12-1-2010

# CONTAMINATION EVENTS AND LINKAGES IN WORLD RICE MARKETS

Mana-anya Iemsam-arng
*Southern Illinois University Carbondale*, doraemon_138@hotmail.com

# CONTAMINATION EVENTS AND LINKAGES IN WORLD RICE MARKETS

by

Mana-anya Iemsam-arng

Bachelor of Science in Post Harvest Technology, Maejo University, 2007

A Thesis Submitted in Partial Fulfillment

of the Requirements for the

Master of Science Degree

Department of Agribusiness Economics

in the Graduate School

Southern Illinois University at Carbondale

December 2010

THESIS APPROVAL

CONTAMINATION EVENTS AND LINKAGES IN WORLD RICE MARKETS

by

Mana-anya Iemsam-arng

A Thesis Submitted in Partial

Fulfillment of the Requirements

for the Degree of

Master of Science

in the field of Agribusiness Economics

Approved by:

Dr. Dwight Sanders, Chair

Dr. Charles Rendelman

Dr. David Lightfoot

Graduate School

Southern Illinois University Carbondale

November 9, 2010

AN ABSTRACT OF THE THESIS OF

Mana-anya Iemsam-arng, for the Master's degree in Agribusiness Economics, presented on November 9, 2010, at Southern Illinois University Carbondale.

TITLE: Contamination Events and Linkages in World Rice Markets

MAJOR PROFESSOR: Dr. Dwight Sanders

In August of 2006, genetically modified LibertyLink rice contaminated the supply of non-GMO rice in the United States, causing damage to the U.S. rice production sector's credibility in their export market. The damage to the United States' credibility included doubt as to whether or not they had the ability to separate GMO and non-GMO rice strains during planting and/or production. This may have caused a short-term decline in the price of U.S. rice. The purpose of this paper is to examine rice price relationships from August 1997 to February 2010 among the four major rice exporting countries (Thailand, Vietnam, the United States, and India) before and after the genetically modified rice contamination event. Using unit root tests and cointegration tests, the results show that international rice export prices are independent from each other, yet the U.S., Thailand, and Vietnam 5 percent broken DWP rice prices tended to change in the same direction. The fact that the change in rice prices occurred right after the U.S. GMO contamination event of August 2006 is statistically significant. However, the results of this study cannot be proven to indicate that the contamination event's impact caused this change in rice export prices.

**Keywords:** ***Rice prices, Contamination Events***

ACKNOWLEDGMENTS

First of all, I would like to sincerely thank the chairman of my thesis committee, Dr. Dwight Sanders, for his commitment, encouragement, and helpful guidance throughout the thesis. This thesis would not have been possible without the patient assistance and kindness of Dr. Dwight Sanders.

My appreciation goes to Dr. Charles Rendleman as a thesis committee member for his valuable suggestions and comments. I also gladly express my appreciation for Dr. David Lightfoot, a member of my thesis committee, for his suggestion and comments on genetically modified crops and writing technique.

Finally, my thanks to all of the faculty members, staff, and fellow graduate students in the Department of Agribusiness Economics for making my study interesting and meaningful.

TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

# CHAPTER I

# INTRODUCTION

*This chapter constitutes an overview of rice cultivation along with a general background of rice and its nutritional qualities. It also demonstrates the effect of the contamination of rice crops with genetically modified varieties, literature review and a problem statement, with justifications for the objective of the study.*

## The Recent Situation

In mid-August 2006, the USDA confirmed the finding of LL601 rice traces in commercial samples of long-grain rice in Arkansas and Missouri awakening concern for the contamination of conventional varieties by genetically modified rice (Vogel, 2008). After the announcement, the European Union affirmed the existence of the traces of LL601in rice that had been imported from the U.S since January 2006 (Li et al, 2006). The rice strain LL601 is not commercially approved in the U.S., yet it has found its way into non-GM crops. Representatives of anti-GM groups questioned how the contamination happened since rice is a self-pollinating plant. Consequently, U.S. rice prices fell nearly 10 percent in 2 days (Vogel, 2008). Europe and Japan, two large high-quality rice markets for the U.S., stopped any further imports of U.S. rice right after the discovery of LibertyLink rice. The European Union responded to the incident by searching for ways to prevent future contamination. The discovery of traces of LL601 in U.S. supplies was said to be a failure of biotechnology companies in containing field trials and of the government's inability to control and keep food supplies secure from unapproved trials (Vermij, 2006). Demont and Devos (2008) suggest potential sources of the contamination of non-GM crops by GM crops including impure seed, cross-fertilization between neighbor crop trials and the use of the same machines for both GM and non-GM crops in both pre- and post-harvest operations.

Furthermore, in the same year, the unauthorized Bt63 strain had contaminated Chinese rice exports both in wholesale rice supplies and in processed food products in European countries and another commercially unapproved rice strain, Bayer GM's LL62 variety, also imported from the U.S., was detected in France (Vogel, 2006). The GM rice contamination has affected many people in the rice production chain: rice producers, millers, traders, and retailers, around the world. Costs included those of testing recalled rice along with, import bans, and the distrust of consumers resulting from them. The consequence of this scandal is likely to have an impact on finances and international trade agreements (Gurere, Bouet and Mevel, 2007).

Although genetically modified rice is still controversial internationally, China, the world's largest rice producer and consumer, is considering allowing the first authorizations for marketing several GM rice varieties without funding from biotechnology companies, despite strong opposition in Europe to GM crops and the imposition of trade restrictions (Wang and Johnson, 2007). Despite these contamination events, the United Sates still maintains 57.7 million hectares of genetically modified crops of soy and maize for research and commerce. Although genetically modified crops are not yet widely acceptable in international trading due to the uncertainty surrounding them, many countries around the world have adopted the trials including Argentina, Brazil, Canada, India, Paraguay and South Africa, the only African country allowing the use of GM-crops.

## Overview and Background of Rice Cultivation

Most of the world's population consumes rice, which accounts more than 50 percent of their calories consumed ("Rice is Life", 2004). It is believed that rice cultivation began over 6,500 years ago in many countries in India and Indo-China: China, Thailand, Cambodia, Vietnam and Southern India (Grit, 1984). The most commonly produced Asian rice types are: *Indica,* a long-grain irrigated rice of warm tropical zones with long, thin, flat grains, which accounts for more than 75 percent of the world's rice trade at the present day, *Japonica*, a scented short-grain rice grown in cooler climates with medium or short grains, *Aromatic*, a scented long-grain variety, and *Glutinous*, with a waxy grain that is very sticky when cooked. Rice was adapted for farming in the Middle East and Mediterranean Europe in 800 B.C. Rice was brought to the U.S. in the late 1600's by a ship from Madagascar, though rice did not become commercially viable there until irrigation systems were introduced to many states south of the Ohio River and the east of the Mississippi as well as in Illinois, Virginia, Arkansas, California and Texas (Childs, 2009).

There are two main rice species that are used currently: *Oryza sativa,* a common variety found in most rice-producing countries, and *Oryza glaberrima*, an annual species originating in West Africa found mostly in a large region extending from the central Delta of the Niger River to Senegal (Grist, 1978). The most widely produced of these two species is *O. sativa*, an Asian rice species that is now grown on all continents. Rice is a cereal of the grass family, the same family as wheat, rye, oats and barley, but rice has a wider range of suitable planting temperatures than those crops. Although rice is widely consumed and produced, the area for farming it is limited due to the availability and control of water, temperature, wind, light, length of day, and soil type.

## Human Nutrition

Almost half of the world's population relies on rice as a staple food ("Rice is Life," 2004). It is more convenient to cook rice than most other staple foods because it requires less fuel and can be stored for long periods. In addition, rice is inexpensive and accessible to both rural and urban areas. Rice is a source of carbohydrates, magnesium, thiamin, niacin, phosphorus, vitamin B6, zinc and copper. A rice grain consists of the hull (including the awn, lemma and palea) and the caryopsis, which is edible. Rice that includes the caryopsis, is called brown rice ("The Stabilization," 1955). Levels of dietary fiber, minerals and B-vitamins are highest in the bran and lowest in the aleurone layers. The endosperm is rich in carbohydrates and contains a fair amount of digestible protein, composed of an amino acid profile, which compares favorably with other grains. Moreover, rice has high good protein content, comparable to lentil and peanut proteins. However, the nutrition content of rice varies according to varieties.

Rice Nutrition Table.1 shows that there is no clear indication from studies that rice with less milling has more nutritive value than polished rice ("Rice is Life," 2004). However, certain nutrients will occur at different levels as a result of each method of rice processing, which will be discussed in Chapter 2. Rice lacks many other important nutrients such as vitamins C and D, beta-carotene and other micronutrients, which can result in protein-energy malnutrition and deficiencies in vitamin A, iron, calcium and protein for peoples in the East. The causes of these deficiencies are that the rice grain itself lacks certain nutrients and that the milling process removes the brown outer layer (the bran) leaving only the white grain. Although the white grain takes less time to cook and has a longer storage life, this process removes many important nutrients. The starch content of rice changes after harvesting. The change in the starch content of paddy results in a grain of firmer texture than is that of freshly-harvested rice. Not only is the rice grain rich in many important nutrients, growing rice also improves conditions in the surrounding environment. Because planting rice requires a wetland ecosystem containing an enormous number of food sources, this healthy ecosystem also benefits other plants, insects, amphibians and reptiles existing naturally in the watery field.

Table 1.1
Rice Nutrient Database for Standard Reference

| | | **Brown** | **White** | **Parboiled** |
|---|---|---|---|---|
| **Nutrient** | **Unit** | ¼ cup raw (46.25grams) | ¼ cup raw (46.25grams) | ¼ cup raw (46.25grams) |
| Calories | kcal | 171 | 169 | 172 |
| Protein | g | 3.64 | 3.30 | 3.14 |
| Total Fat | g | 1.35 | 0.31 | 0.26 |
| Carbohydrate | g | 35.72 | 36.98 | 37.80 |
| Fiber | g | 1.62 | 0.60 | 0.79 |
| **Mineral** | | | | |
| Calcium, Ca | mg | 10.64 | 12.95 | 27.75 |
| Iron, Fe | mg | 0.68 | 0.37 | 0.69 |
| Magnesium, Mg | mg | 66.14 | 11.56 | 14.34 |
| Phosphorus, P | mg | 154.01 | 53.19 | 62.90 |
| Potassium, K | mg | 103.14 | 53.19 | 55.50 |
| Sodium, Na | mg | 3.24 | 2.31 | 2.31 |
| Zinc, Zn | mg | 0.93 | 0.50 | 0.44 |
| Copper, Cu | mg | 0.13 | 0.10 | 0.09 |
| Manganese, Mn | mg | 1.73 | 0.50 | 0.39 |
| **Vitamins** | | | | |
| Vitamin C | mg | 0.00 | 0.00 | 0.00 |
| Thiamin | mg | 0.19 | 0.03 | 0.05 |
| Vitamin B-6 | mg | 0.24 | 0.08 | 0.16 |
| Folate | mcg | 9.25 | 3.70 | 7.86 |
| Vitamin B-12 | mcg | 0.00 | 0.00 | 0.00 |
| Vitamin A | mcg | 0.00 | 0.00 | 0.00 |
| Vitamin E | IU | 0.33 | 0.06 | 0.07 |

Source: Adjust from The United States Department of Agriculture, Agricultural Research Service, 2002.

## Genetically Modified Rice

A concern has grown that much of the world's population, mostly in Southeast Asia, are facing malnourishment and vitamin A deficiency. This is combined with the rapid increase in population which is proportionally greater in developing countries (Enserink, 2008). In 1999, Potrykus, a German Plant biotechnologist, and his colleagues introduced "Golden Rice," a rice variety that contains pro-vitamin A in its seed. This rice variety has been claimed to be the solution for the malnutrition and vitamin deficiencies of the world's poor. However, opponents argue that the real motivation behind the introduction of Golden Rice is to open the door for the usage of other genetically modified crops and that consumers' preference for genetically modified crops has an unacceptable impact on conventional crops and their prices.

The wide range of rice production and consumption emphasizes its importance in feeding half of the world's population ("Rice is life," 2004). Innovations in biotechnology research have led to the development of genetically modified crops as a means of improving various aspects of rice production (Ching, 2004). Research on GM rice is conducted in order to create trails with the following charactertistics: 1) *Herbicide* ***tolerance***. LLRICE06 and LLRICE62, developed by Aventis, contain the herbicide glufosinate and can now be grown commercially in the U.S., but still lacks both domestic and international markets to support its production. 2) *Insect resistance*. Crytoxin genes, usually Cry1Ab and Cry1Ac genes, from the bacterium *Baccillus thuringiensis* (Bt) have been introduced into rice to protect the crop from Lepidopteran pests. 3) *Disease resistance*. Researchers use genetic modification to build resistance to diseases caused by bacterium blight, the fungus *Pyricularia oryzae* and the rice yellow mottle virus**. 4)** ***Tolerance to abiotic stress.*** Genetically engineered rice has been developed to tolerate low iron availability in alkaline soil with the insertion of the barley gene *Hva1* into rice to reduced drought damage. 5) *Nutritional enhancement*. Pro-vitamin A has been inserted into Golden Rice grains as a cure for vitamin A deficiency, while a ferritin gene from the bean *Phaselus valguris* has been used in GM rice to combat iron deficiency anemia. 6) *Production of pharmaceuticals*. GE rice is being developed in California to produce the human milk proteins lactoferrrin, lysozyme and alpha-1-antitrypsin.7) *High yields*. A rice variety producing high yields was created during the Green Revolution to increase global food production.

Because of the importance of rice for the world's population, the attempt to alleviate for malnutrition can be seen in many active international programs, companies and organizations (Brookes and Barfoot, 2003). The Asian Rice Biotechnology Network (ARBN) supported by the Asian Development Bank (ADB), the German government, and the Swiss Federal Institute of Technology, which the latest initially developed Golden Rice, are one of several international rice programs that aim at developing rice biotechnology, focusing on increasing farmer's incomes and promoting human nutrition. Aventis, BASF Plant Science GmbH, Dow AgroScience, Dupont (Pioneer), Monsanto, Syngenta, Applied Phytologics Inc., Crop Design, Orynova NV, and Paradigm Genetics are examples of companies that are involved in developing genetically modified crops, specifically rice for both research and commerce. Aventis is the first company to become involved in GM rice research, operating since the mid 90s. It has spread its GM rice field trials throughout the United States, South America, Europe and Japan. Pioneer, originally known as Dupont, began research on genetically modified rice in India. Its main purposes for GM rice research were improved yield, food quality and disease resistance. Pioneer's rice research is now conducted as a model for further GM corn studies. The International Rice Research Institute (IRRI) is an agricultural non-profit organization that concentrates on rice research for low-income and developing countries. GM rice research is one of the company's research specializations.

Despite the positive outlook for genetically engineered rice, it is still not widely accepted by consumers due to its unknown impact on human health, socio-economic factors, and the environment ("Rice is Life," 2004). The health concerns are that genetically engineering rice through the random insertion of DNA sequences into the plant genome, which may disrupt or silence genes, activate silent genes or modify gene expression, may have unintended effects. Studies by independent researchers show differences in the behavior of animals fed with GM and non-GM crops, though the results are not the same as those from studies conducted by biotech industries.

Rice is more than a diet crop for many people, found to be bonded with the culture, religions, and social characteristics of many societies ("Rice is Life," 2004). Rice-growing communities often have elaborate festivals- during their planting and harvest seasons. In Thailand, the Royal Ploughing Ceremony signals the beginning of the rice-planting season. There is a festival in southern India in which newly harvested rice is offered to cows, and in Korea, rice farmers will keep rice is a small jar and worship it as a household god. Moreover, rice is an important source of employment and income in many developing regions of the world. Thus, contamination by GM rice could potentially have an impact on farmers' income and welfare, rural employment ethics and ideas about agriculture, and technology. Furthermore, the adoption of genetically modified rice might jeopardize people's right to choose non-GM rice and affect export markets. GM rice that has been planted in the same field as non-GM rice could cause cross-pollination leading to the spread of genetically modified rice. In addition, there are issues surrounding intellectual property rights (IPRs) involving genetically modified rice. To be precise, owners of GMO rice would control rice seeds, so that farmers could no longer save, replant, or sell the seeds of GMO rice. The potential socio-economic issues arising from the adoption of genetically modified rice include the inequitable distribution of benefits, land concentration and labor displacement (Annou, Thomsen and Wailes, 2001). Many developed countries such as Japan, South Korea, some European countries and Russia, have put restrictions on genetically modified crops.

A study conducted by Gruere et al (2007) indicates that the fear of losing export markets is the main reason that many developing countries have not yet approved the use of genetic modification technology. India and China have developed GM cotton, which generates benefits for their farmers. GM cotton has been partly regularized for large-scale production in India, yet because cotton is not used for food; there is no need for GM cotton to be tested for food safety, or to be labeled or traced. In fact, Gruere et al claim that due to misinformation and a lack of knowledge about international trade systems, countries adopting GM technologies have not lost export shares for certain commodities. Although it is believed marketing GM and non-GM crops separately is infeasible and costly, countries producing large GM crops such as the U.S., Argentina, Canada and South Africa produce and separate conventional non-GM crops for both domestic and international markets.

## Problem Statement

Since rice is a staple food for many people from many cultures, societies, and economics regions, protectionist attempts to reach national self-sufficiency are of particular interest to governments (David and Huang, 1996). Although the production and consumption of corn and soy dominate a great share of U.S. agricultural commodities, an increase in its domestic population tending to cultural diversity owing to second and/or third generation immigrants combined with the emergence of new market niches in the Middle East has caused rice to gain its part in the United States' production and trading (Childs, 2009). Because growing rice involves high costs in production, irrigation, fertilizer and labor, and because rice paddy needs particular physical requirements for planting, there is a demand for researchers and scientists to create new rice strains. Genetically modified rice has been developed in order for the U.S. to be more competitive with Asian rice producing countries in the international rice trade. Due to strong opposition from the European Union and Japan, two of the biggest rice markets, many rice-producing countries retain GM-free practices in order to remain in these markets.

Li et al (2010) conducted a recent study on genetically modified rice contamination focusing on its impact on rice prices in the U.S. and Thailand. However, global rice markets trade rice of various milling degrees and types from other major rice exporters. Thus, this study examines the effects of LL601 contamination on four major rice-exporting countries: India, Vietnam, Thailand and the U.S. The rice from these countries in term of its quality is substitutable, and changes in rice policy and levels of rice stocks in each country potentially have an impact upon the world's rice prices. Regarding genetically modified crops, the U.S. is an open country that has adopted GM crops since the mid-1990s. The existing research on world rice prices is quite limited due to the fact that the rice trade is a segment market. There has not been much research on the dynamics of rice prices in the world market. The study of rice price dynamics is important as it comes at a time when U.S. producers both of non-GM and of GM rice are looking for ways to have some understanding over the prices they receive in the domestic market. Vinuya (2006) indicates that a cointegrated market will need to achieve equilibrium in the long-run necessitating an adjustment of prices. Those adjustments may come as suppliers adjust their behavior to maximize profit and from the demand side in a movement away from more expensive suppliers.

## Specific Objectives of the Research

The main purpose of this study is to understand the long-and short-run equilibrium of rice prices in the export markets of India, Thailand, Vietnam and the United States individually and in pairs. More specifically, the purposes of the study are as follows:

a. To analyze the long-run rice price relationship among the four major rice exporters before and after the occurrence of genetically modified rice contamination.

b. To analyze the short-run relationship among rice markets due to the effects of contamination.

c. To explain the impact of contamination using both statistical modeling and policy analysis.

For the purpose of analyzing long-run equilibrium of agricultural commodities in the world market, three approaches are commonly used by researchers. These include: (a) stationary trend, (b) long-run equilibrium cointegration, and (c) error correction models for short run equilibrium. This study will analyzes these three approaches.

## LITERATURE REVIEW

Although there has been much economic research on rice, most of it has studied competition and market structure. Recently, the effects of genetically modified crop contamination has gained some attention from researchers examining its effect on particular aspects including consumers' acceptance of GM food , the effect of adopting GM rice on producers' benefits, the impact on prices of non-Gm and GM crops, and how trade agreements and regulations change due to both the contamination and the adoption of GM crops.

Carter and Smith (2003) study the effect of StarLink contamination on U.S. corn prices. The shock of this contamination appeared to hurt U.S. corn markets domestically and internationally because of the domination of corn production in the U.S. economy, mostly in the corn-belt region. As with many other crops, corn biogenetic technology research has attempted to improve corn production with a greater benefit to producers. Although one-third of U.S domestic corn production is biogenetic, StarLink corn was not approved for human consumption by the U.S. government because it contains Cry9C, a protein that might be allergenic in humans. With a split license approval, it is acceptable for animal feed. However, StarLink corn was first discovered in processed human food within the U.S. in September 2000. Starlink contamination was also discovered in Japan, and then in South Korean and Canadian corn supplies. The effect of the contamination was reflected in declining corn future prices.

To analyze the effect of StarLink corn contamination on U.S. corn prices, Carter and Smith (2003) started by estimating the equilibrium of the long-run price of corn along with its substitute, sorghum. The price of sorghum was at its peak when the news of the StarLink contamination broke. Their study focused on U.S. domestic corn prices, collecting daily spot prices from 1989 through 2002. They began by testing the price relationship between commodities from 1989 to 1999, prior to the contamination news release. The two-step method of Engle and Granger (1987) and the Johansen method were used for testing individual series for unit root or stochastic trends. The two would show long-run equilibrium if they were cointegrated. This would be true when each price series had a common stochastic trend or unit root and presented no trend for the series combination. In function form the models for the unit root and cointegration test and the error correction mechanism test can be expressed as follows:

(1.1) $$C_t = \mu + \beta S_t + Z_t$$

(1.2) $$S_t = S_{t-1} + \mu_t$$

where:

$C_t$ = log price of corn

$S_t$ = log price of sorghum

$Z_t$ = stationary error term

$\mu_t$ = stationary error term

(1.3 a) $$\Delta C_t = \alpha Z_{t-1} + \gamma_c (L) \Delta C_{t-1} + \delta_c (L) \Delta S_{t-1} + \varepsilon_{ct}$$

(1.3 b) $$\Delta S_t = \alpha Z_{t-1} + \gamma_S (L) \Delta C_{t-1} + \delta_S (L) \Delta S_{t-1} + \varepsilon_{st}$$

where:

$\gamma_c(L)$, $\delta_c$ (L), $\gamma_S(L)$ and $\delta_S$ (L) are polynomials in the lag operator

The results of the study by Carter and Smith (2003) are summarized in Table 1.2. As shown in the tables, cointegration results from Augmented Dickey-Fuller Tests and the Johansen Test are similar. Corn and sorghum prices significantly present a unit root trend as in individual series and the prices and corn and sorghum are cointegrated at a level of 0.05. These indicate that there was a stable long-run relationship between corn and sorghum prices from 1989-1999.

They then incoperated the StarLink contamination period into a model and tested for a stable cointegration of the two prices by using Hansen (1991) and Bai and Perron (1998). The Hansen test is a sup F-test, used for a single structural break in cointegration.

In cases of laws concerning one-price testing and levels of market integration, Carter and Smith indicated that the coefficient of β must be equal to one, so that the long-run relative price stays constant when two commodities are substitutable. In the structural break in cointegration when β equals one, it involves a testing for a break in the mean of the log relative log price. As a consequence of the previous cointegration test showing that the log price was stationary, the Bai and Perron procedure was appropriated to find the number and location of breaks. The result of the Hansen break test indicated a statistically significant break in July 2000. The Bai and Perron result are the same in that there are two significant breaks in cointegration in July 2000 and December 2001.

Carter and Smith (2003) point out that the first break in the relative price of corn and sorghum in July 2000, occurred two weeks earlier than the report of the commingling of StarLink corn with human food. Its early detection by Japan indicates that there is a possibility that traders were aware of the commingling. To forecast the change in corn price due to the contamination, they use an event study analysis that indicates that non-GM corn farmers are likely to lose approximately $500 million, a 6 percent drop in U.S. corn prices.

According to Li's (2010) study of the contamination by LibertyLink Rice 601 (which has not been approved for commercial use in the U.S. for human consumption and export), the United States is advanced in production of genetically modified crops and hosts many top biotechnology companies, concentrating on rough rice and high-quality rice. Genetically modified crops in the United States are increasingly focused on cotton along with the major U.S. cereals such as corn, soybean, and wheat. Despite the increase in research and attention on GM commodities in the U.S., Europe and some Asian countries such as Japan and South Korea, have strict regulations on importing genetically modified crops due to their potentially negative effects on human health.

Li et al (2010) state that after the USDA's announcement of GM contamination in August 2006, there was an impact on domestic traders and farmers and on international trade and regulations. From 2008, Europe stopped purchasing U.S. rice exports that were not certified as free of GM. Japan also banned imports of any long grain rice from the U.S. These reactions to the contamination resulted in the decline of long-grain rice futures.

To estimate long-run stable relationships between two commodities, the commodities have to be substitutable either in their consumption or in production, so that Thai rice, which is a main competitor for U.S. long-grain rice in international markets, is considered to be a substitute in its production. Li et al conduct a study of contamination of unapproved rice to estimate its impact on U.S. rice prices. Time series techniques are used to test contamination events. First, Li al et conduct the study by determining the existence of a unit root for the pre-event of the contamination with logarithms of U.S. rice prices and Thailand 100% grade B using the Augmented Dickey-Fuller (ADF) approach. The unit root will serve as an indicator to determine long-run cointegration relationship for the data. If the data series is found to be cointegrated, the next step is to forecast prices.  An error correction model (ECM) is useful for this purpose. The formula for this model can be expressed as follows:

**Table 1.2**

**Cointegration Tests**

| | **Test Statistic** | **5% Critical Value** | **Conclusion** |
|---|---|---|---|
| **Augmented Dickey-Fuller Tests** | | | |
| Corn | -1.72 | -2.86 | Unit Root |
| Sorghum | -1.93 | -2.86 | Unit Root |
| Log Difference | -4.33 | -2.86 | Cointegration |
| OLS Residual | -5.13 | -4.71 | Cointegration |
| **Johansen Tests** | | | |
| Trace: r=0 | 51.58 | 19.96 | |
| Trace: r=1 | 5.36 | 9.24 | Cointegration |

Source: Adjusted from Carter and Smith (2003)

(1.3a) $$\Delta P_t^{US} = \lambda + \rho\mu_{t-1} + \sum_{s=1}^{k} \beta_s \ \Delta P_{t-s}^{US} + \sum_{s=1}^{l} \gamma_s \Delta P_{t-s}^{Thai} + V_t$$

(1.3b) $$\Delta P_t^{Thai} = \lambda + \rho\mu_{t-1} + \sum_{s=1}^{k} \beta_s \ \Delta P_{t-s}^{Thai} + \sum_{s=1}^{l} \gamma_s \Delta P_{t-s}^{US} + V_t$$

where :

P = logged price

Δ= difference operator

$\mu_{t-1}$ = error correction term

k and l = number of lags

$V_t$ = a stationary, white noise; a residual term

Because there is a unit root between U.S. and Thai rice prices, the cointegration test is processed to find whether a stable long-run relationship between the two price series exists. From that, the two rice price series are cointegrated. The last procedure is to estimate the ECM, which uses the residual from the equilibrium regression of the cointegrated variables. The results from the event study window shows that U.S. rice prices decreased significantly (by 7.36 percent of the price forecast) after the USDA's announcement, but the response was short-lived. The price recovered by September of the same year. There was a slight decrease in Thai rice prices due to the harvest cycle, but there is no evidence of an impact from GM contamination on Thai rice prices.

Another study involving a unit root test and cointegration approach is conducted by Gordon and Hannessson (1996). Gordon and Hannessson examine frozen and fresh cod fish in three European importers of cod (France, Germany and United Kingdom) and the

U.S. They state that if the cod market is well integrated in the international market, prices change in Europe and the U.S. market should move according to the same pattern. The purpose of the study is to inquire into the long-run and short-run relationships of import frozen and fresh cod, separately, in France, Germany, the United Kingdom and the United States from January 1980 to December 1992. The study looks into both statistical results and policy analysis to explain the outcome. Frozen cod fillets and fresh cod are imported from Canada, Ireland and Norway. The monthly cod import data for the U.S. is collected by the U.S. Department of Commerce, showing quantity and value in U.S. dollars. The data is then converted into ECUs and the other three European countries data are collected monthly by Eurostat, presenting quantity and value in ECUs. Over time, there is a fluctuation in the quantity and import value in all four countries.

The study by Gordon and Hannessson uses the same theory and framework as the previous two studies, first testing for long-run stability in each price series and then determining cointegration relationship use the Engle and Granger method. After this, the more complicated procedure of Johansen and Joselius is used for testing more than one cointegrating vector. The formula for the model can be expressed as:

(1.4a) $$\Delta \mathrm{P}_{\mathrm{it}} = \beta_0 + \beta T + \rho P_{i,t-1} + \sum_{\gamma=1}^{\mathrm{k}} \alpha_\gamma \Delta \mathrm{P}_{\mathrm{i,t-\gamma}} + \varepsilon_{\mathrm{t}}$$

where $\Delta$ is the difference operator and $T$ is the time trend. The null hypothesis is that the series is non-stationary. With the result that the hypothesis cannot be rejected, it refers to each price series as ~*I(1)* and continues with the cointegration testing. The result from the cointegration test indicates that there is no evidence for a long-run relationship among fresh cod in Europe and the U.S. In the other words, the U.S. fresh cod market is separate from the three European countries' fresh cod markets. In the frozen market, there is one weak cointegation derived from the Engle and Granger procedure. The Johansen procedure is applied to test for cointegration in both frozen and fresh cod for a comparison. The results from both procedures indicate that there is no evidence of a long-run relationship among the U.S. and the three European countries in fresh cod. However, there is a weak cointegation among them in the frozen market.

Next, the study looks for short-run movement using the error correction model for frozen cod in those four countries and for the fresh cod markets in the European countries. The equation for the error correction model can be expressed as:

(1.4b) $$\Delta Y_{\mathrm{it}} = \rho_i Z_{it-1} + \; lagged\left(\Delta X_{it,} \Delta Y_{it}\right) + \; e_{it}$$

Where y and the vector X represent the different fish price and $Z_{it-1}$is the lagged value of the estimated error term and $e_{it}$ is a random error term. The result for the error correction model shows that both fresh and frozen cod markets in the U.S. have no short-run relationship with the three European markets, while France dominates European cod prices over Germany and the UK.

Approaches to Long-Run Equilibrium

Goodwin (1992) states that the law of one price (LOP) which claims that " an equilibrium relationship between two markets in which price changes in one market are reflected by equilibrating changes in the other market" is an important postulate for international trade. It can be expressed as

(1.5) $pt^{1} = \alpha + \beta p_t^{2} + e_t$,

where $p_t^{1}$ and $p_t^{2}$ are commodity prices.

For this conventional model the LOP will be satisfied when a null hypothesis of $\beta$=1 cannot be rejected. However, it has several weaknesses, particularly where the simultaneity bias of a comparison is concerned. As indicated by Gordon and Hannessson (1996), "The price of the same commodity product cannot deviate too far from prices in the other market before market forces price to restore a balance price relationship." This implies a cointegration relationship in the price series. In the other words, in the short-run is possible that a price in one market will diverge from the others while in the long-run there will be an equilibrium among all prices in the market.

As seen above from Gordon and Hannessson (1996), Carter and Smith (2003), and Li el at (2010), Engle and Granger's (1986) time series procedure can be used for testing and determining long-run equilibrium. If there is a long run relationship, a short-run error correction model exists which is used to test for price movement in the short run. In addition, if a market is not cointegrated across countries, then the impact of an event in one market will not have an impact on the overall international market. In fact, if international markets are linked, a price shock in one country will lead to a short-run effect on the international market, but will clear out in the long-run.

# CHAPTER 2

# INTERNATIONAL TRADE

*This chapter documents international rice production, consumption, quality, rice types, global trade, and the effect of policies on genetically modified rice on major rice exporting countries, along with tariff aspects. The focus will be on the importance of rice production and domestic and international policies in four major rice-exporting countries: Thailand, Vietnam, the United States and India.*

The global rice market pattern is small and thin with about 7 percent of world trade due to the residual character of exchanges (producing countries preserve rice grains for their own consumption first) (“The Stabilization”, 1955). The volume of trade is estimated to be between 25 and 27 million tons per year. Rice has retained an important role in Asia both economically and politically although several commodities including cotton, corn, coffee, rubber, and wheat are much more important than rice in international trade (David and Huang, 1996). Rice production is practices worldwide; yet, Asian countries are the dominant suppliers for the international market. Mediterranean Europe and the United States also play an important role in global trade owing to the development of new food trends in developed countries and new market niches in developing countries (Childs, 2009). Long-time rice exporters Thailand and India are close competitors for part of the U.S. rice market due to improvements in quality and grading systems. The top export markets for the U.S. are Mexico and Central America along with Canada and the European Union. Rice in international markets is traded across frontiers either (a) by a government as in Japan and Myanmar or (b) by private traders subject to very detailed government permits as in Thailand and Italy or (c) by private traders subject at most to very general controls as in the Netherlands and the U.K. ("The Stabilization", 1955).

## Rice Global Production and Global Consumption

In most of Asia, rice is grown on small farms, primarily to meet basic needs. Rice production is more concentrated in the monsoon regions (Hareau et al, 2002). Table 2.1 lists the top 10 countries in milled rice production, consumption, exporting and importing. China is the leader in rice production and consumption, but with its high domestic consumption and continuously increasing population most of China's rice is preserved for domestic use. The same situation applies to most of the rice producing countries. The Philippines is one of the countries in which rice production has been increasing over the years, from 9,775 metric tons in 2003 to 108,000 in September 2010 (Table 2.3). However, the government is still required to import rice for consumption. This is due more to the proportional increase in its population than to its rice production or the geography of the country.

Rice consumption in Asia has tended to increase over time due to the rise in population and an increase in per capita rice disappearance in non-Asian nations mostly in the West and the Middle East (Hareau et al, 2002). This has created a new market for many rice-producing and exporting countries. High-income countries in Asia show a slight slowdown in rice consumption due to the fact that a higher income leads to diet diversification. India has slowed its rice exporting in the previous year (Table 2.2) which is a result of security food notion because of the significant increase in its population and domestic consumption. The international rice trade has been stable for the past 2-3 years after a 90 percent increase in trade volume caused by an increase in rice production and yield (Brookes and Barfoot, 2003). For example, rice production in Thailand and China has increased from 18,250 and 127,200 metric tons respectively in 2006 to 20,400 and 136,000 metric tons in 2011(September). Rice production has increased over time due to better technology and production systems resulting in an increase in the number of rice-exporting countries (Table 2.3).

## Quality and Types

As indicated in the first chapter, rice is widely consumed and produced around the globe. Global trade prices for rice are classified mainly according to quality and type (Kang, Kennedy and Hilbun, 2009). The International Rice Research Institute (IRRI) has collected more than 83,000 varieties of rice genes for research, in which there are differences in morphology, productivity, and resistance to and tolerance of biotic and non-biotic factors (Jayne, 1993). Currently, four main rice varieties are commonly used: Indica, Japonica, Aromatic and Glutinous.

The rice trade consists almost entirely of grain that has undergone some milling in contrast to other cereals (“The Stabilization”, 1955). The different degrees of rice milling are a response to consumers’ preferences with thousands of rice strains being produced. This indicates that rice is not completely homogenous. One could classify rice according to its grading, type, parboiling process, and milling process (“Rice Industry is in Crisis”, 2007). Thailand, the United States, and India dominate the premium high-quality rice market. *High-quality rice* containing less than 10 percent broken grains is preferred mostly in the developed countries and the Middle East. The market for *medium-quality rice* containing 15 to 20 percent broken grains and *low-quality rice* containing 25 to 35 up to 100 percent broken grains are dominated by Thailand, India and Vietnam along with other developing countries in Asia, Africa and Latin America.

In addition, rice is traded internationally in many different forms depending on its final usage and the preferences of its consumers (Jayne, 1993). The most common types of rice in terms of modes of processing traded in the current market are brown, white, and red rice. The latest one is considered a non-tradable variety. Rough rice or paddy rice is rice as it is found in the field with its kernels encased in an inedible, protective hull. *Brown rice* is the least processed form of threshed rice, as the kernels have had only the hull removed. Its light brown color is due to the presence of bran layers, which are rich in minerals and vitamins, especially the B-complex group. With a natural aroma and flavor similar to that of roasted nuts or popcorn, it is chewier and slightly more nutritious than white rice, but takes longer to cook. Brown rice may be eaten as is or milled into white rice. Rice that the outer layer (the husk and bran) has been removed is called *white rice*. Though it is believed to have less nutritional value than brown rice, in some countries it can be enriched to recover its original nutritional value. Many importing countries prefer this form of rice because it is cheaper to ship along with the fact that the value of the husk is low compared to the cost of milling.

Table 2.1
Leading Rice Producing, Consuming, Exporting and Importing Countries

| Rank | Producing | Consuming | Exporting | Importing |
|---|---|---|---|---|
| **1** | China | China | Thailand | The Philippines |
| **2** | India | India | United States | Nigeria |
| **3** | Indonesia | Indonesia | Vietnam | EU-27 |
| **4** | Bangladesh | Bangladesh | Pakistan | Saudi Arabia |
| **5** | Thailand | Vietnam | India | Iran |
| **6** | Myanmar | The Philippines | China | Iraq |
| **7** | The Philippines | Myanmar | Cambodia | Malaysia |
| **8** | Brazil | Thailand | Myanmar | Cote d'Ivoire |
| **9** | United States | Brazil | Argentina | South Africa |
| **10** | Japan | Japan | Brazil | Senegal |

Source: Brookes and Barfoot (2003)
UNCTAD Secretariat of the Food and Agriculture Organization of the United Nations (FAO) data, USDA&PSD Online

Table 2.2
The World's Top 10 Rice Exporting and Importing Countries,
2006/07(Aug)-2010/11(Sep)

| **Exports** | **2006/07** | **2007/08** | **2008/09** | **2009/10** | **2010/11Aug** | **2010/11Sep** |
|---|---|---|---|---|---|---|
| Thailand | 9557 | 10011 | 8570 | 9000 | 10000 | 10000 |
| United States | 3003 | 3219 | 2983 | 3525 | 3475 | 3550 |
| Vietnam | 4522 | 4649 | 5950 | 6200 | 5800 | 5800 |
| Pakistan | 2696 | 3050 | 3187 | 3800 | 3600 | 2850 |
| India | 6301 | 3383 | 2123 | 2200 | 2500 | 2500 |
| China | 1340 | 969 | 783 | 850 | 900 | 900 |
| Cambodia | 450 | 500 | 800 | 850 | 850 | 850 |
| Myanmar | 31 | 541 | 1052 | 300 | 700 | 700 |
| Argentina | 436 | 408 | 594 | 550 | 600 | 600 |
| Brazil | 201 | 511 | 591 | 325 | 500 | 500 |

| **Imports** | **2006/07** | **2007/08** | **2008/09** | **2009/10** | **2010/11Aug** | **2010/11Sep** |
|---|---|---|---|---|---|---|
| The Philippines | 1900 | 2500 | 2000 | 2600 | 2500 | 2500 |
| Nigeria | 1550 | 1800 | 2000 | 1700 | 1900 | 1900 |
| EU-27 | 1342 | 1520 | 1383 | 1350 | 1350 | 1350 |
| Saudi Arabia | 961 | 1166 | 1095 | 1100 | 1300 | 1300 |
| Iran | 1500 | 1550 | 1470 | 1150 | 1500 | 1200 |
| Iraq | 613 | 975 | 1089 | 1100 | 1150 | 1150 |
| Malaysia | 799 | 1039 | 1070 | 1020 | 1020 | 1020 |
| Cote d'Ivoire | 980 | 800 | 800 | 860 | 900 | 900 |
| South Africa | 960 | 650 | 745 | 800 | 850 | 850 |
| Senegal | 700 | 860 | 715 | 700 | 700 | 700 |
| United States[12] | 695 | 651 | 682 | 650 | 665 | 665 |

Source: Brookes and Barfoot (2003)
USDA, PSD
Note: Units are in thousands of metric tons.

Table 2.3
The World's Top 10 Rice Producing and Consuming Countries,
2006/07(Aug)-2010/11(Sep)

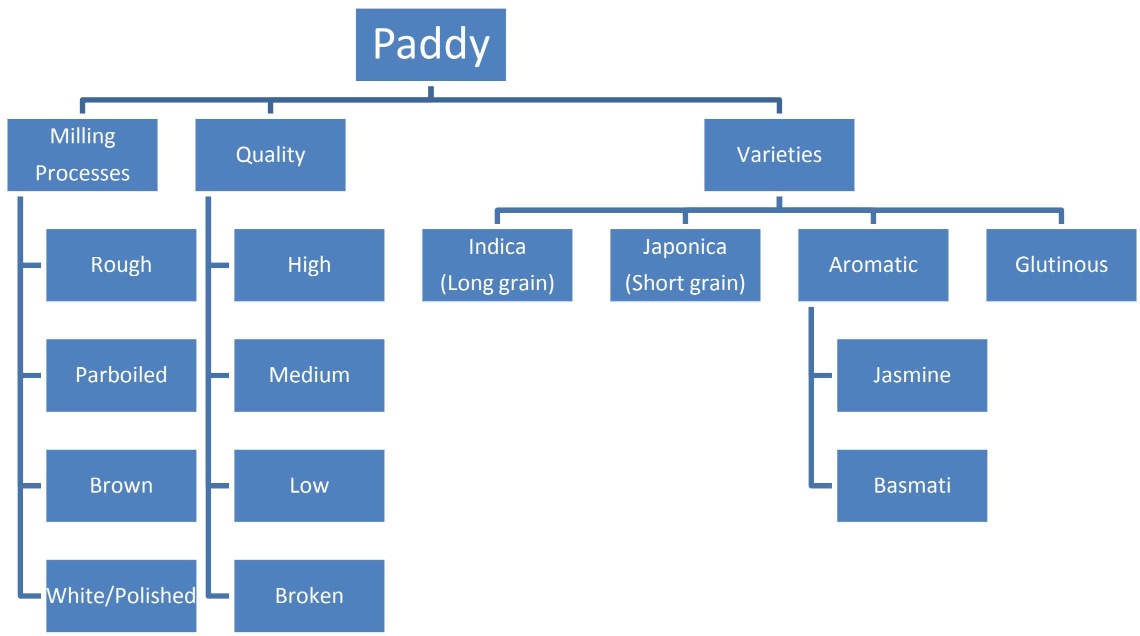
| **Milled Production** | **2006/07** | **2007/08** | **2008/09** | **2009/10** | **2010/11Aug** | **2010/11Sep** |
|---|---|---|---|---|---|---|
| China | 127200 | 130224 | 134330 | 137000 | 137500 | 136,000 |
| India | 93350 | 96690 | 99180 | 89130 | 99000 | 99,000 |
| Indonesia | 35300 | 37000 | 38300 | 37100 | 40000 | 38,000 |
| Bangladesh | 29000 | 28800 | 31000 | 31000 | 32300 | 32,300 |
| Thailand | 18250 | 19800 | 19850 | 20260 | 20600 | 20,400 |
| Burma | 10600 | 10730 | 10150 | 10597 | 11000 | 11,000 |
| The Philippines | 9775 | 10479 | 10755 | 9772 | 10800 | 10,800 |
| Brazil | 7695 | 8199 | 8570 | 7641 | 8400 | 8,400 |
| United States | 6088 | 6149 | 6400 | 6917 | 7680 | 7,975 |
| Japan | 7786 | 7930 | 8029 | 7711 | 7850 | 7,850 |

| **Consumption** | **2006/07** | **2007/08** | **2008/09** | **2009/10** | **2010/11Aug** | **2010/11Sep** |
|---|---|---|---|---|---|---|
| China | 127200 | 127450 | 133000 | 134500 | 135500 | 135,000 |
| India | 86700 | 90466 | 91090 | 85430 | 98000 | 98,000 |
| Indonesia | 35900 | 36350 | 37090 | 37600 | 39500 | 38,150 |
| Bangladesh | 29764 | 30747 | 31000 | 31600 | 32700 | 32,700 |
| Vietnam | 18775 | 19400 | 19000 | 19150 | 19500 | 19,500 |
| The Philippines | 12000 | 13499 | 13650 | 13640 | 13700 | 13,700 |
| Burma | 10670 | 10249 | 9648 | 10000 | 10100 | 10,100 |
| Thailand | 9780 | 9600 | 9500 | 9700 | 9800 | 9,900 |
| Brazil | 7925 | 8254 | 8530 | 8550 | 8600 | 8,600 |
| Japan | 8250 | 8177 | 8326 | 8200 | 8125 | 8,125 |
| United States[13] | 3959 | 3919 | 3964 | 3861 | 4047 | 3,985 |

Source: Brookes and Barfoot (2003)
USDA, PSD
Note: Units are in thousands of metric tons.

Figure 2.1

Rice Types and Degrees of Milling for International Trade



Differences among types of rice and methods of processing strongly reflects consumer preferences for certain types and forms, so that one can say rice is not a homogenous commodity like corn and wheat, the other staple grains ("The Stabilization," 1955). Rice also differs from other grains in international trade in its processing after threshing. Typically, rice will undergo a milling process after threshing before being exported while the threshing process is sufficient for other grains. One of these post-threshing processes is *parboiling*. It is believed that this practice began in Southeast Asia or in tropical Africa. Parboiling involves the soaking, pressure steaming and drying of rice. It is then milled to remove the outer hull. This procedure gelatinize the starch in the grain, hardening it, which results in less breakage and ensures a firmer, more separate grain (Gariboldi, 1984).

Table 2.4

Major Traders by Types of Rice

| TYPE | QUALITY | MAJOR EXPORTERS | MAJOR IMPORTERS |
|---|---|---|---|
| Indica, Milled | broken | Thailand, Myanmar | Senegal, Madagascar, Vietnam, The Gambia |
| | low | Thailand, Pakistan, China, Myanmar | Indonesia, most of West Africa |
| | medium | United States, Thailand, Pakistan | Brazil, Hong Kong, Indonesia, USSR |
| | high | United States, Thailand | Western Europe, Iran, Irag, Malaysia |
| Indica, Parboiled Milled | low | Myanmar, Thailand | Bangladesh, Sri Lanka |
| | high | United States, Thailand | Nigeria, Saudi Arabia, Western Europe |
| Japonica | -- | Japan, China, Australia | Indonesia, South Korea |
| Brown | parboiled | -- | West Europe, South Africa |

Source: Jayne (1993)

## Distortion of Rice Prices and Future Markets

Table 2.4 illustrates the preferences of major trade countries for various types of rice. The demand for high-quality milled rice comes mostly from Europe, Iran, Iraq and Saudi Arabia while low-quality types are concentrated in poorer countries (Jayne, 1993). The rice trade is unique because there are distinct differences between various types of rice. Surpluses and shortages of varieties of rice can occur according to the distinct preferences of rice consumers. In other words, prices of Indica and Japonica rice may move independently. Currently, Indica is the dominant rice variety being traded internationally.

The main factors determining the price of rice are supply and demand. The amount of paddy entering the milling process, the amount of milled rice sold and the amount being held in stock are the primary determinants for local markets (Jayne, 1993). The greater the volume of rice that is milled, the more its price will drop. This can be observed during the harvest season. In Thailand's harvest season in mid-December the price will drop due to the greater supply, when 80 to 90 percent of all rice produced goes to a mill. Another factor affecting rice prices is the report produced by the United States Department of Agriculture (USDA). The USDA applies a satellites system called the Geographical Information System (GIS) to monitor how much rice is being grown anywhere in the world along with data on weather, pests and diseases that will affect rice crops. Although this information does not seem to benefit local rice growers, it is used to determine rice prices after milling.

Pricing rice is difficult because, as a crop rice is extremely susceptible to poor weather conditions and is dependent upon the weather patterns of the countries in which it is grown (Jayne, 1993). Another difficulty in setting rice prices lies in the fact that there is no widespread use of future markets in rice. Although rice stock is being traded, it has a small role in determining worldwide rice prices without a future market. There is no universal standardized grading in the rice trade, nor is there any "reliable internationally accepted spot or futures prices can be quotes for each type or quality of rice" (Jayne, 1993). In general, the majority of agricultural commodities are subjected to a commodity market. Most commodities are traded through future contracts. In order for a commodity to be considered tradable in a future market, it must meet the following requirements: 1). It must be standardized for agricultural and industrial commodities. Rice obviously fails to meet this requirement. 2). Perishable commodities must have an adequate shelf life, due to the fact that delivery on future contracts will be delayed. This is a requirement that is met by rice. 3). Cash commodities' prices must fluctuate enough to create uncertainty. Again, rice meets this requirement. In addition, the rice market has failed to establish a forum in which sellers and buyers can interact at a low cost and it lacks reliable trade information about the market, allowing rice brokers. This means that the lack of information allows brokers to earn more (Roggemann, 2005).

## International Trade and Rice Policies

### International Rice's Economic Structure

The future of the rice international rice trade depends on the exporting sector (Ryan, 2006).With improvements in production technology, rice yields have become more predictable and stable over time. The international rice trade is highly centralized in four major rice-exporting countries: Thailand, Vietnam, the United States and India (Kang, Kennedy and Hilbun, 2009). However, without an external demand for an increased production, a domestic rice price would eventually decrease resulting in low net returns and less incentives for farmers. To solve this problem, rice-producing countries tried to form an incorporated cartel modeled upon the OPEC oil cartel in order to control both domestic and international rice prices and quantity (Dawe, 2002). Unlike oil, rice production is aggregated among many individual rice producers and relies heavily on weather (Hettel, 2006). It is difficult or impossible to control production and determine a surplus. Secondly, rice is a perishable commodity which can be stored for a limited time. This can be costly for sellers. Thirdly, differences in trade purposes and interests among rice producers constitute another difference between a rice cartel and the OPEC group.

The rice market has stayed more efficiently stable in its production due to new technologies such as better irrigation systems (Dawe, 2002). Three periods present a change in international rice prices: 1950-1964, 1965-1981, and 1985-1998. During the first period, prior to the Green Revolution, world rice prices were high and stable. During the Green Revolution between 1965 and 1981, world rice prices were unstable due to the world food crisis in 1973-1975 that led to changes in many Asian countries' policies. The price instabilities were due in part to the adoption of new fertilizers in many countries. World rice prices went back to once again stable and low in the post-Green Revolution phase, 1985-1998. At present, many more rice-exporting countries rely on the global market, creating government revenue for their nations. This results in more stable rice prices. Furthermore, as compared to previous decades, the volume of rice trade is increasing caused by an expansion of trade coming from Latin America since their markets were opened to imports in the late 1980s.

## Trade Liberalization and International Rice Policy

Wiles (2003) opposes the conclusion made by Jayne (1993) that the international instability of the international price of rice is more the result of rice's thin and relatively small trade character than the impact of domestic stabilization policies. He points out several factors that contribute to the volatility of rice prices such as domestic stabilization policies, geography of rice production areas, inelasticity in consumer's preferences and production methods, a thin and fragmented market, and low world stockholdings. As stated above most rice-producing countries trade their rice internationally using the residual from domestic consumptions. This is linked to the concept of food security and trade liberalization. Hettel (2006) explains that trade liberalization means that the domestic price of a commodity is that same as its price outside the country. Food security is defined as having supplies sufficient for both domestic and global levels, an amount that will promote the well-being of consumers ("Trade Reform and Food Security", 2003). Free trade liberalization is believed to be a tool to support poor countries by promoting a country's comparative advantages.

In theory, the price of rice should be determined by integration between supply and demand; however, in most rice-growing countries, the price is controlled by an unfair allocation resulting in a violation of the law of supply and demand. Rice prices are distorted by subsidies, tariff, and food aid program (Roggemann, 2005). The low percent of rice that is traded is the result of self-sufficiency policies, particularly in Asian. These protectionist policies aim to support domestic producers, stabilize domestic rice prices and maintain food security. Government policies in both rice-producing and consuming countries play an important role in controlling the level of rice production, which eventually has an impact on world rice prices. Whether or not a country gains from trade liberalization depends on how well it adjusts to an increase in international trade (Odularu, 2010). Trade liberalization is likely to improve self-sufficiency policies in developing countries. The removal of farm subsidies in developed countries results in an increase in the international price, which in turns harms consumers in developing countries. However, an increase in price results in expansion of production. A market will gain economic market efficiency when tariffs and regulations are removed. This also causes increasing economic growth, but the degree of economic growth depends on a country's trade position regarding its net import and export. The domestic price for an import country with high tariffs will decline if an increase in international price is greater than a decrease in tariffs. In this case, consumers will pay less and producers will gain more. On the other hand, if tariffs are initially low, domestic producers will benefit from an increase in price. Exporting countries will benefit from more market access resulting in an increase in exports to developing countries.

Trade liberalization under the Uruguay Round Agreement has a great influence on the rice trade due to highly protectionist domestic policies, which double the volume of trade and consumption (Brookes and Barfoot, 2003). Agricultural products are highly protected in both industrial and agricultural countries (Aksoy and Beghin, 2004). In the past 20 years, world trade has increased rapidly in the industrial sector with low levels of protection, while moving more slowly in the agricultural sector with high protection levels. Changes in rice policies in Asia are mainly caused by world rice variability (Dawe, 2002), causing governments to favor policies relating to the expansion of production system, irrigation and fertilizer to increase their rice productions. The increase in domestic rice production leads these countries to reach a position of self-sufficiency and to be less reliant on the world market.

As rice is a segmented market, rice prices and their related policies for different varieties, quality and milling process are different in each country (Brookes and Barfoot, 2003). Not only major exporting countries, but also rice-importing countries play an important role on influencing international rice policy. The United States, the European countries and Japan highly protect their rice industries with domestic regulations. Their regulations upon adopting genetically modified rice have a great impact on the world rice trade although Demont and Devos (2008) point out that the European Union regulations concerning the coexistence of GM and conventional crops may be too strict and overstated.

The following section describes policies in several rice producing, consuming and exporting countries that significantly influence the world's rice trade, volume and prices. Specifically, the policies of China, India, Japan, Vietnam, Thailand, and The United States are examined regarding both domestic regulations and international policies and trade agreements.

**China**

China's rice production accounts for one-third of the world's total rice yield (Wiles, 2003). Like other Asian countries, food security in China is fulfilled through maintaining a high level of rice production and the stabilization of domestic prices and supplies. The country's current policy is to concentrate on quality rather than quantity. As medium-grain rice is the most highly protected type in international trade, China, as the largest producer of medium-grain rice, has benefited from trade liberalization reform. China exports medium-grain rice mainly to the markets of Russia, Japan, South Korea, and North Korea. China is also an important low-quality rice exporter to Cote d'lvoire, Indonesia and Cuba. Fragrant Jasmine rice production in China is increasing and is likely to reduce the country's demanded for Thai fragrant Jasmine.

**India**

As the world's second-largest rice producer and consumer, India's trade actions and policies play a significant role in the international rice trade (Wiles, 2003). India specializes in low-quality long grain and fragmented basmati rice. Food security is achieved with government interventions such as grain procurement, price supports and export subsidies. The domestic rice stock is refilled with 25 percent of the annual crop and India has been subsidizing its rice exports at a 50 percent rate, making its low-quality parboiled rice and long-grain rice prices lower than competitors: Vietnam, Thailand and Pakistan. The main export markets for low-quality long grain rice are Indonesia, the Philippines, Bangladesh, Nigeria, Cote d'Ivoire, South Africa, Saudi Arabia, the

European Union, Kuwait, the United Arab Emirates and Iran are the main export markets for India Basmati rice.

**Japan**

Price supports of agricultural commodities such as rice in Japan are high and protected (Brookes and Barfoot, 2003). Rice Farming Income Stabilization was introduced as a part of policy reform in 1998 because of the higher cost of rice production and the effect of the WTO agreement in the Uruguay Round. The program aims to support farmers when the price of rice is less than the average price standard, giving farmers 80 percent of the differences between the prices. The payment is contributed by the government to rice producers who participate in the program at a ratio of 1: 3 (Wiles, 2003). In order to receive the full benefit of the program, rice producers are required to enroll in the Production Adjustment Promotion Program (PAPP) in which rice producers receive an additional payment by allocating rice land for other crops. This program leads to a reduction in land for rice production in Japan.

**Thailand**

This country has been the world’s leading rice exporter for several years although its domestic production has one of the highest yields in the world (Brookes and Barfoot, 2003). Thailand is well-known for its high-quality and fragmented Jasmine rice. The level of protection for agriculture is low and the amount of planting in determined in consideration of the market. The government provides a price floor support for farmers when the international rice price is low and offers a paddy mortgage or loan program operated under the Bank for Agriculture and Agricultural Cooperatives (BAAC) which sets the price at 95 percent of a target price (Wiles, 2003). The more farmers enter this program, the more the increasing government's rice stock increases.

**Vietnam**

The adoption of a new rice variety and economic reform by the government led to a rapid increase in rice production in the mid-1990s resulting in Vietnam's reaching the second rank among the world's rice exporters (Wiles, 2003). Its main exporting markets for both high- and low-quality rice are Iraq, Indonesia, Cuba, Malaysia, and the African countries. Vietnam is the world's major rice producer and consumer. Although there is no major production policy within the country, the Vietnamese government's priority is to ensure food and income security for farmers. The government provides domestic assistance in the form of a price support program and by providing private rice storage when there is a rice surplus (Brookes and Barfoot, 2003).

**The United States of America**

As one of the world's top four rice-exporting countries, the United States has several policies to support its domestic rice sector such as Commodity Loans, Production Flexibility Contracts (PFCs), Loan Deficiency Payments (LDPs), Counter Cyclical Payment (CCPs) and Average Crop Avenue Election (ACRE) (Brookes and Barfoot, 2003, Childs, 2009). In 2000, payments received from these programs were high as 40 percent of total farm revenues, which made rice production attractive to farmers. The Export Credit Guarantee Program, the Market Access Program and the Foreign Market Development Program help promote U.S. rice purchases in foreign countries. The U.S. concentrates on unmilled, parboiled, brown and milled rice. Its markets for unmilled rice are Mexico and Central America and the other large markets for unmilled rice are Northeast Asia, the Caribbean, and the Middle East.

# CHAPTER 3

# DATA AND METHODOLOGY

*This chapter presents and discusses the source and types of data used to analyze the rice prices of four major rice-exporting countries: India, Thailand, Vietnam and the United States. The second part presents the methodology and econometric models used in the study and the theoretical and practical frameworks used for analysis of the relationship of rice prices among different markets.*

## Types and Sources of Data

Monthly data from August 1997 to February 2010 from four important rice-exporting countries are used in this study. All aggregated data has been collected from secondary sources. Data pertaining to India's 5 percent broken parboiled price series, Thailand's 100 percent grade B price series, Vietnam's 5 percent broken DWP price series, Vietnam's 5 percent broken price series and the U.S.' long-grain Texas price series were taken online from the Rice Year Book, from the Economics Research Service (ERS: this is a USDA database containing time-series information). All prices are quoted in U.S. dollars with the quantity in tone. The unit quantity has been converted to hundredweight units. Ghoshray and Lloyd (2003) point out several criticisms of the use of price quotes in economic analysis. First, there is concern that the quoted price might not represent the actual price. Although this might be true, a quoted price will still follow the law of supply and demand and therefore might be able to speak for the actual price. Second, data frequency in an economic analysis is significant for its results. The last concern is the effect of subsidies on diverging quoted prices and actual prices.

Information from the source mentioned above has been supplemented by data collected from Commodities Prices yearbooks and Rice Situation and Outlook reports.

A graphical representation of the rice price trends from the four top rice-exporting countries in each product classification is given in Figure 3.1. Although there are observable differences from month to month, the five price series (Thailand's 100 percent grade B price series, Vietnam's price series in 5 percent broken and 5 percent broken DWP, and India's price series 5 percent parboiled broken) seem to share a similar pattern throughout the period from August 1997 to around February 2008. During the same period, the U.S.' price series was consistently higher that the other price series. Since February 2008, there were two separate patterns to be observed. The first pattern appears among the US', Thailand's and Vietnam's 5 percent broken DWP in the skyrocketing movement of their price series. The second pattern is to be seen in the constancy of the price series, which can be observed by comparing Vietnam's 5 percent broken and India's 5 percent broken parboiled price series. The second price series pattern was the result of trade actions in the two countries, taken in order to preserve their rice supply for domestic consumption. The main hypothesis of this study focuses on the impact of the contamination of U.S. supplies by genetically modified rice. Nonetheless, Figure 3.1 shows that there was no price decline from any of the five-price series from the month-to-month. Thus, it is necessary to examine the sample for a long-run cointegation relationship to be able to verify the hypothesis.

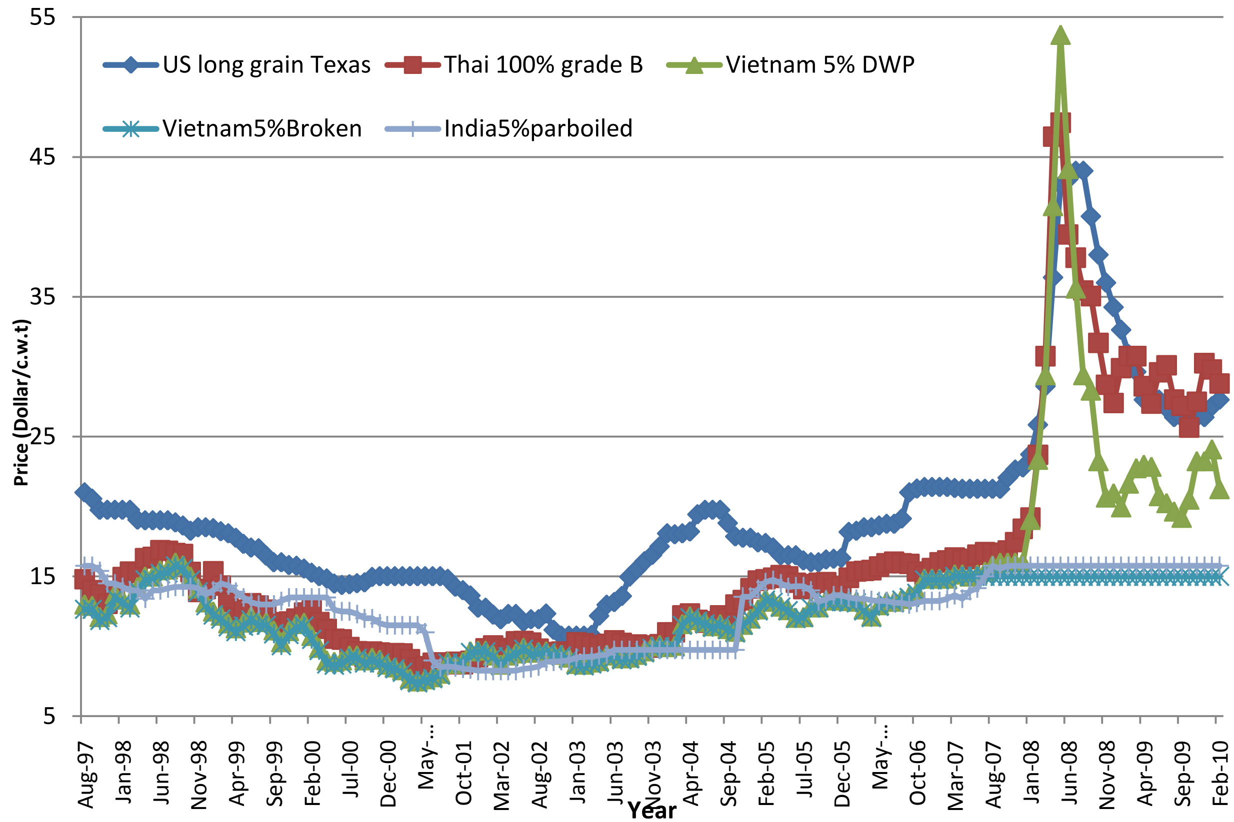



*Figure 3.1* Rice Prices in the United States, Thailand, Vietnam and India, 1997-2010

## Econometric Methodology

Zohrabyan, Leatham and Bessler (2007) point out that methodology is the heart of a study since the researcher can present the best method by which a reliable and creditable outcome may be ensured. In the present study, long-run equilibrium prices have been investigated to determine the impact of genetically modified rice contamination in U.S. supplies on international rice-exporting prices. As Ghoshray and Lloyd (2003) indicate in their study on the law of one price in the international wheat market, a commodity price in one market may be independent from another if the price difference between the two markets is great enough to separate a price in one country from an equilibrium market. It is possible for markets to be tied together in the long-run even though, individually, each price behaves differently. Testing for integration is an introduction to an investigation into the price of a commodity among various markets. Some of the studies that have tested for unit root and long-run cointegration have been discussed in the previous chapter's literature review.

## Unit Root Tests

Generally, time series trend upward over time and can measure both nominal price and real levels of economic variables (Davidson and Mackinnon, 1993). Two common time series models reflect upward trends as follows:

(3.1 a) $$y_t = \gamma_1 + \gamma_2 t + \mu_t$$

(3.1 b) $$y_t - \gamma_2 t = \gamma_1 + \mu_t$$

(3.2 a) $\mathrm{y_t} = \delta_1 + \gamma_{t-1} + \mu_t$ (3.2 b) $\mathrm{y_t} - \gamma_{t-1} = \delta_1 + \mu_t$

The equation in (3.1a) is trend-stationary while $\mathrm{y_t}$ in the equation (3.2 a) has a random walk with a drift. Although both $\gamma_1$ $and$ $\delta_1$ terms cause an upward trend in the time series, the behavior of $\mathrm{y_t}$ in both equations is different when the time series is converted to a stationary one. To transform a random walk with or without a drift to a stationary process, it is necessary simply to subtract $\gamma_{t-1}$ from $\mathrm{y_t}$ or differencing, resulting in a differencing-stationary as in equation (3.2b). The same method may be applied to detrend processing of the non-stationary equation (3.1a) into a stationary process (equation 3.2b).

When working with long-run equilibrium, stationary and non-stationary variables must be distinguished for the time series properties. Failing to do so will lead to a spurious regression with a high $R^2$ and significant *t*-statistic lacking any economic meaning. In equation 3.1, Enders (1996) explicates the general regression model when both $\{y_t\}$ and $\{Z_t\}$ are stationary and has a zero mean and finite variance. The presence of a non-stationary variable, however, leads to a spurious result.

(3.2 a) $y_t = a_0 + a_1 Z_1 + \varepsilon_t$

Regarding equation 3.2, there are four cases in which users should be aware of and stationary and non-stationary variables:

a) When both $\{y_t\}$ and $\{Z_t\}$ are stationary as in equation 3.1, the general equation is appropriate for further testing.

b) When $\{y_t\}$ and $\{Z_t\}$ are cointegrated at different orders, the use of the normal equation is meaningless.

c) When both $\{y_t\}$ and $\{Z_t\}$ are non-stationary and cointegrated at the same order and a residual sequence contains a stochastic trend, the regression is spurious and the result is meaningless.

d) When both $\{y_t\}$ and $\{Z_t\}$ are non-stationary and cointegrated at the same order while the residual is stationary, $\{y_t\}$ and $\{Z_t\}$ are cointegrated

Unstable price series referred to as non-stationary can be made stable if converted to a difference (*d*) one or more times (Gordon, 1996). In this case, it is referred to as an integrated series of order *d, [~I (d)]*. In economics, most macroeconomic variables are integrated to order one. If two variables are non-stationary, transformation of the variables may cause them to become stationary, and the two variables are said to be cointegrated. Generally, the unit root test initiates the cointegration procedure. If variables are cointegrated according to different orders, their long-run equilibrium will not be cointegrated. The Augmented Dickey-Fuller (ADF) test is employed to test for stationary and non-stationary trends among variables. The general form of the ADF test is:

(3.2b) $$\Delta y_t = \propto + \gamma y_{t-1} + \sum_{i=1}^{m} \beta_i \Delta y_{t-i-1} + \varepsilon_t$$

The value of *m* or amount of time lagged can be determined by applying Akaike criteria or Schwarz-Bayesian criteria to maximize the amount of information. The ADF test can be used with a constant and a time trend.

**Cointegration Test and Long-Run Equilibrium**

Engle and Granger (1987) provide two steps to test for cointegration in a single equation after the result of two variables, x and y, are cointegrated of order *I*(1) (Enders, p375,1996). The function for estimating long run equilibrium between price series is expressed as presented in equation (3.3 a):

(3.3 a) $$Y_t = \beta_0 + \beta_1 Z_t + \varepsilon_t$$

where $\varepsilon_t$ denotes the estimated residual term of the long-run equilibrium relationship.

If the deviations of the estimated residual of the long run equilibrium, $\varepsilon_t$, are stationary, then it can be concluded that $\{y_t\}$ and $\{Z_t\}$ are cointegrated of order (1,1).

(3.3 b) $$\Delta e_t = a_1 e_{t-1} + \epsilon_t$$

In detail, the DF test is used to test for the $a_1$ parameter in equation (3.3 b). If the null hypothesis that $a_1$ is no different from zero cannot be rejected, then the estimated residual contains a unit root which indicates non-cointegation between $\{y_t\}$ and $\{Z_t\}$. Thus, $y_t$ and $Z_t$are not cointegrated of order *I*(1,1). There is no linear combination between variables in the long-run equilibrium relationship.

In addition to the Engle and Granger procedure, the Johansen procedure can also be used to perform cointegration of the data when the data series are cointegrated of the same order. In many economic studies, researchers prefer the Johansen to the Engle and Granger procedure. Nicols and Ahmadi-Esfahani (2009) test the law of one price in the Australian vegetable market using the Johansen procedure because it allows for and is capable of testing a hypothesis for the LOOP. In addition, Gordon and Hannesson (1996) state that the Johansen procedure (1988) and Johansen and Juselius procedure (1990) methods that are based on the concept of canonical correlations for multivariate analysis. Under the assumption of $I(1)$, the linear combinations are cointegrated or stationary. The data is divided into two parts: a differenced part and a level part. The linear combinations are found in levels data that are highly correlated with difference data.

**Error Correction Models and Short-Run Equilibrium**

If the variables from the cointegration procedure are cointegrated (rejecting the null hypothesis of the cointegation relationship), the next step is to construct an error correction model using the residual that was estimated from the regression equation (3.3) (Enders, 1996). The procedures presented so far are useful for capturing the long-run equilibrium relationship of price series. Clearly, good models should be able to describe both long-run and short-run relationships and movements. The error correction model developed by Engle and Granger has been used in time series econometrics since1964 (Goodwin, 1992).  The error correction functions for cointegration can be expressed as follows:

$$(3.4\text{ a})\ \Delta y_t = \alpha_1 + \alpha_y(\varepsilon_{t-1}) + \sum_{i=1} \alpha_{11}(i)\Delta y_{t-i} + \sum_{i=1} \alpha_{12}(i)\Delta Z_{t-i} + \varepsilon_{yt}$$

$$(3.4\text{ b})\ \Delta Z_t = \alpha_2 + \alpha_z(\varepsilon_{t-1}) + \sum_{i=1} \alpha_{21}(i)\Delta y_{t-i} + \sum_{i=1} \alpha_{22}(i)\Delta Z_{t-i} + \varepsilon_{zt}$$

Where $\alpha_1$, $\alpha_2$, $\alpha_y$, $\alpha_z$, $\alpha_{11}(i)$, $\alpha_{12}(i)$, $\alpha_{21}(i)$ and $\alpha_{22}(i)$ are all parameters.

$\varepsilon_{t-1}$ is the residual from the estimation of the long-run relationship in equation (3.3).

## Specification of the Statistical Model

This study uses a statistical model in order to explain the long-run equilibrium relationship in international rice prices. In order for international rice prices to be cointegrated, all rice should share the same long-run price pattern regardless of rice types or country of origin. Generally, economic time series change over time. If the changes are stable or predictable, the mean and variance of the relationship will be defined. On the other hand, the mean and variance of series with unstable changes will fluctuate over time. The cointegration approach developed by Engle and Granger (1986) is the main method used in this study because its simplicity and directness of application. This study will include one additional explanatory variable as specified in the error correction model in equations 3.3a and 3.3b (the official announcement of the contamination event in August 2006). The main interest in studying rice price relationships among the four major rice-exporting countries is to examine the impact upon the international rice market of genetically modified LibertyLink rice in U.S. rice supplies. The potential benefit or harm that genetically modified crops may have for society is still being debated.

## Procedures of Analysis

An initial analysis is done by testing for stationary and non-stationary variables on time series data of rice-exporting prices in the U.S., Thailand, India and Vietnam markets. The study's procedures are divided into two sections: pre-testing for rice price relationships among these markets between August 1997 and August 2006, prior to the official announcement of the LibertyLink Rice contamination, and testing for rice price relationships including the contamination period between August 1997 and February 2010. Both test sections make use of the same procedures. However, isolating the data pertaining to the contamination event provides an overall view of the rice-exporting price markets' behavior and relationships prior to and after the contamination.

This first procedure determines the properties of each price series in order to proceed to the next procedure. The price series are denoted as follows: U.S. long-grain Texas, Thailand 100 percent grade B, Vietnam 5 percent broken DWP, Vietnam 5 percent broken, and India 5 percent broken parboiled for the August 1997 to August 2006 data set. To derive results from the Augmented Dickey and Fuller procedure, the t-statistic of each price series is used and compared with the t-critical value of Dickey and Fuller and optimally lagged from AIC criteria. If the null hypothesis is rejected for each price series, then we will conclude that that particular price series is stationary. In other word, that price series must be eliminated before adopting the next procedure.

The next step is to run the data that are cointegrated of the same order from the first procedure. Both sets of data are looked at for the t-statistic value and p-value to determine whether or not to reject the null hypothesis of no cointegration as compared to the *t*-critical value of the Engle and Granger procedure (adapted from Ardeni, 1989). Keep in mind that the numbers of the price series of the data set for this procedure depend on the conclusion drawn from the first procedure, the unit root test. The data are then tested for short-run dynamics using an error correction model to carry on the numbers of the price series from the cointegrated pairs.

After determining the rice price relationship among the four markets before the contamination event, the data set expands to cover the event period from August 1997 to February 2010. In this section, the procedure of testing for rice price equilibrium is the same as that used for testing for price relationships prior to the contamination event, starting with a unit root test using the Augmented Dickey and Fuller for stationary and non-stationary variables. Then, the Engle and Granger procedure is performed for long-run cointegration relationship ending with determining a possible short-run price dynamic between cointegrated price series pairs.

This object of this study is to determine whether a structural change has occurred. Structural change is defined as a change in the pattern of the relationship between the dependent variable and independent variables over the study period. To determine whether or not a structural change has occurred , the data will be split into two subgroups denote as a dummy event. This variable will be added to the error correction model to determine whether there is a different pattern within each subgroup of the two prices series that show a long-run equilibrium relationship. Thus, using the general equation formulas in (3.4 a) and (3.4 b), the specific model can be expressed as follows:

(3.5 a) $Y_t = \alpha + \beta_1 Z_t + \varepsilon_{it}$

(3.5 b) $\Delta Y_t = \alpha + \sum_{i=1}^{N} \beta_i \, \Delta y_{t-i} + \sum_{i=1}^{N} \gamma_i \, \Delta Z_{t-i} + \theta EVENT2006 + \emptyset \varepsilon_{it-1}$

(3.5 c) $\Delta Z_t = \alpha + \sum_{i=1}^{N} \beta_i \, \Delta z_{t-i} + \sum_{i=1}^{N} \gamma_i \, \Delta Y_{t-i} + \theta EVENT2006 + \emptyset \varepsilon_{it-1}$

where:

$\beta_1$ = the coefficient of the independent variable in the simple regression between both variables that are cointegrated

$\beta_i$ = the coefficient of time lagged of the dependent variable

$\gamma_i$ = the coefficient of time lagged of the independent variable

$\theta$ = the coefficient of the dummy EVENT 2006 variable

Event 0 = August 1997 – August 2006

Event 1= September 2006- February 2010

$\emptyset$ = the coefficient of the error term from the equation (3.5 a)

The hypothesis to be tested is:

a. Ho: $\theta = 0$
b. Ha: $\theta \neq 0$

The null hypothesis suggests that the parameters of event 0 and event 1 are not different, meaning structural change did not occur due to the impact of the contamination. In other words, the estimated value of the parameter is no different from zero. If the p-value is greater than the $\alpha$-value, we cannot reject the null hypothesis and conclude that a structural change did not occur. However, if the $\alpha$-value is greater than the p-value, we must conclude that a structural change did occur. If there is no evidence of a structural change, the next procedure is to identify outliers referring to a difference between the actual and predicted value of more than two standard deviations.

**Multiple Regression Analysis**

Multiple regression analysis is a common quantitative method used to identify relationships among variables in an analysis (Gujarati, 2005). A regression model is used in this study to explain the price series variables that account for the variation in the U.S. exporting-rice price from 1997 to 2010. The main advantage of using multiple regression analysis is its ability to handle both quantitative and qualitative data without any restriction on data size. Moreover, it is used to measure the influence of one variable when holding the effect of other variables constant. A function model can be expressed as follows:

(3.6) $$Y_i = f\{X_{1,} X_2, X_3, X_4, \ldots, X_n\}$$

where $Y_i$ = dependent (explained) variable

Xs = independent variables

To estimate the relationships of the U.S. rice-exporting price series and the other independent variables upon the genetically modified contamination event, an ordinary least-squares regression equation has been developed. The structural model can be represented as follows:

(3.7) $Y_i = a_0 + b_1X_{1i} + b_2X + e_i$

where $Y_i$ = the U.S. long-grain Texas rice price

$X_1$ = independent variables

$X_{2\,=}$ dummy variable

$X_2 = 0$ denotes the period before the contamination event

$X_2 = 1$ denotes the period after the contamination event

$B_2$ = the estimated of regression coefficients

$a_0$ = the intercept term

$e_i$ = the error term

It is assumed that the estimated coefficients are the best linear unbiased estimators (BLUEs) of the regression parameter. The coefficient $b_1$ in the equation 3.7 measure the changes in $Y_i$, which is the U.S. long-grain rice price for this study, with a unit change in $X_1$, denoting the other major rice-exporting countries, on the assumption that all other variables in the regression equation are held constant. Likewise, $b_2$ measures the changes in $Y_i$ in response to a unit change in $X_2$, accounted for by the contamination event.

To determine whether or not individual regression coefficients differ significantly from zero, a t-test statistic is an important test to verify a test's significance. The t-statistic is calculated as follows:

(3.8) $$t = \frac{\mathrm{b}-0}{\mathrm{S_b}}$$

where b is the value of a particular estimated coefficient and $S_b$ is the standard error of the regression coefficient. This t-statistic is compared with the critical t-values obtained from the t-table for different confidence levels. The null hypothesis will be retained if the computed t-statistic is less than or equal to the critical t-value from the t-distribution table meaning that an individual price series is not accounted for by the change in the U.S. rice prices. On the other hand, the null hypothesis will be rejected if the t-statistic value is greater than the critical t-value. Saying that, an individual price series is significant it is accounted for by the change in the U.S. rice price.

# CHAPTER 4

# EMPIRICAL RESULTS

*This research uses time-series data from the ERS, USDA to analyze long- run and short- run equilibrium relationship for rice-exporting prices due to the impact of contamination of conventional rice supplies by genetically modified rice. The study concerns four major rice-exporting countries: Thailand, Vietnam, the United States and India covering the period 1997-2010.*

## General Procedure Description

All of the full models described in Chapter 3 to capture a stationary trend in each price series along with the long-run and short run-rice price relationships regarding the genetically modified rice contamination event are run separately using TSP 5.1 software. This study analyzes the long-run equilibrium and, if any, short-run equilibrium of the four major rice-exporting countries: India, Thailand, Vietnam and the United States. A cointegration procedure is used to measure the long-run price relationships. For the short-run effect, an error correction model is applied, consisting of a short-run dynamic term and an error correction term. The hypothesis of this study states that international rice exporting prices are cointegrated and had been affected by the contamination event. Several models were developed. Only those equations that are economically and statistically relevant and important are presented. The procedures for this study are as follows: pre-test for long-run equilibrium from the data set prior to the contamination, between August 1997 and August 2006, and then testing overall for the long-run equilibrium of price series including the contamination event. The short-run dynamic price is tested if there is a long-run cointegration between a pair of price series that are cointegrated and which include the dummy variable of the contamination event.

To determine the impact of the contamination event on rice prices among supplier countries, the data from August 1997 to August 2006 is first tested for long-run equilibrium prior to the contamination event. Table 4.1 shows the mean, standard deviation, maximum and minimum of the 109 variables studied. All price series appear to have a close range of standard deviation with each price series ranging from a high of 2.6 in the U.S. price series to a low of 1.9 in the Vietnam 5 percent broken price series. The Vietnam 5 percent broken price series presents the lowest price, 7.5 dollars per hundredweight while the US long grain price series contains the highest price, 21 dollars per hundredweight.

**Pre-test, August 1997-August 2006**

**Unit Root Results**

Starting with the test for their order of integration throughout the series, the Augmented Dickey Fuller (ADF) tests for each price series is used for both periods expressed as a nominal-level. The null hypothesis is that each price series is non-stationary [~$I(1)$], against the alternative hypothesis that each price series is stationary [~$I(0)$]. The results of the ADF tests are reported in Table 4.2. Optimum lag lengths for each price series have been chosen based on the Akaike Information Criteria (AIC). In the five rice prices series, the null hypothesis cannot be rejected at a 10 percent level of confidence, so the prices of each price series has a unit root or non-stationary trend.

There is evidence for the presence of a unit root in every case, thus indicating the non-stationary nature of each of the price series.

## Cointegration Results

The rice export prices are examined in pairs to demonstrate their long-run relationships. Cointegration in pairs is tested by the Engle and Granger procedure (1987), keeping in mind that the cointegration tests are done using prices in a level form (the non-stationary form). The presence of a common stochastic trend indicates the cointegration of a time series pair. Individually, each price series contains a unit root trend, yet the linear combination shows no trend. Examining for the pairs' cointegration is done by making use of the data obtained from the results of the unit root test (ADF). All five price series are shown to be non stationary according to the result of the unit root. This cointegration is shown in Table 4.3. The rejection point is at a 10 percent level of confidence. U.S. long grain rice prices show no equilibrium relationship of a linear combination with the four price series: Thailand 100 percent grade B price, Vietnam 5 percent broken DWP price, Vietnam 5 percent broken price and India 5 percent broken parboiled price. Although the U.S. rice price series do not show a linear combination equilibrium with the others, an individual equation testing the null hypothesis of the presence of the cointegration between the U.S. price and the Vietnam 5 percent broken DWP and the Vietnam 5 percent broken prices are rejected at a 5 percent level of confidence when the U.S. price series is an independent variable. The null hypothesis is also rejected at a 1 percent level of confidence in the cointegration equations that have the Thailand price series and the India 5 percent broken parboiled price series as independent variables in the equations.

The Thailand rice price series is statistically significant at a 1 percent level of confidence, along with the Vietnam 5 percent broken price series and 5 percent broken DWP prices series. We may conclude that the linear combination of the Thailand and the Vietnam rice prices are $I(0)$. In other words, there is a long-run equilibrium between the Thailand and the Vietnam rice prices series. The null hypothesis cannot be rejected between the cointegrated pairs consisting of the Thailand and the India 5 percent broken parboiled price series at a 10 percent level of confidence. Thus, there is no evidence of a long-run relationship between the Thailand price series and the India 5 percent parboiled price series.

By designating the two Vietnam rice price series as dependent variables and testing for cointegration, the null hypothesizes of both equations are rejected a at 5 percent level of confidence. The Vietnam 5 percent broken price series and the Vietnam 5 percent broken DWP price series present a cointegration of the linear combination in their long run relationship. The null hypotheses cannot be rejected for the other price series of the paired equations in either the Vietnam price series or the India 5percent broken parboiled price series at a 10 percent level of confidence.

To sum up the cointegration results, there is strong evidence of the presence of a linear combination in the long-run relationship between the Thailand price series and the Vietnam 5 percent broken DWP price series pair and between the Thailand price series and the Vietnam 5 percent broken price series pair. Moreover, the relationship between the two Vietnam prices series show a cointegration of their long-run equilibrium while the U.S. price series does not show cointegration with any price series during the time of this study. The presence of the cointegration results between Thailand and Vietnam rice prices reveals that there is a link among those markets through either substitution or arbitrage during August 1997 to August 2006 whereas the U.S. rice price is not linked to Thailand’s, Vietnam’s and India’s rice prices during the same period.

Table 4.1
Descriptive Data 1997 (Aug)-2006 (Aug)

| **Variables**[a] | **Obs** | **Mean** | **Std.Dev** | **Minimum** | **Maximum** |
|---|---|---|---|---|---|
| US | 109 | 16.15541 | 2.62972 | 10.75 | 21 |
| THB | 109 | 12.21615 | 2.47197 | 8.49 | 16.88 |
| VT_DWP | 109 | 11.13486 | 2.0779 | 7.5 | 16 |
| VT_BKN | 109 | 10.98211 | 2.05661 | 7.4 | 15.75 |
| IN_PARB | 109 | 11.84587 | 2.2967 | 8.25 | 15.75 |

[a]The definitions of each price variable are in Appendix Table1.

Table 4.2
Univariate Stationary Tests: ADF Statistics
1997(Aug)-2006(Aug)

| **Variables**[a] | **Augmented Dickey Fuller Test Statistics**[b] | **P-Value** | **Lag Order** |
|---|---|---|---|
| US | -1.98256 | 0.61090 | 6 |
| THB | -1.13034 | 0.92383 | 5 |
| VT_DWP | -1.33288 | 0.87956 | 4 |
| VT_BKN | -1.34912 | 0.87524 | 4 |
| IN_PARB | -1.41743 | 0.85572 | 2 |

[a]The definitions of each price variable are in Appendix Table1.
[b]The critical values for the t-statistics are from Fuller (Adjusted from Arden, 1989);
100 obs – 3.51(99 percent); - 2.89(95 percent); - 2.58(90 percent)

Table 4.3

Cointegration Tests: Engle-Granger Test
August 1997-August 2006

| Dependent Variable | Test Statistic | 10 % Critical Value | Conclusion |
|---|---|---|---|
| US | $-3.47227^{**}$ | | |
| TH | -2.53989 | 2.91 | No cointegration |
| US | $-3.03101^{*}$ | | |
| VT_DWP | -2.88461 | 2.91 | No cointegration |
| US | $-3.01789^{*}$ | | |
| VT_BKN | -2.88768 | 2.91 | No cointegration |
| US | $-3.36152^{**}$ | | |
| INPARB | -2.5724 | 2.91 | No cointegration |
| TH | $-4.61355^{***}$ | | |
| VT_DWP | $-4.91843^{***}$ | 2.91 | Cointegration |
| TH | $-4.46256^{***}$ | | |
| VT_BKN | $-4.77332^{***}$ | 2.91 | Cointegration |
| TH | -2.25156 | | |
| IN_PARB | -2.55177 | 2.91 | No cointegration |
| VT_DWP | $-3.16881^{*}$ | | |
| VT_BKN | $-3.20694^{**}$ | 2.91 | Cointegration |
| VT_DWP | -1.67798 | | |
| IN_BKN | -2.47596 | 2.91 | No cointegration |
| VT_DWP | -2.37891 | | |
| IN_PARB | -2.38056 | 2.91 | No cointegration |
| VT_BKN | -2.37261 | | |
| IN_PARB | -2.35793 | 2.91 | No cointegration |

[a]The definitions of each price variable are in Appendix Table1.
[b]The critical values from Engle and Granger (Adjusted from Ardeni, 1989)
100 obs: 3.73(99 percent); – 3.17 (95 percent); – 2.91 (90 percent);
$^{*}$, $^{**}$, $^{***}$ are levels of significance at 90 percent, 95 percent and 99 percent

## Overall Data Results August 1997-February 2010

The sample data have been expanded to include the contamination event, testing with the same procedures as above: first testing for a unit root for a long-run relationship among the price series and then examining the presence of short- run dynamics, if there is a result from the cointegration procedure that can be used. Table 4.4 shows the descriptive data from August1997 to February 2010.  A total of 151 prices for each series have been observed. The Thailand 100 percent grade B price series appears to have the most variation in price over time at a standard deviation of 7.78. Its price ranges from a high of 47.45 dollars per hundredweight to a low of 8. 49 dollars per hundredweight. The Vietnam 5 percent broken price series contains the most stable price at a standard deviation of 2.45 with a high and a low price of 15.75 and 7.4 dollars per hundredweight, respectively. The Vietnam 5 percent broken DWP price series presents the overall highest price at 53.75 dollars per hundredweight.

When compared with the descriptive data in Tables 4.1 to 4.4, it can be seen both similarities and differences between the two data periods. The standard deviations of the Vietnam 5 percent broken price and the India 5 percent broken parboiled between August 1997 and August 2006 shows a pattern consistent with the overall standard deviation of data from August 1997 and February 2010. However, the standard deviations of the U.S. long grain Texas price, the Thailand 100 percent price and the Vietnam 5 percent broken DWP price shows no consistent pattern between the two data periods.

## Unit root test

The next procedure is testing for a unit root. The results are shown in Table 4.5. The four main international rice price markets (the Thailand 100 percent grade B price, the Vietnam 5 percent broken price, and the India 5percent broken parboiled price) fail to reject the null hypotheses at a 10 percent level of confidence. In other words, these rice prices series have unit root trends. These three rice prices series are non-stationary, and the stationary trends of these price series are fulfilling after the first differencing. The U.S. long grain Texas price series rejects the null hypothesis at a 10 percent level of confidence but fails to reject the null at a 5 percent level of confidence. The Vietnam 5 percent DWP price series variable fails to reject the null hypothesis at a 1 percent level of confidence; that is , to say, the residual of the variable is stationary. Next, we proceed to the test for cointegration in the long-run relationship.

## Cointegration Results

Examining for cointegrated pairs, this section carries on from the results of the unit root test (ADF) by dropping the U.S. long-grain price series variable and the Vietnam 5 percent DWP price series variable because the price series are not $\sim I(1)$ as has been explained earlier regarding the previous result. The results shown in Table 4.6 reveal that all the price series pairs fail to reject the null hypothesis at a 10 percent level of confidence in testing for the presence of linear combinations of long-run equilibrium. There is no evidence of cointegration in any possible combination of the price series in the three export markets.

Consequently, the cointegration results do not provide a consistent test for the existence of a long-run equilibrium relationships among the Thailand price series, the Vietnam prices series and the India price series. That there are no long-run relationships among the Thailand price, the Vietnam price and the India rice price prove that different rice prices from those countries can be separted without common factors holding their prices together (Gordon and Hannesson, 1996). However, Ghoshray and Lloyd (2003) suggest failing to find a cointegration relationship of a commodity between markets does not mean two market prices are permanently independent of each other.

Comparing the results of the cointegration tests of both data sets, we end up with a different long-run equilibrium relationship before and after the contamination event. First of all, the U.S. rice price series does not show a long-run cointegration relationship with the other rice prices series for either the period before the contamination event or afterward. The linear combinations of the cointegration containing the U.S. price series fail to reject the null hypothesis of the presence of cointegration. From August 1997 to August 2006, the Thailand price series is cointegrated with both the Vietnam 5 percent broken DWP price series and 5 percent broken price series, yet there is no linear cointegration relationship between the Thailand price series and the Vietnam 5 percent broken price series from the second data set. However, from the second data set, August 1997 to February 2010, there is no presence of a cointegration relationship among the price series.

## Multiple Regression Results

As stated earlier, the main purpose of this study is to determine the impact of genetically modified rice contamination on the rice-exporting markets; yet the coingetration tests from the pre-test data sample and the overall sample show that U.S. rice price series do not indicate a linear combination of a long-run equilibrium relationships among the other rice price series events though there is a presence of a linear combination of long-run relationships in the Thailand price series and the Vietnam prices series pairs in the pre-test. Clearly, the relationships between the U.S. rice prices and the other rice price series are the concentration of this study. Thus, an error correction model could not proceed for an investigation of further short-run price dynamics.

Instead, a general multiple regression model is used to determine the relationship of the U.S price series with the others. In addition, the model includes the dummy variable denoting 0 as “before August 2006” and 1 as “after August 2006” to capture the potential impact of the contamination on rice-exporting prices in the sample. Table 4.7 presents the results of the multiple regression equations between the U.S price series and the other rice price series. The adjusted R-square ranges from 0.89 to 0.61 for the sample data. Every price series rejects the null hypothesis, indicating that the estimated coefficients of each price series, the Thailand price, the Vietnam 5 percent DWP price, the Vietnam 5 percent broken price and the India 5 percent broken parboiled price, is different from zero at a 1 percent level of confidence ( 0.746628, 0.733735, 0.990985, and 0.968845, respectively).

The other variable in the multiple regression equation is the dummy variable denoting the periods before and after the contamination event (August 2006). The estimated coefficients of the dummy event in each price equation are -1.85730 for the Thailand price equation, -3.94160 for the Vietnam 5 percent broken DWP equation, -7.84903 for the Vietnam 5 percent broken price equation, and -8.51568 for the India 5 percent broken parboiled price. The equations show a negative sign and are statistically different from zero at a 1 percent level of confidence. The negative sign of the estimated coefficient indicates that the period before August 2006 has less impact on the changes of the U.S. rice price than the period after the contamination event. From these multiple regression equations, the question arises whether error terms of these equations would still present a unit root trend while holding the contamination event variable constant. The results shown in Table 4.8 indicate that the error terms from the U.S. rice price, the Thailand rice price, the Vietnam 5 percent broken and 5 percent broken DWP and the India's 5 percent parboiled rice price equations present a stationary trend. In other words, there is no unit root in an error term from regression equations.

### Price correlation and Movements

The rice price series in the data sample is estimated for correlation relation and price movement because international rice prices show fluctuation between August 1997 and February 2010 ( Figure 3.1 and Appendix Table.2). The correlation estimated and the correlation significant test results are shown in Table 4.9. The correlation coefficient estimate explains the relationship between the price series along with the previous test. Although there is no linear combination of the long run equilibrium between U.S. price series and its price series pairs before or including the contamination event periods, the prices' movements and their estimated relationship directions may be observed. Since rice prices of the data sample both in the pre-test and overall- test contain a non-stationary or unit root trend, estimating for a correlation coefficient would lead to a spurious result. Price change levels are then used for the correlation estimation test. The estimated correlation coefficients of the Thailand price and the Vietnam 5 percent DWP price are statistically significant indicating that the Thailand price and the Vietnam price tend to change in the same direction as the U.S. price.

Table 4.4

Descriptive Data 1997(August) -2010(February)

| **Variables**[a] | **Obs** | **Mean** | **Std. Dev** | **Minimum** | **Maximum** |
|---|---|---|---|---|---|
| US | 151 | 19.42179 | 6.87399 | 10.75 | 44 |
| TH_B | 151 | 15.89907 | 7.78118 | 8.49 | 47.45 |
| VT_DWP | 151 | 14.09238 | 6.7882 | 7.5 | 53.75 |
| VT_BKN | 151 | 12.07517 | 2.48814 | 7.4 | 15.75 |
| IN_PARB | 151 | 12.77252 | 2.51343 | 8.25 | 15.75 |

[a]The definitions of each price variable are in Appendix Table1.

Table 4.5
Univariate Stationary Tests: ADF Statistic
1997 (Aug)-2010 (Feb)

| **Variable**[a] | **Augmented Dickey-Fuller Test Statistic**[b] | **P-Value** | **Lag Order**[c] |
|---|---|---|---|
| US | -2.58268* | 0.28793 | 6 |
| TH | -2.35989 | 0.40115 | 4 |
| VT_DWP | -3.25007** | 0.074878 | 4 |
| VT_BKN | -2.09272 | 0.55017 | 4 |
| IN_PARB | -1.73658 | 0.7345 | 3 |

[a]The definitions of each price variable are in Appendix Table1.

[b]Critical values for the t-statistics are from Fuller (Arden, 1989);
100 obs – 3.51(99 percent); - 2.89(95 percent); - 2.58(90 percent);
*, ** are levels of significance at 90 % and 95 %
Rejection of the null hypothesis of a unit root at the 10 level.

[c]Lag orders for augmented tests chosen using the minimum value of Akaike Information Criteria (AIC).

Table 4.6
Cointegration Test: Engle-Granger Test
August 1997-February 2010

| **Dependent Variable[a]** | **Test Statistic** | **10 % Critical Value** | **Conclusion** |
|---|---|---|---|
| TH | -2.92652 | 2.91 | No cointegration |
| VT_BKN | -2.4842 | | |
| TH | -3.36792 | 2.91 | No cointegration |
| IN_PARB | -2.77765 | | |
| VT_BKN | -3.48547 | 2.91 | No cointegration |
| IN_PARB | -2.8414 | | |

[a]The definitions of each price variable are in Appendix Table1.
[b]Critical value from Engle and Granger (Adjusted from Ardeni, 1989)
100 obs: 3.73(99 percent); – 3.17 (95 percent); – 2.91 (90 percent);
*, **, *** are levels of significance at 90%, 95 % and 99%, respectively

Table 4.7

Ordinary Least Squared Regression Models, August 1997-February 2010

| **Independent Variables**[a] | **Estimated Coefficient** | **Standard Error** | **T-statistic** | **Adj.$R^2$** |
|---|---|---|---|---|
| THB | 0.746628 | 0.038049 | 19.623*** | 0.884601 |
| EVENT Before Aug 2006 | -1.8573 | 0.658536 | -2.82035*** | |
| VT_DWP | 0.733735 | 0.044713 | 16.41*** | 0.852583 |
| EVENT Before Aug 2006 | -3.9416 | 0.675123 | -5.83834*** | |
| VT_BKN | 0.990985 | 0.189793 | 5.22141*** | 0.649012 |
| EVENT Before Aug 2006 | -7.84903 | 1.05039 | -7.4725*** | |
| IN_PARB | 0.968845 | 0.160612 | 6.03221*** | 0.666381 |
| EVENT Before Aug 2006 | -8.51568 | 0.897926 | -9.48372*** | |

[a]The definitions of each price variable are in Appendix Table1.
*, **, *** are levels of significance at 10%, 5 % and 1%, respectively

Table 4.8

Univariate Stationary Tests: ADF Statistics, from Regression Equations

| Error term of Equation[a] | T-Test Statistic[b] | Lag Order |
|---|---|---|
| THB | -3.70269*** | 11 |
| VTDWP | -3.73836*** | 6 |
| VTBKN | -3.66228*** | 5 |
| INPARB | -4.05957*** | 5 |

[a]The definitions of each price variable are in Appendix Table1.

[b]Critical values for the t-statistics are from Fuller (Arden, 1989);
100 obs – 3.51(99 percent); - 2.89(95 percent); - 2.58(90 percent);
*** is the level of significance at 99 %
Rejection of the null hypothesis of a unit root at the 10 level.

[c]Lag orders for augmented tests chosen using the minimum value of Akaike Information Criteria (AIC).

Table 4.9

Correlation between Prices Series, August 1997-February 2010

| | | UST | THBT | VTDWPT | VTBKNT | INPARBT |
|---|---|---|---|---|---|---|
| UST[a] | Pearson Correlation | 1 | .825** | .780** | 0.156 | 0.114 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.056 | 0.164 |
| THBT | Pearson Correlation | | 1 | .925** | .235** | .275** |
| | Sig. (2-tailed) | | | 0 | 0.004 | 0.001 |
| VTDWPT | Pearson Correlation | | | 1 | .243** | .214** |
| | Sig. (2-tailed) | | | | 0.003 | 0.008 |
| VTBKNT | Pearson Correlation | | | | 1 | .303** |
| | Sig. (2-tailed) | | | | | 0 |
| INPARBT | Pearson Correlation | | | | | 1 |
| | Sig. (2-tailed) | | | | | |

[a]The definitions of each price variable are in Appendix Table1.
** is the level of significance at 95 %

## CHAPTER 5

## CONCLUSION

Changes in domestic and international policy in both rice-producing and rice-consuming nations, increasing trade volume, and the potential of declining prices compared with other cereal crops has had an impact on the international rice market (Kang, Kennedy and Hilbun, 2009). In addition, a change in one country's domestic regulations is believed to affect other countries in the market. Most agricultural commodities such as corn, wheat and soybeans are traded within a free trade environment, unrestricted in terms of trade regulations for both sellers and buyers. The fact that rice is not truly categorized as a freely trade commodity in the international market due to governments' regulation domestically and internationally may explain the unstable behavior of the rice trade. Major rice-exporting countries are responsible for changes in the trade because, unlike other cereals, rice is traded at a volume that is proportionally low in comparison with its production. This research tests if a cointegration in international rice prices has lead to a long run price equilibrium relationship, or if the same price movement path will be found among four major rice-exporting countries: Thailand, Vietnam, the United States, and India.

Thailand is a one of the world's top rice producers and the largest rice exporter. Its main export markets are Iran, Indonesia, Singapore and the United States ("Rice is life", 2004). The country is well-known for its high-quality long-grain white rice and this is one of the reasons for a limiting willingness of farmers for an adoption of a GM high-yielding rice variety. The country remains a GM-free country for commercial crops.

Historically, Vietnam was one of the world's original cultivators of rice. Vietnam is the world's second largest rice-exporting countries. Despite this, its farmers still benefit little due to the low price of Vietnamese rice.

The United States' dominant rice producing regions are in Arkansas's Grand Prairie, the Mississippi Delta, the Gulf Coast, and the Sacramento Valley of California (Childs, 2009). It is one of the world's major rice-exporting countries despite its small domestic production.

India, another of the world's rice producers, is also one of the world's main rice-exporters. Rice cultivation is practiced all around the country and rice production accounts for much of the country's income and employment.

The overall objective of this research is to determine the impact of genetically modified rice contamination on rice-export prices by answering the following questions:

1. In general, is there any relationship among prices of rice internationally?
2. What impact, if any, did the 2006 contamination event have on rice exporting markets?

The empirical results provide consistent evidence that the U.S. rice market is not integrated in the long-run with any of the other main rice-exporting markets nor is there any price integration among all the five rice-exporting markets. However, we may observe some evidence of long-run price relationships of the prices among Thailand's 100 percent grade B and both of Vietnam's markets, the 5 percent broken DWP and the 5 percent broken, for the period before the contamination event. In addition, Vietnam markets show long-run price linkages. Put differently, these three rice prices must converge into an equilibrium price path to prevent the prices to separate too far from each other.

The results of an extended time period including the contamination event are the same. There is no evidence of price integration among prices in the U.S. and the other rice-exporting countries. In other words, the five markets are not linked. The prices of rice in these five countries occasionally diverge considerably during the time of the study. Nonetheless, the U.S. price, Thailand price and Vietnam 5 percent broken DWP price present the same price relationship in terms of pattern and direction. Moreover, Thailand's, Vietnam's, and India's rice prices, individually, all positively correlate to changes in the U.S. rice price. The price of rice is the U.S. changes less during the period before the announcement of the contamination of genetically modified LibertyLink rice has during less the period afterward.

Gordon and Hannesson (1996) state that if there is a well-integrated relationship in a market, a trade restrictions from the side of either supply or demand will result in a shock to the price system. The effect of the shock, however, does not last long and the market will return to its equilibrium price. Thus, the effect of one major exporting rice country's trade action would possibly lead to a permanent impact on the rice price system due to that fact that the rice-exporting market is not well cointegrated. The non-integrated pattern of rice price markets seen in this study may be a result of trade actions of the four countries. Rice prices of the U.S., Thailand, Vietnam and India are independent of each other with or without the impact of the contamination of genetically modified rice. Gordon (1996) concludes that if the two rice prices are not cointegrated, a shock in one country will have a long permanent impact on that country without an international spillover. An institutional factor within a country and/or among countries might be one of the reasons that international rice prices are not linked. Another explanation is the changes of explicit and implicit costs such as exchange rate and transportation cost. One implication of this study can be useful for the rice-producing sector and rice policy makers, which is that rice-producing farmers should pay more attention to the demand for GM crops. Although genetically modified crops are not currently proven to be safe for human consumption in international level, many countries allow the use of GM crops for other usages such as for animal, in industrial sectors, and in research. Thus, it is likely that GM crops would trade in a certain new market. Policy makers could use the contamination event as a guideline and adjust their regulations for the greatest most possible benefit.

## Recommendation for Further Research

Although the regression results did capture the impact upon Thailand's, Vietnam's, and India's rice price from the changes in the U.S. rice price due to the contamination event, it is possible that result does not reflect the impact of the GM rice contamination event. Thus, it is very important that a researcher select an accurate data sample for a specific research question when conducting a test for a secondary data. In addition, studying the price behavior and price variability of different types of rice from various groups of rice-related countries such as those of low and high-income may help measure the impact of genetically modified rice. Trade policies and potential price imparts relating to genetically modified crops are worth further research.

## BIBLIOGRAPHY


Aksoy, M. Ataman and John C. Beghin. 2004. "Global Agricultural Trade and Developing Countries." The International Bank for Reconstruction and Development. The World Bank. Washington D.C. Chapter 1. pp 1-16

Annou, Mamane, Michael Thomsen, and Eric Wailes. 2001. "Impact of Herbicide Resistant Rice Technology on Rice-Soybean Rotation." *Journal of Agricultural Agrobiotechnology Management and Economics,* 4(2), pp 79-86.

Ardeni, Pier Giorgio. August 1989. "Does the Law of One Price Really Hold for Commodity Price?" *American Journal of Agricultural Economics*: 71, pp. 661-669.

Brookes, Graham and Peter Barfoot. 2003. "GM Rice: Will This Lead The Way for Global Acceptance of GM Crop Technology?" *Abridged version of the June 2002 PG Economics Report. Made available to ISAAA for publication*.

Carter, Colin A. and Aaron Smith. (2003). "StarLink Contamination and Impact on Corn Prices." *Contributed Paper Presented at the International Conference Agricultural Policy Reform and the WTO: Where are We Heading?* Capri, Italy, June 23-26, 2003. AgEcon Search.

Childs, Nathan. November 2009. "Rice: Background and Policy." *Rice Briefing Room.* Economics Research Service. The United States Department of Agriculture.

Ching, Lim Li. November 2004. "Safety Consideration for Genetically Engineering Rice." *Asian Biotechnology and Development Review*: 7(1), pp 67-80.

Demont, Matty and Yann Devos. April 2008. "Regulating Coexistence of GM and Non-GM crops Without Jeopardizing Economic Incentives." *Trends in Biotechnology*: 26(7), pp 353-358.

David, Cristina C. and Jikun Huang. 1996. "Political Economy of Rice Price Protection in Asia." *Economic Development and Cultural Change*: 44(3), pp 463-483. AgEcon Search.

David, Russell and James G. Mackinnon. 1993. "Estimation and Inference in Econometrics." New York, Oxford University Press.

Dawe, David. 2002. "The Changing Structure of the World Rice Markets, 1950-2000." *Food Policy*: 27, pp 355-370.

Enders, Walter. 1996. Applied Econometric Time Series. Wiley Publisher: Second edition.

Enserink, Martin. 2008. "Tough Lessons from Golden Rice." *Science Magazine : 320, pp 468-471*

Hareau, Guy, Brandford F. Mills, Georage W. Norton and Darrell Bosch. "The Economic Impact of GMO in Small Developing Countries." *Paper prepared for presentation at the Annual Meeting of the American Agricultural Economics Association.* Long Beach, CA, July 28-31, 2002.

Hettel, Gene. 2006. "Trick of the Trade.".Rice Today: 5(3), pp 16-17.

Gariboldi, F. 1984. "Rice Parboiling." FAO Agricultural Services Bulletin 56. Rome: Food and Agriculture Organization of the United Nations.

Ghoshray, Atanu and Tim Lloyd. " Price Linkages in the International Wheat Market." *Selected Paper for Presentation to the International Association of Agricultural Economists Triennial Conference, Durban, South Africa, August,18-22, 2003.* AgEcon Research.

Goodwin, Barry K. (1992) "Multivariate Cointegration Tests and the Law of One Price in International Wheat Markets." *Review of Agricultural Economics:* 14(1), pp 117-124.

Gordon, Daniel V. and Rognvaldur Hanessesson. 1996. "On Price of Fresh and Frozen Cod Fish in Europe and U.S. Markets." *Marine Resources Economics*: 11, pp 223-238. AgEcon Search.

Grist, D.H. 1978. "Rice." Longman Group. London and New York .

Gruere, Guillaume, Antoine Bouet and Simon Mevel. December 2007. "Genetically Modified Food and International Trade: The Case of India, Bangladesh, Indonesia and the Philippines." *Discussion paper. International Food Policy Research Institue*. Ecohost Database.

Gujarati, Damodar N. 2005. "Basic Econometrics." Fourth Edition. New York. Tata McGraw-Hill .

Kang, Hyunsoo, P. Lynn Kennedy, and Brian Hilbun. "Structure and Conduct of the World Rice Market." *Selected Paper for Presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31- February 3, 2009.* AgEconSreach.

Li, Yarui, J. Wailes, A. McKenzie and M. Thomsen. 2010. "LL601 Contamination and Its Impact on U.S. Rice Prices." *Journal of Agricultural and Applied Economics:* 42 (1), pp 31-38. AgEcon Search.

Jayne, T.S. 1993. "Sources and Effect of Instability in the World Rice Market." *Michigan State University International Development Papers*. AgEcon Search.

Nicols, Panos and Fredoun Ahmadi-Esfahani. "Are Australian Wholesale Vegetable Markets LOOPy?" *Contributed paper presented at the Australian Resource Economics Society, 53rd Annual Conference in Carins, Queensland, February 11-13, 2009.*

Odularu, Gbadebo olusegun. May 2010. "Rice Trade Policy Options in an Open Developing Economy: The Nigerian Case Study." *Journal of Development and Agricultural Economics:* 2(5), pp 166-177.

"Rice Industry in Crisis: Major Rice Markets Close Doors to Genetically Engineered Rice After Contamination of the Global Food Supply Chain." 2007. Greenpeace International.

"Rice is Life: International Year of Rice 2004 and its Implementation." International Rice Commission. Food and Agriculture Organization of the United Nations. Rome, Italy. October, 2005.

Roggemann, Ellen. August 2005. "Fair Trade Thai Jasmine Rice: Social Change and Alternative Food Strategies Across Borders." *Educational Networks for Global and Grassroots Exchange (ENGAGE).* Migration Policy and Resource Center. Urban and Environmental Policy Institute.

Ryan, James G. January 1999. “Assessing the Impact of Rice Policy Changes in Vietnam and the Contribution of Policy Research: Impact Assessment Discussion Paper No.8.” *International Food Policy Research Institute.*

“Trade Reforms and Food Security: Conceptualizing Linkages.” Commodity Policy and Projection Service: Commodity and Trade Division. Food and Agricultural Organization of the United Nations. Rome, Italy. 2003

“The Stabilization of the International Trade in Rice: A Report on Possible Measures.” August, 1955. *Commodity Policy Studies No.7*. Food and Agriculture Organization of the United Nations. Rome, Italy.

Vermij, Peter. 2006. “Liberty Link Rice Raises Specter of Tightened Regulations.” *Nature Biotechnology:* 24(11), pp 1301-1302.

Vogel, Gretchen. 2008. “Tracing the Transatlantic Spread of GM Rice.” *ScienceMag* 313: 1714.

Vinuya, Ferdinand. “Testing for Market Integration and the Law of One Price in World Shrimp Markets.” *Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando, Florida, February 5-8, 2006.* AgEcon Search.

Wailes, Eric J. 2004. “Global Trade and Protection Regimes in Rice Trade.” Global Agricultural Trade and Developing Countries. Chapter 10, pp 177-194. Washington D.C. The World Bank.

Wang, Yanging and Sam Johnson. 2007. “The Status of GM Rice in R&D in China.” *Nature Biotechnology:* 25(7), pp 717-718.

Zohrabyan, Tatevik, David Leatham and David Bessler. "Cointegration Analysis of Regional House Prices in the U.S." *Proceedings of Regional Research Committee NC-1014 St. Louis, Missouri October 4-5, 2007. Dr. Michael A. Gunderson, Editor.*

# APPENDICES

**APPENDICIES**

Table A. The Definitions of Variables

| Variables | Definitions |
|---|---|
| **US** | **Export U.S. rice price (U.S. dollar/cwt)** |
| | source: U.S. Long Grain Texas. ERS, USDA |
| **TH** | **Export Thailand rice price (U.S. dollar/cwt)** |
| | source: Thai 100% Grade B. ERS, USDA |
| **VT_DWP** | **Export Vietnam rice price (U.S. dollar/cwt)** source: Vietnam 5% Broken, Double Water Polished. ERS, USDA |
| **VT_BKN** | **Export Vietnam rice price (U.S. dollar/cwt)** |
| | source: Vietnam 5% Broken. ERS, USDA |
| **IN_PARB** | **Export India rice price (U.S. dollar/cwt)** |
| | source: India 5% Broken Parboiled. ERS, USDA |
| **EVENT0** | **Period before the contamination event, August 2006** |
| **EVENT1** | **Period after the contamination event, August 2006** |
| **UST** | **Export U.S. rice price change (U.S. dollar/cwt)** |
| | source: U.S. long grain Texas. ERS, USDA |
| **THT** | **Export Thai rice price change (U.S. dollar/cwt)** |
| | source: Thai 100% Grade B. ERS, USDA |
| **VT_DWPT** | **Export Vietnam rice price change (U.S. dollar/cwt)** source: Vietnam 5% Broken, Double Water Polished. ERS, USDA |
| **VT_BKNT** | **Export Vietnam rice price change (U.S. dollar/cwt)** |
| | source: Vietnam 5% Broken. ERS, USDA |
| **IN_PARBT** | **Export India rice price change (U.S. dollar/cwt)** |
| | source: India 5% Broken Parboiled. ERS, USDA |

Table B. International Rice Exporting Price (U.S. dollar/hundredweight)

| Date | US long grain Texas | Thailand 100% grade B | Vietnam 5% DWP | Vietnam 5% broken | India 5% parboiled |
|---|---|---|---|---|---|
| Aug-97 | 21.00 | 14.80 | 13.00 | 12.65 | 15.75 |
| Sep-97 | 20.55 | 14.01 | 12.90 | 12.65 | 15.75 |
| Oct-97 | 19.75 | 13.74 | 12.10 | 11.85 | 15.40 |
| Nov-97 | 19.75 | 13.03 | 12.30 | 12.05 | 14.50 |
| Dec-97 | 19.75 | 13.72 | 13.75 | 13.50 | 14.50 |
| Jan-98 | 19.75 | 14.96 | 13.35 | 13.10 | 14.25 |
| Feb-98 | 19.75 | 15.35 | 13.00 | 12.75 | 14.00 |
| Mar-98 | 19.05 | 15.27 | 14.25 | 14.00 | 14.00 |
| Apr-98 | 19.00 | 16.30 | 15.00 | 14.75 | 13.40 |
| May-98 | 19.00 | 16.39 | 15.00 | 14.75 | 14.00 |
| Jun-98 | 19.00 | 16.88 | 15.45 | 15.20 | 14.00 |
| Jul-98 | 19.00 | 16.84 | 15.50 | 15.25 | 14.15 |
| Aug-98 | 18.85 | 16.68 | 16.00 | 15.75 | 14.25 |
| Sep-98 | 18.63 | 16.61 | 15.80 | 15.55 | 14.25 |
| Oct-98 | 18.25 | 15.31 | 15.00 | 14.75 | 14.25 |
| Nov-98 | 18.50 | 13.90 | 14.15 | 13.90 | 14.15 |
| Dec-98 | 18.50 | 14.10 | 13.15 | 12.90 | 13.70 |
| Jan-99 | 18.44 | 15.38 | 12.50 | 12.25 | 14.00 |
| Feb-99 | 18.22 | 14.35 | 12.20 | 11.95 | 14.50 |
| Mar-99 | 18.07 | 13.17 | 11.65 | 11.40 | 14.35 |
| Apr-99 | 17.75 | 12.08 | 11.30 | 11.05 | 13.90 |
| May-99 | 17.31 | 12.61 | 11.70 | 11.45 | 13.50 |
| Jun-99 | 17.05 | 13.08 | 12.15 | 11.90 | 13.15 |
| Jul-99 | 17.00 | 12.93 | 11.75 | 11.50 | 13.00 |
| Aug-99 | 16.48 | 12.63 | 11.75 | 11.50 | 13.00 |
| Sep-99 | 16.00 | 11.73 | 11.15 | 10.90 | 13.00 |
| Oct-99 | 16.00 | 11.15 | 10.30 | 10.05 | 13.25 |
| Nov-99 | 15.80 | 11.78 | 11.10 | 10.85 | 13.50 |
| Dec-99 | 15.75 | 11.98 | 11.60 | 11.35 | 13.50 |

International Rice Exporting Price (U.S. dollar/hundredweight)-Continue1

| Date | US long grain Texas | Thailand 100% grade B | Vietnam 5% DWP | Vietnam 5% broken | India 5% parboiled |
|---|---|---|---|---|---|
| Jan-00 | 15.55 | 12.41 | 11.70 | 11.45 | 13.50 |
| Feb-00 | 15.25 | 12.58 | 10.75 | 10.50 | 13.50 |
| Mar-00 | 15.00 | 11.74 | 9.90 | 9.70 | 13.50 |
| Apr-00 | 14.84 | 11.25 | 9.00 | 8.75 | 13.50 |
| May-00 | 14.48 | 10.54 | 8.90 | 8.65 | 12.60 |
| Jun-00 | 14.38 | 10.49 | 9.00 | 8.75 | 12.50 |
| Jul-00 | 14.43 | 9.94 | 9.35 | 9.15 | 12.50 |
| Aug-00 | 14.50 | 9.66 | 9.35 | 9.15 | 12.30 |
| Sep-00 | 14.56 | 9.23 | 9.00 | 8.80 | 12.00 |
| Oct-00 | 14.95 | 9.62 | 9.20 | 8.95 | 12.00 |
| Nov-00 | 15.00 | 9.55 | 9.05 | 8.80 | 11.65 |
| Dec-00 | 15.00 | 9.49 | 8.70 | 8.50 | 11.50 |
| Jan-01 | 15.00 | 9.51 | 8.50 | 8.40 | 11.50 |
| Feb-01 | 15.00 | 9.49 | 8.30 | 8.15 | 11.50 |
| Mar-01 | 15.00 | 9.08 | 7.70 | 7.55 | 11.50 |
| Apr-01 | 15.00 | 8.49 | 7.50 | 7.40 | 11.50 |
| May-01 | 15.00 | 8.58 | 7.65 | 7.55 | 11.00 |
| Jun-01 | 15.00 | 8.83 | 7.80 | 7.70 | 9.00 |
| Jul-01 | 15.00 | 8.85 | 8.05 | 7.95 | 8.50 |
| Aug-01 | 14.81 | 8.71 | 8.90 | 8.80 | 8.55 |
| Sep-01 | 14.25 | 8.89 | 8.75 | 8.65 | 8.50 |
| Oct-01 | 14.00 | 8.72 | 8.90 | 8.80 | 8.40 |
| Nov-01 | 13.63 | 8.97 | 9.65 | 9.55 | 8.35 |
| Dec-01 | 12.75 | 9.22 | 9.70 | 9.60 | 8.25 |
| Jan-02 | 12.75 | 9.85 | 9.70 | 9.60 | 8.25 |
| Feb-02 | 12.25 | 10.05 | 9.35 | 9.25 | 8.25 |
| Mar-02 | 11.92 | 9.88 | 8.70 | 8.60 | 8.25 |
| Apr-02 | 12.30 | 9.79 | 9.35 | 9.25 | 8.25 |
| May-02 | 12.30 | 10.35 | 9.50 | 9.40 | 8.25 |

International Rice Exporting Price (U.S. dollar/hundredweight)-Continue 2

| Date | US long grain Texas | Thailand 100% grade B | Vietnam 5% DWP | Vietnam 5% broken | India 5% parboiled |
|---|---|---|---|---|---|
| Jun-02 | 11.74 | 10.39 | 9.90 | 9.80 | 8.40 |
| Jul-02 | 11.93 | 10.26 | 9.55 | 9.45 | 8.45 |
| Aug-02 | 11.93 | 9.83 | 9.60 | 9.50 | 8.55 |
| Sep-02 | 12.33 | 9.58 | 9.65 | 9.55 | 8.90 |
| Oct-02 | 11.17 | 9.59 | 9.50 | 9.40 | 8.90 |
| Nov-02 | 10.75 | 9.63 | 9.40 | 9.30 | 8.95 |
| Dec-02 | 10.75 | 9.53 | 9.20 | 9.10 | 9.00 |
| Jan-03 | 10.75 | 10.29 | 8.75 | 8.65 | 9.20 |
| Feb-03 | 10.75 | 10.21 | 8.70 | 8.60 | 9.25 |
| Mar-03 | 10.80 | 10.05 | 8.85 | 8.75 | 9.25 |
| Apr-03 | 12.18 | 10.00 | 8.95 | 8.85 | 9.35 |
| May-03 | 12.96 | 10.18 | 9.40 | 9.25 | 9.40 |
| Jun-03 | 13.15 | 10.42 | 9.35 | 9.25 | 9.75 |
| Jul-03 | 13.59 | 10.24 | 9.15 | 9.05 | 9.75 |
| Aug-03 | 14.96 | 10.05 | 9.20 | 9.10 | 9.75 |
| Sep-03 | 15.51 | 10.12 | 9.40 | 9.30 | 9.75 |
| Oct-03 | 16.07 | 10.06 | 9.65 | 9.55 | 9.75 |
| Nov-03 | 16.52 | 9.91 | 10.00 | 9.85 | 9.75 |
| Dec-03 | 17.14 | 10.15 | 10.10 | 10.00 | 9.75 |
| Jan-04 | 18.07 | 11.00 | 9.95 | 9.85 | 9.75 |
| Feb-04 | 18.00 | 11.00 | 10.05 | 9.95 | 9.75 |
| Mar-04 | 18.07 | 12.20 | 11.60 | 11.50 | 9.75 |
| Apr-04 | 18.20 | 12.35 | 12.15 | 12.05 | 9.75 |
| May-04 | 19.43 | 11.90 | 11.90 | 11.80 | 9.75 |
| Jun-04 | 19.75 | 11.70 | 11.75 | 11.60 | 9.75 |
| Jul-04 | 19.75 | 11.80 | 11.45 | 11.35 | 9.75 |
| Aug-04 | 19.75 | 12.20 | 11.60 | 11.50 | 9.75 |
| Sep-04 | 18.81 | 12.00 | 11.25 | 11.20 | 9.75 |
| Oct-04 | 17.85 | 13.00 | 11.05 | 10.95 | 9.75 |

International Rice Exporting Price (U.S. dollar/hundredweight)-Continue 3

| Date | US long grain Texas | Thailand 100% grade B | Vietnam 5% DWP | Vietnam 5% broken | India 5% parboiled |
|---|---|---|---|---|---|
| Nov-04 | 17.75 | 13.30 | 11.55 | 11.50 | 13.55 |
| Dec-04 | 17.75 | 14.15 | 12.00 | 11.95 | 13.55 |
| Jan-05 | 17.42 | 14.70 | 12.65 | 12.55 | 14.10 |
| Feb-05 | 17.38 | 14.80 | 13.40 | 13.30 | 14.60 |
| Mar-05 | 17.06 | 14.90 | 13.20 | 13.15 | 14.75 |
| Apr-05 | 16.50 | 15.10 | 12.85 | 12.80 | 14.50 |
| May-05 | 16.50 | 15.00 | 12.60 | 12.55 | 14.25 |
| Jun-05 | 16.50 | 14.55 | 12.05 | 12.00 | 14.30 |
| Jul-05 | 16.13 | 14.10 | 12.10 | 12.05 | 14.30 |
| Aug-05 | 16.00 | 14.45 | 12.80 | 12.75 | 14.00 |
| Sep-05 | 16.00 | 14.55 | 12.80 | 12.75 | 13.20 |
| Oct-05 | 16.20 | 14.60 | 13.30 | 13.20 | 13.35 |
| Nov-05 | 16.25 | 14.15 | 13.30 | 13.20 | 13.65 |
| Dec-05 | 16.31 | 14.30 | 13.30 | 13.20 | 13.65 |
| Jan-06 | 18.17 | 14.90 | 13.25 | 13.15 | 13.50 |
| Feb-06 | 18.25 | 15.35 | 13.20 | 13.10 | 13.40 |
| Mar-06 | 18.50 | 15.40 | 12.65 | 12.55 | 13.40 |
| Apr-06 | 18.50 | 15.45 | 12.15 | 12.05 | 13.30 |
| May-06 | 18.63 | 15.70 | 12.95 | 12.85 | 13.25 |
| Jun-06 | 18.75 | 15.95 | 13.20 | 13.10 | 13.25 |
| Jul-06 | 18.75 | 16.05 | 13.20 | 13.10 | 13.10 |
| Aug-06 | 19.13 | 15.95 | 13.40 | 13.30 | 13.10 |
| Sep-06 | 21.00 | 15.90 | 13.60 | 13.50 | 13.00 |
| Oct-06 | 21.27 | 15.35 | 13.90 | 13.80 | 13.10 |
| Nov-06 | 21.38 | 15.10 | 14.85 | 14.75 | 13.25 |
| Dec-06 | 21.38 | 15.60 | 14.85 | 14.75 | 13.25 |
| Jan-07 | 21.38 | 16.00 | 14.85 | 14.75 | 13.25 |
| Feb-07 | 21.38 | 16.15 | 14.85 | 14.75 | 13.40 |
| Mar-07 | 21.31 | 16.35 | 15.15 | 15.00 | 13.65 |

International Rice Exporting Price (U.S. dollar/hundredweight)-Continue 4

| Date | US long grain Texas | Thailand 100% grade B | Vietnam 5% DWP | Vietnam 5% broken | India 5% parboiled |
|---|---|---|---|---|---|
| Apr-07 | 21.25 | 16.20 | 15.15 | 15.00 | 13.40 |
| May-07 | 21.25 | 16.25 | 15.00 | 15.00 | 13.95 |
| Jun-07 | 21.25 | 16.55 | 15.15 | 15.00 | 14.15 |
| Jul-07 | 21.25 | 16.75 | 15.35 | 15.00 | 15.00 |
| Aug-07 | 21.25 | 16.70 | 15.80 | 15.00 | 15.75 |
| Sep-07 | 21.25 | 16.60 | 16.00 | 15.00 | 15.55 |
| Oct-07 | 22.05 | 16.85 | 16.00 | 15.00 | 15.75 |
| Nov-07 | 22.63 | 17.45 | 16.00 | 15.00 | 15.75 |
| Dec-07 | 22.78 | 18.40 | 16.00 | 15.00 | 15.75 |
| Jan-08 | 23.72 | 19.20 | 19.05 | 15.00 | 15.75 |
| Feb-08 | 25.84 | 23.70 | 23.35 | 15.00 | 15.75 |
| Mar-08 | 28.60 | 30.75 | 29.40 | 15.00 | 15.75 |
| Apr-08 | 36.38 | 46.45 | 41.50 | 15.00 | 15.75 |
| May-08 | 43.00 | 47.45 | 53.75 | 15.00 | 15.75 |
| Jun-08 | 43.40 | 39.45 | 44.15 | 15.00 | 15.75 |
| Jul-08 | 44.00 | 37.80 | 35.60 | 15.00 | 15.75 |
| Aug-08 | 44.00 | 35.45 | 29.40 | 15.00 | 15.75 |
| Sep-08 | 40.75 | 35.05 | 28.30 | 15.00 | 15.75 |
| Oct-08 | 38.00 | 31.70 | 23.25 | 15.00 | 15.75 |
| Nov-08 | 36.00 | 28.70 | 20.65 | 15.00 | 15.75 |
| Dec-08 | 34.25 | 27.40 | 20.95 | 15.00 | 15.75 |
| Jan-09 | 32.63 | 29.90 | 19.95 | 15.00 | 15.75 |
| Feb-09 | 30.88 | 30.75 | 21.65 | 15.00 | 15.75 |
| Mar-09 | 29.63 | 30.75 | 22.75 | 15.00 | 15.75 |
| Apr-09 | 27.63 | 28.60 | 23.00 | 15.00 | 15.75 |
| May-09 | 27.63 | 27.35 | 22.85 | 15.00 | 15.75 |
| Jun-09 | 27.63 | 29.60 | 20.75 | 15.00 | 15.75 |
| Jul-09 | 27.03 | 30.10 | 20.25 | 15.00 | 15.75 |
| Aug-09 | 26.38 | 27.65 | 19.65 | 15.00 | 15.75 |

International Rice Exporting Price (U.S. dollar/hundredweight)-Continue 5

| Date | US long grain Texas | Thailand 100% grade B | Vietnam 5% DWP | Vietnam 5% broken | India 5% parboiled |
|---|---|---|---|---|---|
| Sep-09 | 26.38 | 27.20 | 19.20 | 15.00 | 15.75 |
| Oct-09 | 26.38 | 25.65 | 20.50 | 15.00 | 15.75 |
| Nov-09 | 26.38 | 27.50 | 23.25 | 15.00 | 15.75 |
| Dec-09 | 26.38 | 30.25 | 23.25 | 15.00 | 15.75 |
| Jan-10 | 27.16 | 29.80 | 24.10 | 15.00 | 15.75 |
| Feb-10 | 27.63 | 28.80 | 21.25 | 15.00 | 15.75 |

VITA

Graduate School

Southern Illinois University

Mana-anya Iemsam-arng Date of Birth: February 23, 1985

756 N. Lake Drive, Du Quoin, IL 62832

11 Lane 7B, Paaton Road, Amphur Muang, Chiangmai, Thailand 50300

Doraemon_138@hotmail.com

MaeJo University, Thailand

Bachelor of Science, Post Harvest Technology, May 2007

Thesis Title: Contamination Events and Linkages in World Rice Markets

Major Professor: Dr. Dwight Sanders