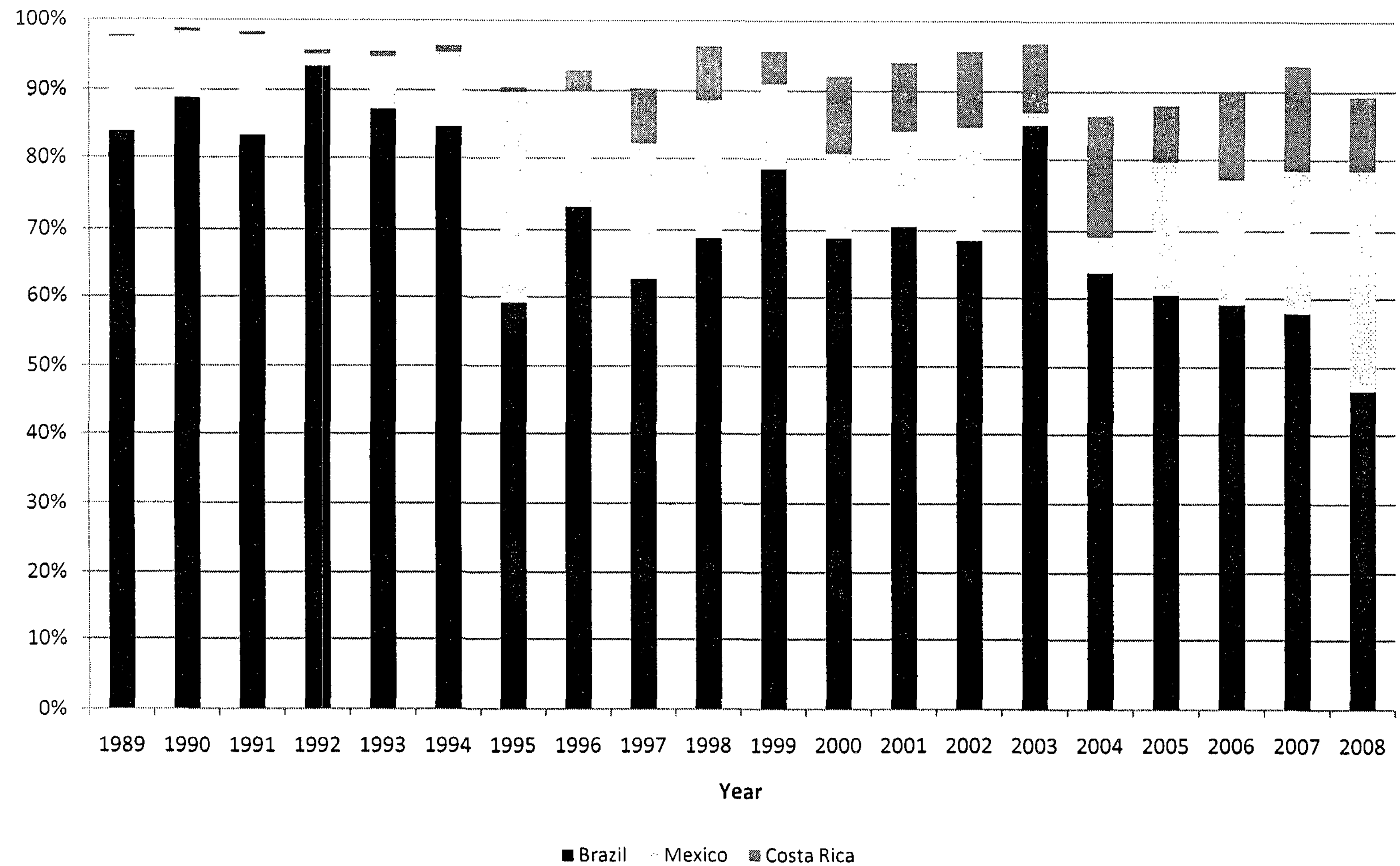

Figure 3. Exchange rate between the Brazilian Real and the U. S. Dollar

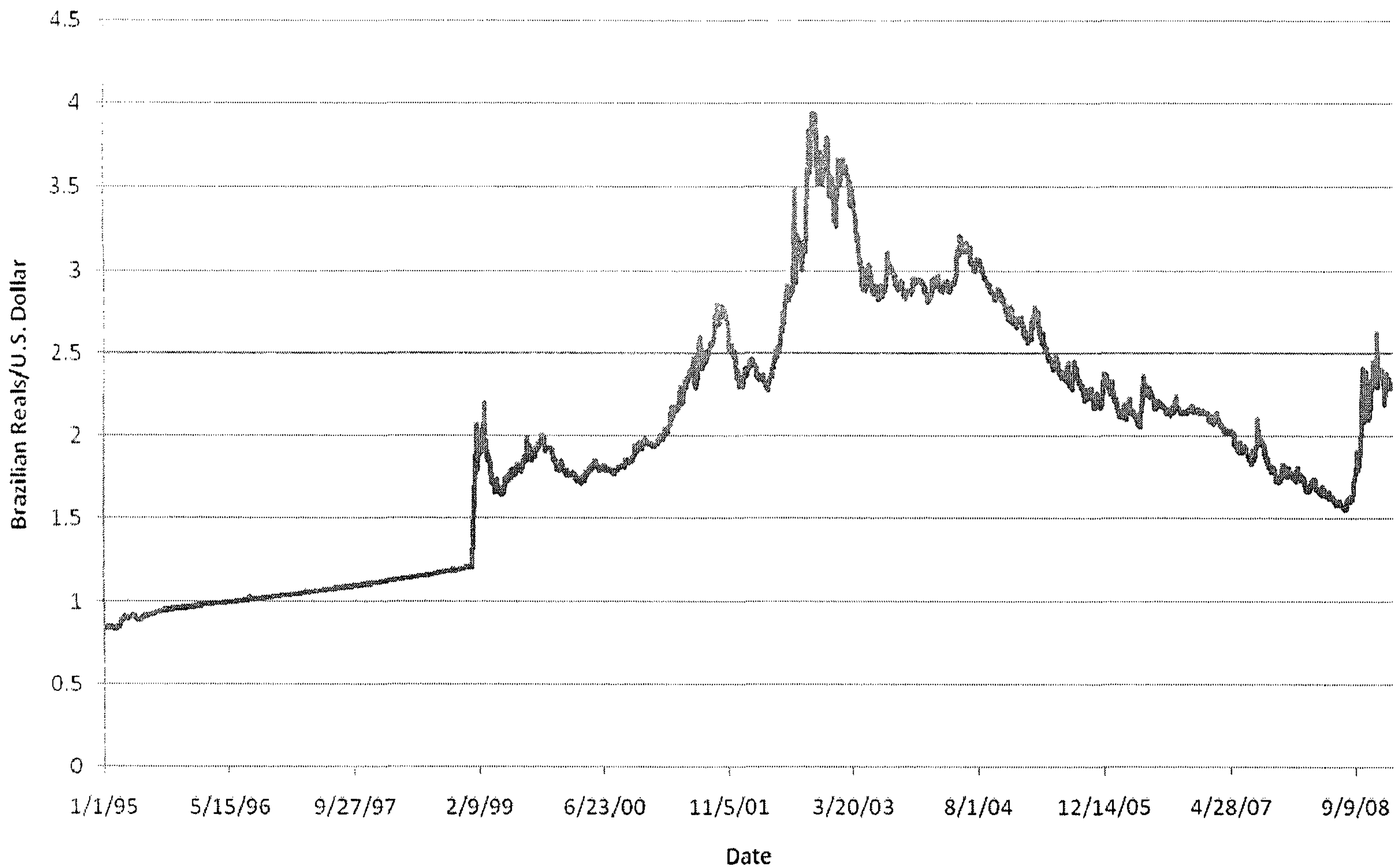

Figure 4. A comparison of monthly FCOJ spot prices from Florida and Brazil (without consideration of tariffs)

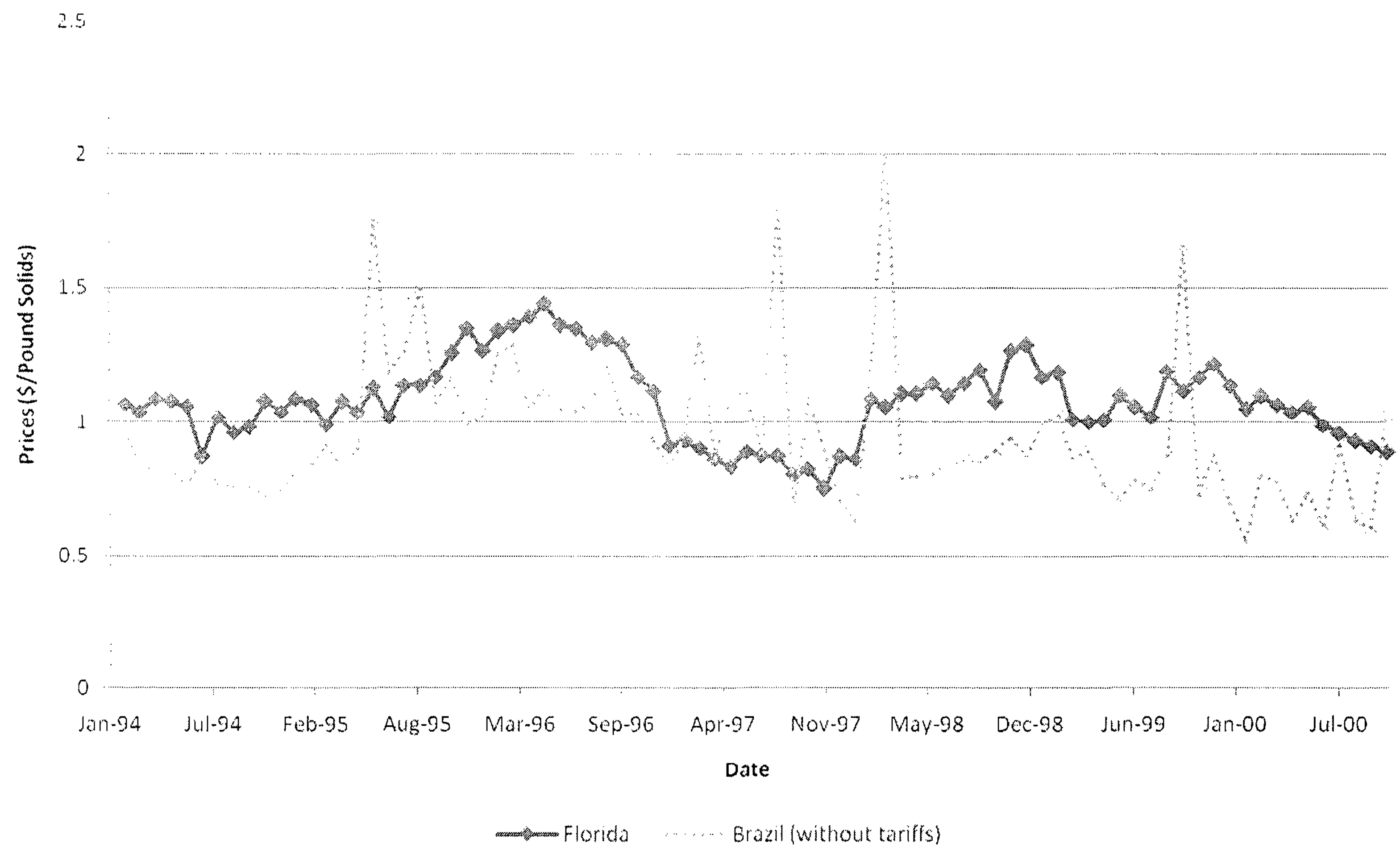

Figure 5. Percentage of FCOJ imported from Brazil through ports in Florida

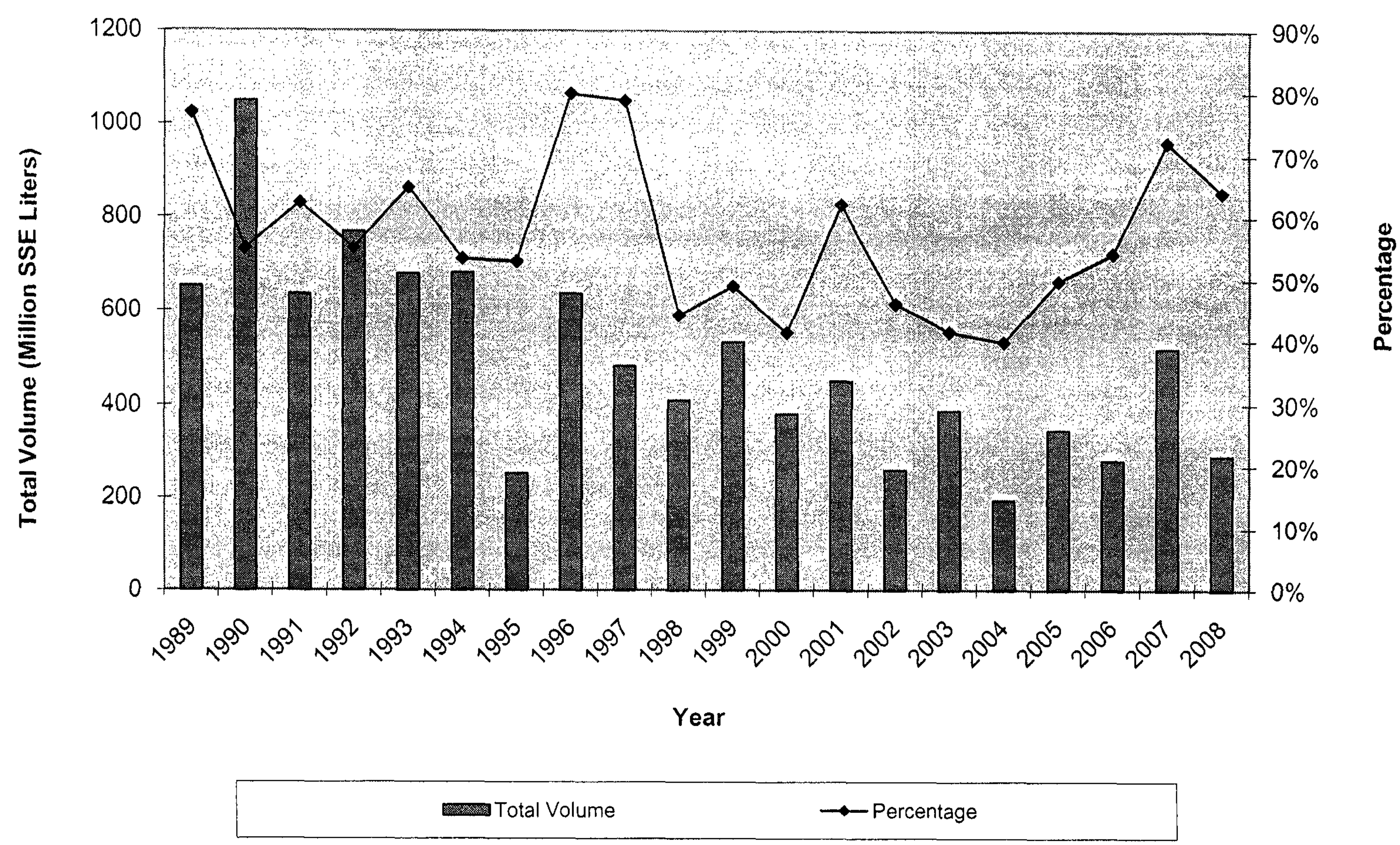

Figure 6. A comparison of monthly FCOJ spot prices from Florida and Brazil (with consideration of tariffs)

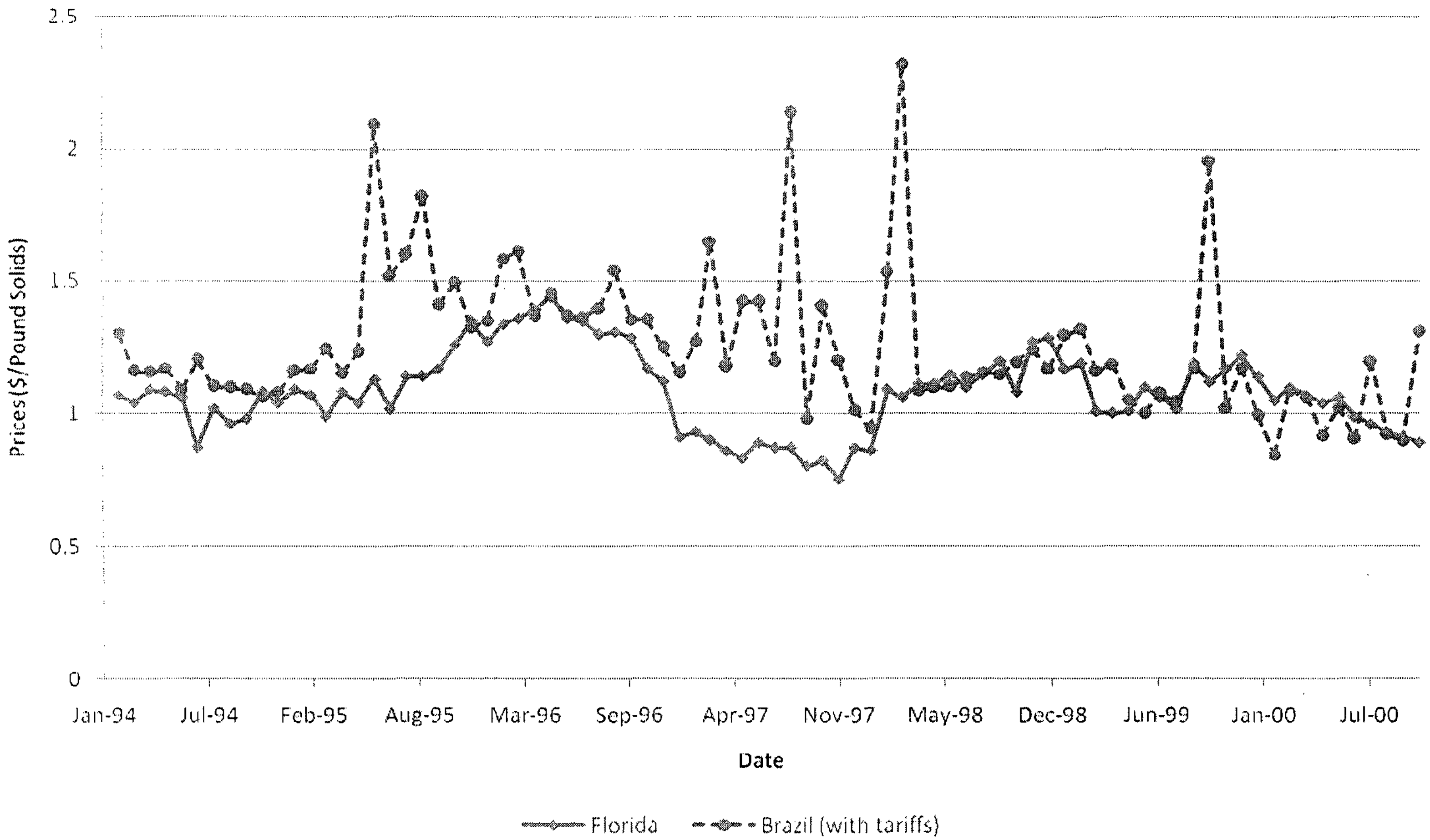

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Table 1. History of the U.S. Frozen Concentrated Orange Juice tariff

	GATT - General (MFN)		
Year	**Cents/Pounds Solids**	**Cents/SSE Gallon**	**Cents/SSE Liter**
1989	34.04	35.02	9.25
1990	34.04	35.02	9.25
1991	34.04	35.02	9.25
1992	34.04	35.02	9.25
1993	34.04	35.02	9.25
1994	34.04	35.02	9.25
1995	33.19	34.15	9.02
1996	32.31	33.24	8.78
1997	31.46	32.37	8.55
1998	30.62	31.50	8.32
1999	29.73	30.59	8.08
2000	28.89	29.72	7.85
2001	28.89	29.72	7.85
2002	28.89	29.72	7.85
2003	28.89	29.72	7.85
2004	28.89	29.72	7.85
2005	28.89	29.72	7.85
2006	28.89	29.72	7.85
2007	28.89	29.72	7.85
2008	28.89	29.72	7.85

Data Source: http://www.floridajuice.ifas.ufl.edu/data/ojtariff.pdf
Florida Department of Citrus - Economic and Market Research, University of Florida

Table 2. Florida production, Brazil exports, and U.S. imports from Brazil

Panel A. Annual FCOJ Data and Descriptive Statistics

Year	Florida Production	Brazil Exports	U.S. Imports from Brazil	Changes in Florida Production	Changes in Brazil Exports	Changes in U.S. Imports from Brazil
1989	2949	3743	850			
1990	2493	4743	1904	-456	1000	1054
1991	3520	4816	1020	1027	74	-884
1992	3289	5106	1393	-231	289	373
1993	4459	6142	1049	1170	1036	-344
1994	4034	6045	1276	-425	-97	228
1995	4725	5065	474	691	-980	-803
1996	4820	6338	796	95	1273	322
1997	5401	6218	611	581	-120	-185
1998	5979	6752	928	578	534	317
1999	4444	6012	1086	-1535	-740	158
2000	5571	6830	922	1127	818	-164
2001	5356	6513	725	-215	-317	-197
2002	5464	5448	563	108	-1065	-163
Mean	4465	5698	971	193	131	-22
Standard Deviation	1075.04	897.73	373.89	745.24	748.27	495.69
Correlation with Changes in U.S. Imports from Brazil				-0.58	0.44	

Panel B. Explaining U.S. Imports from Brazil

State	Average Changes in Florida Production	Average Changes in Brazil Exports	Average Changes in U.S. Imports from Brazil
Δ Florida Production > 0	672.12		-237.89
Δ Florida Production < 0	-289.30		323.16
Δ Brazil Exports > 0		717.70	96.27
Δ Brazil Exports < 0		-553.11	-160.20

Note: The source for data is the Citrus Reference Book 2004, Florida Department of Citrus. All annual numbers of production, imports and exports are converted to million SSE liters.

Table 3. Summary statistics on monthly data on FCOJ futures prices, futures returns, FCOJ spot prices, the estimated value of the quality option, and the minimum temperature for different seasons

		Mean / Standard Deviation						
Season	Number of Observations	Futures Price ($)	Futures Return (%)	Spot Price - Brazil ($)	Spot Price - Florida ($)	Temperature (^{0} Celsius)	Quality Options Value ($)	Quality Option Value / Futures Price
Winter (Dec. Jan. Feb.)	51	0.96	-4.06	1.33	1.08	10.89	0.1425	0.1505
		0.16	*10.01*	*0.34*	*0.15*	*5.05*	*0.1097*	*0.1292*
Freezing Months	24	1.04	1.32	1.32	1.22	9.72	0.2362	0.2423
		0.22	*8.03*	*0.29*	*0.12*	*4.98*	*0.0962*	*0.1305*
Spring (Mar. Apr. May)	54	0.97	0.54	1.23	1.09	15.29	0.1525	0.1520
		0.19	*8.46*	*0.26*	*0.16*	*4.76*	*0.1336*	*0.1332*
Summer (Jun. Jul. Aug.)	54	0.95	-1.10	1.30	1.08	22.54	0.1343	0.1405
		0.18	*8.60*	*0.32*	*0.16*	*1.72*	*0.1160*	*0.1151*
Fall (Sep. Oct. Nov.)	51	0.96	1.29	1.28	1.10	18.87	0.1454	0.1451
		0.20	*8.85*	*0.23*	*0.18*	*4.29*	*0.1151*	*0.1105*

Table 4. Summary statistics on monthly data on FCOJ futures prices, futures returns, FCOJ spot prices, the estimated value of the quality option for different years

		Mean / Standard Deviation					
Season	Number of Observations	Futures Price ($)	Futures Return (%)	Spot Price - Brazil ($)	Spot Price - Florida ($)	Quality Option Value ($)	Quality Option Value/ Futures Price
1995	36	1.08	-0.78	1.45	1.14	0.0757	6.46%
		0.09	*7.77*	*0.27*	*0.11*	*0.0654*	*0.0507*
1996	36	1.16	-2.45	1.40	1.28	0.1016	8.39%
		0.16	*8.16*	*0.13*	*0.14*	*0.0742*	*0.0571*
1997	36	0.75	-1.12	1.32	0.85	0.0607	7.55%
		0.06	*10.64*	*0.32*	*0.05*	*0.0757*	*0.0912*
1998	36	1.07	0.90	1.29	1.15	0.2759	24.58%
		0.06	*10.30*	*0.34*	*0.07*	*0.1127*	*0.0956*
1999	36	0.88	0.36	1.18	1.10	0.1470	0.1654
		0.07	*10.24*	*0.26*	*0.08*	*0.1126*	*0.1241*
2000	30	0.78	-2.10	1.02	1.00	0.2126	0.2667
		0.06	*6.24*	*0.15*	*0.07*	*0.0930*	*0.1132*

Table 5. Relationship between FCOJ futures prices and the value of the quality option

Season	Number of Observations		γ_1	γ_2	Adjusted R^2
Winter	48	Coefficient	1.1279	-0.2058	88.71%
		t-statistic	19.07	-2.52	
		p-value	<0.0001	0.0152	
Spring	54	Coefficient	0.7248	0.0861	68.18%
		t-statistic	10.79	2.24	
		p-value	<0.0001	0.0192	
Summer	54	Coefficient	0.8943	-0.0804	66.17%
		t-statistic	10.37	-1.08	
		p-value	<0.0001	0.2869	
Fall	51	Coefficient	0.8903	-0.0041	90.84%
		t-statistic	20.26	-0.13	
		p-value	<0.0001	0.8934	

Table 6. Relationship between FCOJ futures prices, the value of the quality option and freezing temperature

		Winter	Winter	Freezing Months	Freezing Months
Independent Variable		**(1)**	**(2)**	**(3)**	**(4)**
Intercept	Coefficient	-0.0015	-0.0873	-0.1086	-0.0943
	t-statistic	-0.05	-1.67	-11.34	-19.08
	p-value	0.963	0.1105	<0.0001	<0.0001
$\Delta Z_t(T)$	Coefficient		0.9495		0.7517
	t-statistic		2.00		6.01
	p-value		0.0596		0.0003
$\Delta CFDD_t$	Coefficient	0.0295	0.0433	-0.0567	-0.1205
	t-statistic	1.93	2.73	-10.56	-1.54
	p-value	*0.0668*	0.0129	*<0.0001*	0.1612
$\Delta CFDD_t$ squared	Coefficient	-0.0194	-0.0137	0.0344	0.0115
	t-statistic	-2.29	-1.63	10.22	2.81
	p-value	0.0326	0.1194	<0.0001	0.0228
Number of Observations		24	24	12	12
Adjusted R^2		18.67%	28.79%	91.31%	98.23%

GLOSSARY OF TERMS

Brix "The percent of weight of soluble solids (sugars and acids) in a solution measured at sea level at 20 degrees Celsius. The Brix scale determines the percent by weight of soluble solids, with the present minimum of 42-degree Brix indicating that 100 pounds of concentrated juice would contain 42 pounds of soluble solids at a specific temperature."[a]

Bulk "Processed product (especially frozen concentrated orange juice for manufacturing and frozen concentrated grapefruit juice for manufacturing) stored in 55-gallon drums or tank farms." [a]

Carry-over "Inventory of processed product on hand at the end of a marketing season as of the beginning of the first week in December for concentrated juices." [a]

Crop Estimate "A monthly appraisal of crop size, issued by the United States Department of Agriculture (USDA). The first estimate of citrus production is announced in early October each year, with updated estimates issued each month through July." [a]

FCOJ "Frozen concentrated orange juice, especially that production in retail or institutional packs between 41.8 degrees and 47.0 degrees Brix." [a] FCOJ imported from Brazil has 65 degrees Brix.

FCOJM Frozen concentrated orange juice for further manufacturing

FOB Price Freight on board price. "Price for finished product (processed or fresh), includes loading onto transportation medium, but excludes the cost of transportation to the buyer." [a]

Pound Solids "The amount of soluble solids (sugars and acids) contained in one box of fruit." [a] "A pound solid is a basic and standardized measurement of the amount of dissolved citrus sugar found in juice." [b]

Single Strength Juice "Orange juice at 11 degrees to 12 degrees Brix, which is the concentration of orange juice when extracted from oranges and the concentration of ready to drink retail juice products." [c]

Single Strength Equivalent (SSE) Gallons "SSE gallons are a standard volume measurement for orange juice at a ready-to-drink concentration level of 11.8 Brix. One gallon of SSE orange juice of 11.8 degrees Brix is equivalent to 1.029 pounds solids." [b]

Solids "The soluble sugar and acids content of a solution." [a]

*(a) Definition quoted from the Citrus Glossary on the web page of the Florida Department of Citrus. http://www.floridajuice.com/glossary.php

*(b) Definition quoted from the footnote 132 in Orange Juice from Brazil, DIANE Publishing, March 2006.

*(c) Definition quoted from the Glossary in Brazilian Orange Juice, Rabobank International, 2007.
http://www.rabobank.com/content/images/Rabobank_Brazilian_orange_juice_intro_tcm43-55739.pdf