MARKET EFFICIENCY AND PRICE DISCOVERY AMONG LEADING RICE-EXPORTING COUNTRIES

Thanasin Tanompongphandh

January 2010

Abstract

This paper explores evidence of linkages, represented by price transmission elasticity, among the top three rice exporting countries, namely Thailand, Vietnam, and the United States, and, within the US domestic markets, including the Chicago agricultural futures market. Secondly, it utilizes the Gonzalo & Granger decomposition method to uncover long-run price discovery among each pair of markets. Through three bivariate cointegrated systems, the study shows that long-run price co-movements exist among the three major rice-exporting countries. The Gonzalo and Granger decomposition finds that the Thai and US rice price are dominant forces in the price discovery process among the three. This finding is sensible as Thailand is the world’s largest rice exporter while the United States dominates high-quality rice and high-income markets.

Keywords: Rice, Rice exporter, Price transmission elasticity, Price discovery, Gonzalo and Granger.

1 Lecturer in the Economics Program, School of Management, Mae Fah Luang University, thanasin@gmail.com.
1 INTRODUCTION

Rice is one of the most common commodities in global agricultural trade. In 2009, the USDA estimated that rice is critical to the diet of half of the global population. It also observed that countries with lower income per capita tend to spend a higher percentage of income on food, and a greater amount of caloric intake comes from rice. As income rises, per capita rice consumption declines and is replaced with increasing meat and dairy consumption (see Childs & Kiawu, 2009). This long term growth trend facilitates the view that stable global rice production is crucial to the welfare of low income populations. The challenge, however, lies within the market’s infrastructure to bring the surplus of rice produced to international trade. Given the present low trade volume of rice compared to global production volume, the rice market is considered thin (see Slayton, 2009). Two major concerns arose; first the thinness of the rice market could potentially allow international rice prices to be determined by only a few major players. And secondly relying on this thin market the capacity of a rice exporting country to meet demand from rice importing countries becomes even more critical. Given the recent rice price peak, in early 2008, following government mandates for export restrictions, the question of steady supply of rice and dietary welfare of people at the margins becomes even more essential.

Before one can formulate a policy relevant to rice trade, the first task would be to understand the unique structure of the global rice trade and importance of linkages among major players. Accordingly, this study aims to understand the price behavior of key rice exporting countries, and once the linkages between rice exporting countries are established, to test whether each pair of markets is efficient. Secondly this study aims to measure the degree of price leadership through price discovery decomposition, specifically each market’s long-term contribution to the permanent value of rice. This contribution of price discovery is the key to understanding the organizational behavior of the rice market as it assesses the degree of price leadership among its main participants.
To this end, the paper sets up two main objectives. First it seeks to establish, under Johansen’s procedure, that there are linkages, represented by price transmission elasticity, where price innovations from one market transmit to another among the top three rice exporting countries, namely Thailand, Vietnam, and the United States (Arkansas market), and, within the United States domestic markets, including the Chicago agricultural futures market. Secondly, it utilizes the Gonzalo & Granger decomposition method to uncover long-run price discovery among each pair of markets. The possibility of linking the Chicago futures market with leading exporters is also considered, but a framework to directly compare the two seems lacking, since the Chicago future market trades rice futures in rough form while Thailand and Vietnam only export rice in milled form.

This paper follows a bivariate approach in time series in contrast to a multivariate approach due to a limited ability of the latter to identify and interpret coefficients involving market efficiency for a system larger than two markets (see Barrett, 2001, Fackler & Goodwin, 2001). Consequently, through three bivariate cointegrated systems, this study shows that long-run price co-movements exist among the three major rice-exporting countries. In addition to this finding, the hypothesis of market efficiency, captured by the price transmission elasticity, are rejected in two of the three pairs, namely Thai-Vietnam and Thai-US (Arkansas). The magnitudes of the estimated price transmission elasticities reveal that the Thai rice price is more volatile in the long-run co-movement than that of US (Arkansas) and Vietnamese rice. To examine further, the Gonzalo & Granger common factor decomposition technique finds that the Thai rice price is a dominant force in the price discovery process, along with the United States. This finding is sensible as Thailand is the world’s largest rice exporter while the United States dominates high-quality rice and high-income markets.

To evaluate the performance of the USDA adjusted world price relative to other major rice exporting countries, this study looks for evidence of a long-run relationship of the adjusted world price with Thailand, Vietnam, and United States (Arkansas). In this regard, the USDA adjusted world price shows only a long-run linkage with the Vietnamese market. The size of the
estimated coefficient, being far from one, also pinpoints that there could be other factors influencing the USDA world price. Adding to the fact that we fail to establish long-run price relationships between the USDA world rice price with the other two leading rice exporting markets, underscores a weakened ground to support validity and transparency of the USDA’s methodology. This conclusion reinforces Taylor, Bessler, Waller, and Rister’s (1996)’s skepticism that other considerations besides market force are in place for formulation of the USDA adjusted world price.

For the US domestic rice markets, this study finds the efficient linkage between spot and future prices of rough rice, as the Chicago Board of Trade rough rice futures converge to USDA rough rice prices in a cash market as the price transmission elasticity does not statistically differ from one. In the vertical markets, the result also reveals the significant price linkage between two marketing level of rough and milled rice in the United States. Building on these linkages, the Gonzalo & Granger’s decomposition characterizes the dominant source of the price discovery process in the futures market followed by the cash market of the rough rice and then the milled rice export price.

For the remainder of the paper, section two provides background for rice exporting countries. Section three provides a survey of literature on spatial markets. Section four discusses empirical strategy. Section five discusses sources and time series properties of the data. Results are given in section six. Section seven presents policy implications, and Section 8 concludes the paper.

2 COUNTRIES AND PRODUCTS

Thailand is the largest rice exporter in the world in terms of trade volume. Between 2005/06 and 2009/10, the USDA estimates that Thailand transferred around 48% of its rice production to exports. Based on information compiled from the Thai Rice Exporters Association (Statistics 2008, 2010), in 2008, Thailand shipped 25% of its exportable rice, around 10 million
tons, to destinations in Asia, 46% to Africa, 14% to the Middle East, 8% to Europe, 6% to the Americas, and 2% to Oceanic countries. Thai rice export volume is comprised of 25% high quality rice, mostly long-grain *Aromatic* “Hom Mali Rice” or Thai Jasmine rice yet this generates about 30% of export revenue, and 75% long-grain *Indica* white rice, making up 70% of export revenue. Premium Thai Jasmine rice is popular in high income markets such as Hong Kong, Malaysia, Singapore, the United States, the EU, and the Middle East. Thai white rice finds markets in African countries, the Philippines, Indonesia, and China (see Prasertsri, 2009).

Vietnam is the second largest rice exporter in the world in terms of volume. From 2005/06 to 2009/10, the USDA estimates that Vietnam transferred 22% of its production to exports. In 2008, Vietnam shipped 52% of its exportable 4.6 million tons of long-grain *Indica* white rice to destinations in Asia, 27% to Africa, 5% to the Middle East, 3% to Europe, and 11% to the Americas. The Vietnamese rice price is traditionally lower than that for Thai rice, making Vietnam rice popular among lower income markets, such as African countries, the Philippines, Malaysia, Bangladesh, and Cuba. Vietnam also has a variant of fragrant rice, but the export volume of Vietnamese Jasmine rice is not significant to its share of total rice export volume (see Quan, 2009)

The United States is the fourth largest rice exporter in terms of volume, after Pakistan\(^2\). From 2005/06 to 2009/10, the USDA estimates that the United States transferred 48% of its production to exports. The United States produces long-grain *Indica*, medium and short-grain *Japonica* rice with 60%, 35%, and 5% of weight-production share respectively. Each southern states, namely Arkansas, Louisiana, Mississippi, Missouri, and Texas, produced between 11.7 and 86 million cwt of long-grain rice in 2008/09, with Arkansas alone producing more than 50% of total long-grain rice in the United States. California is the largest state in terms of producing *Japonica* medium and short-grain rice, with a more than 80% share of total medium-grain rice in the United States. While yield of the United States rice farmers is the highest among top

\(^2\) Due to limited price data on Pakistan rice, the Pakistan is removed from the scope of this paper.
exporters (see appendix), exports of United States milled rice have been declining due to fierce
competition from lower cost Asian exporters. Nonetheless, the decline in milled rice exports has
been compensated for by the rise in exports of rough rice, which has allowed the United States to
reduce its lost share of rice exports (see Childs & Burdett, 2000). While Thailand and Vietnam
only export rice in a milled-form, but in a rough rice arena, the United States remains a dominant
player. Latin America countries prefer to import rough rice from the United States to utilize
their excess milling capacities since few other countries allow exports of rough rice, and no other
countries can export significance volume of rough rice to match that of the United States (see
Cramer, Wailes, Chavez, & Hanzen, 1998). Since 1998, rough rice has accounted for more than
30% of the US rice export mix, with Mexico and Central America as top export destinations.
The United States was also able to export rough rice to Brazil, Ecuador, and Colombia when
there was a need to boost the level of domestic stocks.

In response to lower cost Asian rice producers, the US Marketing Loan program, part of
the Commodity Loan program3 was introduced for rice farmers in 1986 under provisions of the
1985 U.S. Farm Act. The Rice Marketing Loan program (RML) was designed to offer two loan
repayment levels, based on market price above or below an adjusted world price. When market
price is above the adjusted world price, the normal loan rate comes into effect, and when market
price is below the adjusted world price, the lower loan repayment rate kicks in. Therefore, the
benefits to U.S. rice farmers when market price is below the adjusted world price are 1) the
difference between the loan rate and loan repayment, called a marketing loan gain, and 2) waiver
of all accrued interest on the loan. (see Westcott & Price, 2001). Since the RML program
required USDA to calculate the fair world price, it then became subject of criticism. While the
core component of the adjusted world price reflects major milled rice prices in major export

3 Commodity loans may be settled in three ways: 1)Repaying at the loan rate plus interest costs (CCC interest cost
of borrowing from the U.S. Treasury plus 1 percentage point), 2)Repaying at an alternative loan repayment rate, or
3) Forfeiting the pledged crop to the CCC at loan maturity.
markets, the other component also includes the effects of supply-demand changes, government-assisted sales, and other relevant price indicators, which adds significant element of judgment into the world price formula (see Westcott & Price, 2001). In this regard, Taylor, Bessler, Waller, and Rister (1996) argued that lack of transparency in the formula of the USDA adjusted world price makes it susceptible to error in judgment.

Levels of poverty and low income population among the top rice exporting countries 4 certainly affect domestic policy where food price is concerned (see Timmer & Dawe, 2007). As flooding and drought, brought on by climate change, continue to put pressure on rice production, the threat of exporting bans on rice to calm domestic pressure is real. Going forward as we face increasingly scarcer arable land and water supplies to support rice production, the risk of increasing price volatility will remain significant. Recent experiences in many developing countries show that the public unrest could be triggered by the rising cost of staple food.

To improve yield, one area of rising interest is on the Genetically Modified rice. Presently, only the United States, Canada, Argentina, China and Brazil allow the widespread planting and commerce of the Genetically Modified (GM) rice. There is also speculation that the Philippines, India, and Bangladesh might soon follow China in accepting GM rice in Asia (see Serapio, 2010). Thailand remains cautious about GM rice and has completely banned GM rice research as it could threaten its lucrative exports due to fear of farmers smuggling the GM rice out from its research facility. Vietnam allowed GM rice research in 2001, but restricted it to laboratory-stage only (see Rice, 2010). Proponents of GM rice argue that the GM rice improves yields and can solve malnutrition problems for the world’s population (see The Golden Rice Project, 2010). Opponents argue that, with GM rice, there could be a hidden harmful component that, once unleashed in wide-scale planting, would be irreversible (see Hands Off Our Rice, 2010). Resistance from Europe and Middle Eastern countries toward GM rice will limit its growth in these high income markets. Despite this setback, GM rice continues to grow in lower

---

4 Out of the top five exporting countries, only the United States is an advanced economy while Thailand, Vietnam, Pakistan, and India are emerging countries.
income countries where malnutrition problems are greater (see Genetically Modified Rice, 2008).

3 SURVEY OF LITERATURE ON SPATIAL MARKET EFFICIENCY

Engle and Granger (1987) introduced the concept of cointegration, which shows that non-stationary variables are cointegrated if there exists a linear combination among them that is stationary. Cointegration analysis becomes popular with applications that seek the long-term equilibrium in dynamic settings, such as studies of securities price in many electronics markets (see Hasbrouck, 2003), convergence of prices in the future and the cash market (see Figuerola-Ferretti and Gonzalo, 2008). The cointegration concept also finds application in spatial market studies, in which its common use is to test the hypothesis of the Law of One Price in a spatial setting and to measure the degree of ‘integration’ or ‘efficiency’ (see Fackler and Goodwin, 2001 for more discussion).

Criticism of cointegration analysis in spatial markets sees the test of market efficiency as indistinguishable from tests of the assumption underlying the model itself. In essence, the rejection of the model does not imply inefficiency of spatial markets, but may imply flawed assumptions underlying the error-correction model instead (see McNew and Fackler, 1997, Barrett, 2001). While earlier spatial market literature implies that price cointegration is evidence of market integration, Barrett (2001) argued that cointegration analysis based on price information alone cannot be used to infer market integration, that, in the absence of trade flow information, a price-based notion of market equilibrium or price cointegration can only suggest market efficiency. According to his definition, market efficiency is “the satisfaction of zero marginal benefit equilibrium conditions. It is therefore a statement about welfare, about whether there exist potential Pareto improvements in the (international) economy”. In this sense, the market is highly efficient when there are few or no Pareto improvement opportunities.
However, many spatial market studies continue to draw on cointegration analysis and evidences for the efficient markets continue to surface. Dawson and Dey (2002) analyzed rice market pairs in Bangladesh using an error-correction model and found results supportive of market integration. Rashid (2004) employed the same framework to analyze maize in Uganda and found evidence in favor of market efficiency. Thompson, Sul, and Bohl (2002) used the Seemingly Unrelated Regression error-correction model on wheat markets in the UK, France, and Germany and found evidence that conformed to the law of one price as well as efficient markets.

The definition of market efficiency among rice-exporting countries in this study is based on observations of co-movement of the price in the cointegrating equation, specifically the price transmission elasticity. To the extent that two spatial prices show tight co-movement, that price shocks from one market are able to transmit to the other market efficiently, the windows to arbitrage would be minimal, and we can infer high efficiency between the two markets. In contrast, if two spatial prices demonstrate diverging trends, then it would suggest a possible Pareto improvement opportunity, and an indication of a low level of market efficiency as well as evidence in favor of market segmentation.

Finally, the main contributions of this paper are twofold. First, to the best of my knowledge, this is the first time the price discovery concept has been addressed in the context of the global rice trade. Secondly, policymakers often lack tools to gauge the impact of international rice price adjustment. The estimated price transmission elasticities from this research provide a preliminary assessment tool to both market participants and any governmental supervisory body.
4 EMPIRICAL STRATEGY

The section describes the construction of stationary time series model and relevant statistical tests.

(a) Unit root test

Stationarity of variables is the most important concern in modern time series estimation. To determine if price and first differences are stationary I(0). In this study, the modified augmented Dicky-Fuller test (MADF) is considered instead of the augmented Dicky-Fuller (ADF). In essence, the MADF test applies the implementation of the ADF test on the price series that is transformed by a generalized least squares regression. The MADF test demonstrates greater power and more consistent results than the standard Augmented Dicky-Fuller (ADF) in rejecting the null hypothesis of unit root (see Elliott, Rothenberg, and Stock, 1996). The method for selecting lag is the minimum Schwarz information criterion (SIC).

(b) Error correction specification

Consider a price evolution in a vector autoregressive form

\[ y_t = \nu + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \epsilon_t \]

where \( y_t \) is a \( K \times 1 \) vector of the logarithm of rice prices. \( \nu \) is a \( K \times 1 \) vector of constants, \( A_1 \ldots A_p \) are \( K \times K \) matrices of parameters. And \( \epsilon_t \) is a \( K \times 1 \) vector of error terms. \( \epsilon_t \) has zero mean and variance-covariance matrix \( \Sigma \), and is i.i.d. \( K \) is the number of markets in the consideration.

Rewriting (1) in an error correction representation yields the following
\[ \Delta y_t = v + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \epsilon_t \]  
\[ t = 1, ..., T \]

where \( \Pi = \sum_{j=p}^{j=p} A_j - I_p \) and \( \Gamma_i = -\sum_{j=i+1}^{j=p} A_j \).

\( \Gamma_i \) are \( K \times K \) parameter matrices which contain short-run dynamics with \( \Delta y_{t-i} \). \( \Pi \) is a \( K \times K \) parameter matrix containing adjustment to the long-run economic relationships among the element of \( y_t \), and is the main focus of our analysis.

If variables \( y_t \) are non-stationary, or \( y_t \sim I(1) \), but stationary at a first difference, or \( \Delta y_t \sim I(0) \), then, by the Granger representation theorem (Engle & Granger, 1987), \( \Pi \) has rank \( 0 \leq r < K \), where \( r \) is the number of linearly independent cointegrating vectors. The main assumption underpinning VECM is the conjecture that the system of variables should converge to their long term equilibrium, while long-term equilibrium is implied by cointegration.

There are three cases involving estimation of \( \Pi \). First, if \( \Pi \) has a rank of zero, there is no long term equilibrium among variables in \( y_t \) and the estimation in the form of (2), but without the long-run parameters, is sufficient. And, if \( \Pi \) has rank of \( K \), or full rank, then all elements of \( y_t \) are stationary and the estimation in the form of (1) is sufficient. Finally, if \( \Pi \) has reduced rank \( r \) where \( 0 < r < K \), then \( \Pi \) can be decomposed into a loading matrix \( \alpha \), and cointegrating equation \( \beta \) where \( \Pi = \alpha \beta \). In this case, both \( \alpha, \beta' \) are a \( K \times r \) matrix of rank \( r \).

In the case of two markets or a bivariate model \( K = 2 \), if rank \( r = 1 \), then there is a long-run price relationship between the two markets represented by cointegration. However, if rank \( r = 0 \), then there is no long-run relationship between the two prices. The procedure to determine rank \( r \) is given in the next section.

Rearranging terms in (2) gives

\[ \Delta y_t = \alpha \beta y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + v + \epsilon_t \]  

where \( v \) is a \( K \times 1 \) vector of parameters for a linear time trend at \( y_t \).
The deterministic trends $v$ above can be decomposed into the long-run cointegrating equation and a constant.

$$v = \alpha \mu + \gamma, \quad (4)$$

where

$$\gamma' \alpha \mu = 0 \quad (5)$$

and $\mu$ is $r \times 1$ vectors of parameters.

Rearranging terms in (3) with (4) yields

$$\Delta y_t = \alpha (\beta y_{t-1} + \mu) + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \gamma + \epsilon_t. \quad (6)$$

(c) Tests for cointegration and error correction

The Johansen’s procedure to determine whether there is a long run relationship among variables in $y_t$ is followed. Under the maximum likelihood estimation, if the log likelihood of the unconstrained model that includes the cointegrating equations is significantly different from the log likelihood of the constrained model, which excludes cointegrating equations, the null hypothesis of no cointegration is rejected. The procedure always starts with the case of no cointegrating equations, or rank of zero, and accepts the first null hypothesis, which is non-rejection.

By design, this study focuses on bivariate systems; thus, there are always two cases for the null hypotheses for each system. The first null hypothesis is $H(0)$ where there is no cointegrating equation. Second null hypothesis is $H(1)$ where there is only one cointegrating equation. The lags’ order ($p$) in each of the bivariate systems are chosen based on the Akaike Information Criterion (AIC). In small samples, the AIC may have better properties (choose the correct order more often) than the Hannan-Quinn Information Criterion (HQIC) and Schwartz-Baysian Criterion (SBIC), as they are designed for minimizing forecast error variance (see Lutkepohl, 2005).
(d) Cointegrating equations

The cointegrating vector $\beta$ reveals the long-run relationship between the price pairs. Together with $y_t$ and the constant term, the long-run price relationship is represented by $\beta y_t + \mu = \beta_1 \ln P_1 + \beta_2 \ln P_2 + \mu$. The cointegrating vector of each of markets’ pair is displayed in the form of $(1, -\beta_2)$ where the coefficient of the first market is normalized to one, $\beta_2$ is the coefficient of the second corresponding market, and $\mu$ is a constant term that predicts variable costs related to the trade that would make the price in two markets arbitrage-free in the long-run. Since the model is based on the logarithm of prices, $\beta_2$ tell us the long-run percentage change in the rice price in the first market when the price in the second market changes by one percent. This is usually referred to as “price transmission elasticity” in agricultural market literature. To demonstrate a high level of market efficiency, $\beta_2$ should yield a number close to one, indicating that price shock from one market is able to transmit to the other market quickly, making the co-movement of prices of the same commodities close, albeit at different locations. Hence, the deviation from one of the $\beta_2$ will allow us to better understand better the nature of rice market segmentation.

On the other hand, the cointegrating vector of the United States’ spot-futures pair should also yield $(1, -1)'$ to demonstrate long-run convergence of spot and futures markets. While the conjecture on the cointegrating equation between milled and rough rice is less clear, the estimated parameter should reflect the level of marketing markups. Underlying these views is the strong assumption that transaction and transportation costs are stationary, as well as proportional to the price and would be captured within $\mu$.

(e) Price discovery

The concept of price discovery generally refers to the process of discovering an asset’s full information or its permanent value (see Figuerola-Ferretti and Gonzalo, 2008). To observe the degree of price discovery process in each price series, since the fundamental value of the stock or
commodity is unobservable, the observable price must be broken down into two pieces, the core fundamental value and its transitory component. To this end, the use of Gonzalo and Granger’s (1995) permanent transitory decomposition technique has gained traction in mainstream price discovery literature. Among the first were Harris, McInish, and Wood (1997 and 2002). Among many desirable properties, this decomposition technique allows us to project both the permanent component ($W_t$) and the transitory component ($Z_t$) on a linear combination of the original variables, $y_t$, which is observable. Other attractive features of this method, as opposed to the competing price discovery technique (see Hasbrouck, 2003) for example, are that the result of decomposition is unique and valid even when $\beta_2$ in the cointegrating vector $(1, -\beta_2)$ is not one.

Based on the Granger and Gonzalo definition of decomposition, the permanent component is fully identified as

$$W_t = \alpha_\perp y_t$$

(9)

where $\alpha_\perp$ is an orthogonal vector of the $\alpha$ vector, or $\alpha_\perp' \alpha = 0$,

and the transitory component is

$$Z_t = \beta y_t,$$

(10)

where $\beta$ is the cointegrating vector.

Then, the Gonzalo and Granger decomposition of $y_t$ becomes

$$y_t = A_1 W_t + A_2 Z_t$$

(11)

$$y_t = A_1 \alpha_\perp y_t + A_2 \beta y_t$$

(12)

where

$$A_1 = \beta_\perp (\alpha_\perp' \beta_\perp)^{-1},$$

$$A_2 = \alpha (\beta' \alpha)^{-1},$$

with

$$\alpha_\perp' \alpha = 0,$$

$$\beta_\perp' \beta = 0.$$ 

To estimate the proportion of permanent value for each market, or price discovery, the focus is on the $\alpha_\perp$ vector. Baillie, Booth, Tse, and Zabotina (2002) show that, when used in the
context of a bivariate system, the permanent share of each market in the long term price
equilibrium can be obtained from the formula

$$\alpha_{\perp} = \begin{bmatrix} \alpha_{\perp 1} \\ \alpha_{\perp 2} \end{bmatrix} = \begin{bmatrix} \frac{\alpha_2}{\alpha_2 - \alpha_1} \\ \frac{-\alpha_1}{\alpha_2 - \alpha_1} \end{bmatrix},$$  \hspace{1cm} (13)$$

where $\alpha_{\perp 1}$ represents the proportion of long-run price discovery associated with the first
market and vice versa. Based on this formula, statistical testing on price discovery can be done
via the test of significance on the $\alpha$ vector itself. For more discussion of comparing price
discovery measures, please see Yan & Zivot (2007).

5 DATA

The data includes logarithms of monthly rice prices, where obtained from the United States
Department of Agriculture (USDA Economic Research Service, 2010) and a privately obtained
CEIC data subscription.\(^5\) The USDA Rice Yearbook collects monthly rice prices on various
markets both within the US and in other major rice exporting countries. The price series for
CBOT rough rice futures is obtained from the CEIC data subscription. A reference price for the
U.S. market is the Indica long-grain number two, based on the Arkansas market as production
volume of long-grain rice in Arkansas is the largest in the United States. The U.S. long-grain
number two is also the underlying commodity for rough rice futures for the Chicago Board of
Trade. The technical specification of the U.S. long-grain number two is conveniently comparable
to the Thai 100% grade B which is the global benchmark for rice prices. The rice price for the
Vietnamese market is referred to as 5% broken double washed. Although Vietnamese 5%
broken double washed is seen as slightly lower quality and not directly comparable to Thai rice,
this is the highest quality of Vietnamese rice for which data is available. Both Thai 100% Grade

\(^5\) See [www.ceic.com](http://www.ceic.com) for information on the subscription
B and U.S. long-grain number two are considered high standard, and are equivalent (see Bashir, 2002, Kaosa-ard and Juliano, 1990). All three are *Indica* long-grain rice.

Finally, the adjusted world price calculated by USDA, based on its internal formula, is also obtained through the USDA Rice Yearbook. Change in the USDA adjusted world price affects US rice farmers’ benefits and hence their decisions on farms’ operation.

For the remainder of this paper, Thai 100% Grade B will be referred to as ‘Thai rice’, Vietnamese 5% broken will be referred to as ‘Vietnamese rice,’ and Arkansas long-grain US number two broken not exceeding 4% will be referred to as ‘Arkansas rice.’

The data covers price series from January 1998 to February 2010. The Thai, Vietnamese, and Arkansas prices are freight-on-board or F.O.B. pricing. The US rough rice price series on the cash market is the average price received by US rice farmers. All prices are quoted in current US dollars.
Table 1 Summary statistics for the logarithm of rough and milled rice prices 1998:1 - 2010:2

<table>
<thead>
<tr>
<th>(Logarithm of)</th>
<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thai price</td>
<td>146</td>
<td>5.67</td>
<td>0.406</td>
<td>5.13</td>
<td>6.85</td>
</tr>
<tr>
<td>Vietnamese price</td>
<td>146</td>
<td>5.56</td>
<td>0.371</td>
<td>5.01</td>
<td>6.98</td>
</tr>
<tr>
<td>Arkansas price</td>
<td>146</td>
<td>5.89</td>
<td>0.369</td>
<td>5.24</td>
<td>6.84</td>
</tr>
<tr>
<td>Adjusted world price</td>
<td>146</td>
<td>5.37</td>
<td>0.475</td>
<td>4.64</td>
<td>6.46</td>
</tr>
<tr>
<td>CBOT Rough Rice Futures</td>
<td>146</td>
<td>5.15</td>
<td>0.424</td>
<td>4.38</td>
<td>6.18</td>
</tr>
<tr>
<td>USDA Rough Rice price</td>
<td>146</td>
<td>5.16</td>
<td>0.416</td>
<td>4.43</td>
<td>6.08</td>
</tr>
</tbody>
</table>

Source: Author’s calculation
6 RESULTS

(a) Unit root tests

This section gives a standard stationarity analysis preceding the formulation of a vector error correction model. To begin, four of the price series are tested for unit root. A Modified Augmented Dicky-Fuller (MADF) test has been implemented. To control for the effect of the government-imposed export restriction in Vietnamese rice market, the original price series were regressed on the dummy variable that indicates the export restriction during March 2008 – June 2008. The predicted residuals of the series were then used in the MADF. The lag order of each price series is selected by Schwartz Criterion. Table two shows that the null hypotheses of unit roots could not be rejected on all price series at level but were rejected on the first difference on all series. Thus, based on the MADF test, the logarithm of prices is non-stationary at level or I(1) and stationary at the first difference or I(0).

(b) Johansen’s rank test

The first step in estimating a bivariate system in equation (6) is to run a Johansen’s cointegration rank test to determine whether there is any long-run relationship among variables of interest. To control for seasonality, a set of centered seasonal dummies is added. This set of dummies is summed to zero over a year so that linear terms from the dummies disappear and are replaced with a constant term.

Table three reveals strong evidence for a long-run relationship between Thai and Vietnamese rice prices. Johansen’s Rank Test rejects the null hypothesis of no cointegration and fails to reject the hypothesis of one cointegrating equation.
### Table 2 Unit Root Tests

<table>
<thead>
<tr>
<th>Time period (1998:1-2010:2)</th>
<th>Modified Augmented Dicky-Fuller Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
</tr>
<tr>
<td>Thai</td>
<td>-1.08</td>
</tr>
<tr>
<td>Vietnam</td>
<td>-0.71</td>
</tr>
<tr>
<td>Arkansas</td>
<td>-1.44</td>
</tr>
<tr>
<td>World Milled Price</td>
<td>-0.65</td>
</tr>
<tr>
<td>CBOT Rough Rice</td>
<td></td>
</tr>
<tr>
<td>Future</td>
<td>-0.97</td>
</tr>
<tr>
<td>USDA Rough Rice</td>
<td>-0.66</td>
</tr>
</tbody>
</table>

H0: Unit Root. *, and ** denote 5% and 1% significance Level. The MADF test applies the implementation of the ADF test on the price series that is transformed by a generalized least squares regression. To control for the effect of the government-imposed export restriction in Vietnamese rice market, the original prices were regressed on the dummy variable that indicates the export restriction during March 2008 – June 2008. The predicted residuals were then used in the MADF. Lag orders for each series are selected by Schwartz Criterion.

### Table 3 Johansen Cointegration Tests

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H(0)</td>
</tr>
<tr>
<td>Thai - Vietnam</td>
<td>42.32**</td>
</tr>
<tr>
<td>Thai - Arkansas</td>
<td>15.99*</td>
</tr>
<tr>
<td>Vietnam - Arkansas</td>
<td>34.64**</td>
</tr>
<tr>
<td>Thai - WMP</td>
<td>10.00</td>
</tr>
<tr>
<td>Vietnam - WMP</td>
<td>33.54**</td>
</tr>
<tr>
<td>Arkansas - WMP</td>
<td>12.51</td>
</tr>
<tr>
<td>CBOT Rice Future - USDA Rough Rice</td>
<td>36.81**</td>
</tr>
<tr>
<td>Arkansas Milled - USDA Rough Rice</td>
<td>33.95**</td>
</tr>
</tbody>
</table>

H(0): No cointegration, H(1): 1 cointegrating equation. The test specification assumes a constant term in VECM. Lag orders in each system are selected by the Akaike Info Criterion (Lutkepohl, 2005). *, and ** denote 5% and 1% significance level.
Johansen’s Rank test also rejects the null hypothesis of no cointegration and fails to reject the hypothesis of one cointegrating equation between Thai and Arkansas rice prices as well as between Vietnamese and Arkansas rice prices. Strong evidence of price linkages among all major exporters seems to suggest that long-run price shocks could transmit from one region to another. More detailed analysis of the magnitude of these linkages will be presented and discussed in the next section.

As to questions relating to the validity of the USDA world market reference price among major exporters, the first weakness to the argument is seen when the cointegrating rank test finds only one linkage between the USDA World price and the Vietnamese market. The tests do not find any evidence of cointegration between the USDA World price and either the Thai or Arkansas market. While this result cannot be used as an indication of an invalid formula for the true world price, it does cast doubt over its performance.

Within U.S. domestic rice markets, for the spot and futures of rough rice, Johansen’s test finds strong evidence to support a long-run linkage between the cash market and rough rice futures. The test also finds that Arkansas’s milled price and the USDA cash rough rice price are cointegrated.

Results from Johansen’s rank tests allow us to formally decompose the long-run parameter matrix $\pi$ into $\alpha$ and $\beta$ vector. This leaves to the next section detailed analysis of the estimated value of the $\alpha$ and $\beta$ vectors, which will give us a clue to the role of price discovery in each market, and its long-term co-movement.
The next subsection comprises three pairs of estimated price relationships, namely Thai-Vietnamese markets, Vietnamese-US (Arkansas) markets, and Thai-US (Arkansas) markets. The second subsection analyzes an estimated price relationship between the adjusted world price and the Vietnamese rice price. The third subsection discusses a result from estimated price relationship between spot and futures of US rough rice. The final subsection includes an analysis from estimated price relationships between the spot price of rough rice and Arkansas milled rice price to demonstrate vertical market efficiency. Recall that all price relationships are estimated in the following form.

\[
\Delta y_t = \alpha (\beta y_{t-1} + \mu) + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \gamma + \epsilon_t
\]  

(14)

(c) Three leading rice-exporting countries

The results of the VECM estimation on the treated data of Thai-Vietnamese and US (Arkansas) -Vietnamese markets from 1998m1 to 2010m2 are shown in (15) and (16) respectively. To control for the effect of the government-imposed export restriction in Vietnamese rice market, the original price series were regressed on the dummy variable that indicates the export restriction during March 2008 – June 2008. The predicted residuals of the series were then used in the VECM estimation.

The estimated bivariate error correction model between Thai and Arkansas rice price is the shown in (17).
\[
\left[ \frac{\Delta T H_t}{\Delta V N_t} \right] = \begin{bmatrix}
-0.0136 \\ 0.4522^* \\
(0.0368) \\ (0.0670)
\end{bmatrix} \left[ T H_{t-1} - 1.300^{**} V N_{t-1} - 5.662 \right] + \begin{bmatrix}
0.6038^{**} \\ -0.6027^{**} \\
(0.1511) \\ (0.1726)
\end{bmatrix} \begin{bmatrix}
\Delta T H_{t-1} \\
\Delta V N_{t-1}
\end{bmatrix} + \begin{bmatrix}
-0.259^{**} \\ -0.0821 \\
(0.1000) \\ (0.1823)
\end{bmatrix} \begin{bmatrix}
\Delta T H_{t-2} \\
\Delta V N_{t-2}
\end{bmatrix} + \begin{bmatrix}
0.1054 \\ 0.1309 \\
(0.0985) \\ (0.1795)
\end{bmatrix} \begin{bmatrix}
\Delta T H_{t-3} \\
\Delta V N_{t-3}
\end{bmatrix} + \begin{bmatrix}
-0.150^* \\
0.0151 \\
(0.1012) \\ (0.0135)
\end{bmatrix} \begin{bmatrix}
\text{seasonal dummies}
\end{bmatrix} + \begin{bmatrix}
0.0321 \\ 0.0010 \\
(0.0041) \\ (0.0076)
\end{bmatrix} + \begin{bmatrix}
\hat{\epsilon}_{T H} \\
\hat{\epsilon}_{V N}
\end{bmatrix}
\]

\(6^*\) and \(^{**}\) denote 5% and 1% significance level. Standard errors are given in parentheses. The coefficient of the first variable in the cointegrating vector was normalized to one and thus does not have standard errors. The constant term in the cointegrating equation does not have standard errors since it is not directly estimated but is backed out from other estimates.
\[
\begin{bmatrix}
\Delta T_H_t \\
\Delta A_K_t
\end{bmatrix} =
\begin{bmatrix}
-0.368 \\
0.0384^{**}
\end{bmatrix}
\begin{bmatrix}
TH_{t-1} - 1.2930^{**} A_K_{t-1} + 1.9043
\end{bmatrix}
+ \begin{bmatrix}
0.4246^{**} & 0.3468^* \\
(0.0929) & (1.526)
\end{bmatrix}
\begin{bmatrix}
\Delta T_H_{t-1} \\
\Delta A_K_{t-1}
\end{bmatrix} + \begin{bmatrix}
-0.1967^* & -0.1274 \\
(0.0964) & (1.742)
\end{bmatrix}
\begin{bmatrix}
\Delta T_H_{t-2} \\
\Delta A_K_{t-2}
\end{bmatrix}
+ \begin{bmatrix}
-0.0689 & -0.0328 \\
(0.0919) & (1.512)
\end{bmatrix}
\begin{bmatrix}
\Delta T_H_{t-3} \\
\Delta A_K_{t-3}
\end{bmatrix} + \begin{bmatrix}
-0.0234 \\
(0.0146)
\end{bmatrix}
\begin{bmatrix}
seasonal dummy
\end{bmatrix}
+ \begin{bmatrix}
0.0018 \\
0.0019
\end{bmatrix}
\begin{bmatrix}
\hat{\epsilon}_T H \\
\hat{\epsilon}_A K
\end{bmatrix}
\]

From (15), the cointegrating equation, or β vector, between Thai and Vietnamese rice price shows a coefficient of -1.30 on Vietnamese rice price with a 95% confidence interval between -1.41 and -1.19. The cointegrating equation above extracts the long-run co-movement of Thai and Vietnamese rice prices. Since the absolute value of the lower range, 1.19, is larger than 1, we can reject the hypothesis of market efficiency between Thai and Vietnamese rice, and agree that the long-run percentage change in Thai rice price is slightly higher than that for Vietnam. The narrowed range of the estimate also gives us some comfort in terms of precision of magnitude.

Figure one depicts the plot of the predicted cointegrating vector: a relatively stable graph, fluctuating in closed range, until the first half of 2008 when a large swing in the system occurred. The cointegration vector returns to the same but slightly elevated pattern of late 2008. Since the

---

7 From the cointegrating equation $TH = 1.30VN - 5.66 + \hat{\epsilon}$, we have

\[
\frac{\ln P_{TH}}{\ln P_{VN}} = 1.30
\]

\[
\frac{d\ln P_{TH}}{d\ln P_{VN}} = 1.30
\]

\[
\frac{dP_{TH}}{P_{TH}} / \frac{dP_{VN}}{P_{VN}} = 1.30
\]

nature of shock is brief and temporary, one plausible explanation is a price-overshooting in the presence of supply-shock. Early 2008 was a time when many rice exporting countries decided to restrict their exports out of fear that escalating rice prices would create domestic turmoil. India restricted exports of non-basmati rice in February 2008 and Vietnam placed a ban on rice exports in March 2008. This occurred while Thailand allowed business to go on as usual. Altogether, these decisions effectively pulled available tradable supply from the global market, causing a sharp deviation from the long-term co-movement trend. Although this non-market intervention was accounted for by an OLS regression on the dummy variable of the government intervention but the effect of the short-term price overshooting remained visible.

The Gonzalo and Granger (1995) framework allow us to extract more information from the alpha vector. The decomposition method was simplified for the case of bivariate systems by Baillie, Booth, Tse, and Zabotina (2002). Their simple formula, $\alpha_\perp 1 = \frac{\alpha_2}{\alpha_2 - \alpha_1}, \alpha_\perp 2 = \frac{-\alpha_1}{\alpha_2 - \alpha_1}$, computes the proportion of long-run fundamental value associated with each respective markets. Based on this formula, the proportion of long-run price discovery for the Thai market is 97% versus 3% for the Vietnamese market. The p-value for the test of statistical significance for the price discovery measure is 0.00, and 0.71 for Thai and Vietnamese rice market respectively. The result suggests that higher proportion of the price discovery associated with the Thai market pinpoints its dominance in information source compared to the Vietnamese market.

From (16), Arkansas and Vietnamese rice prices show a cointegrating relationship with the coefficient of -1 for Vietnam, and a 95% confidence level between -1.38 and -0.98. Since the absolute value of the range covers 1, we cannot reject the hypothesis that the long-run co-movement between Arkansas and Vietnamese rice prices is tightly integrated or equal to one. The estimated cointegration yields an interesting view that these two markets movements are roughly the same in the long run.\textsuperscript{10}

\textsuperscript{8} See Appendix
\textsuperscript{9} $\frac{.4522 \pm .0136}{.4522 + .0136} = 97\%$, $\frac{.0136 \pm .0136}{.4522 + .0136} = 3\%$
\textsuperscript{10} From the cointegrating equation $AK = 1.19VN - 5.88 + \hat{\epsilon}$, we have $lnP_{AK} = 1.19 lnP_{VN} - 5.88 + \hat{\epsilon}$
The Gonzalo and Granger decomposition method shows that the proportion of long-run price discovery for the Arkansas market is 94%, versus 6% for the Vietnamese market. The p-values associated with Arkansas and Vietnamese market’s price discovery are 0.00 and 0.22 respectively. The higher proportion of the price discovery associated with the Arkansas market and its significance reveals its dominance in information source compared to the Vietnamese market.

From (17), the cointegrating equation between Thai and US (Arkansas) rice price shows a coefficient of -1.29 with 95% confidence interval between -1.55 and -1.04. The absolute value of -1.55 and -1.04 implies that in the long-run percentage change in Thai price is more volatile compared to that of Arkansas price. As a result, market efficiency hypothesis is rejected between the Thai and US (Arkansas) markets. The relatively wider range of the interval suggests that while a long-run relationship may exist, there could be other driving forces outside this two market system for this long-run co-movement.

Figure three depicts the plot of the predicted cointegrating equation between Thai and Arkansas rice prices. The large variation in upswing and downswing between 2002 and 2004 is puzzling. This significant divergence from zero of the predicted cointegrating equation clearly suggests that there could be market-specific factors that drive deviation from the long-run co-

\[
\frac{\ln P_{AK}}{\ln P_{VN}} = 1.19
\]

\[
\frac{\frac{dP_{AK}}{\tau_{AK}}}{\frac{dP_{VN}}{\tau_{VN}}} = 1.19
\]

\[
\text{From the cointegrating equation } TH = 1.29AK - 1.90 + \hat{\varepsilon}, \text{ we have }
\]

\[
\ln P_{TH} = 1.29 \ln P_{AK} - 1.9 + \hat{\varepsilon}
\]

\[
\frac{dP_{TH}}{\tau_{TH}}/\frac{dP_{AK}}{\tau_{AK}} = 1.29
\]
movement. Over the longer term, however, the predicted cointegrating equation does return to
the normal range, which suggests to us that shocks during 2002 and 2004 were temporary.

The Gonzalo & Granger decomposition method shows that the proportion of long-run price
discovery for the Thai market is 51%, versus 49% for Arkansas market. The p-values for the
statistical test of significance for the price discovery measure are 0.009 and 0.140 for Thai and
Arkansas rice markets respectively. If we are to accept 0.15 significance level, this roughly
similar proportion of permanent value associated with each market implies that both markets
equally contribute to price discovery.

\[
\frac{0.0384}{0.0368 + 0.0384} = 51\%, \quad \frac{0.0868}{0.0368 + 0.0384} = 49\%
\]
Table 4 Summary of Price Discovery among Leading Exporters

<table>
<thead>
<tr>
<th>Time period</th>
<th>Rice Market Price Discovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1998:1-2010:2)</td>
<td>TH</td>
</tr>
<tr>
<td>Price Discovery</td>
<td>0.97</td>
</tr>
<tr>
<td>p-value</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Source: Author’s calculation

Figure 1 Predicted Cointegrated Equation between Thai and Vietnam rice markets
Figure 2 Predicted Cointegrated Equation between Arkansas and Vietnamese rice market

Figure 3 Predicted Cointegrated Equation between Thai and Arkansas rice market
To sum up, the evidence above shows that there are long-run linkages among the three major rice exporters. This is a direct result from the fact that we are able to extract the long-run co-movement among the three pairs as shown by the price transmission elasticities. However, of the three cases, except for that between Vietnam and Arkansas, the market efficiency hypothesis is rejected for the two other cases, as the long-run co-movement represented by $\beta_2$ is significantly different from one. Building on these linkages, the finding shows the dominant sources of price discovery are Thailand and Arkansas, while the role of Vietnamese rice market appears to be informational laggard of the three.

The existence of long-run price linkages among the three rice-exporting countries is a sensible discovery as Thailand is the world’s largest rice exporter while the United States dominates high-quality rice and high-income markets. Although the estimated price transmission elasticities do not comply with the market efficiency hypothesis, the analysis of cointegrating equation, with the aid of graphical plot, suggests that the sharp deviation from the cointegrating trend in 2008 could be the root cause of hypothesis’s rejections. Accordingly, this view was reinforced by the result based on data prior to 2008 that saw non-rejection of the hypothesis of market efficiency on all three cases.\(^\text{14}\)

(d) **USDA adjusted world price**

In this subsection, the following analysis considers whether the characteristics of the USDA adjusted world price can be explained by the movement of one rice-exporting country. Recall that only Vietnamese rice price shows a cointegration with the USDA adjusted world price. Accordingly, the estimated bivariate error correction model between USDA adjusted world price and Vietnamese price is shown in (18).

\(^{14}\) Results shown in Appendix
\[
\begin{bmatrix}
\Delta WMP_t \\
\Delta VN_t
\end{bmatrix} = 
\begin{bmatrix}
.0128 \\
.2900^*
\end{bmatrix}
\begin{bmatrix}
WMP_{t-1} - 1.578^{**} N_{t-1} - 5.364
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
.2333^* & -.1643^{**} \\
-.2852^* & .2062^{**}
\end{bmatrix}
\begin{bmatrix}
\Delta WMP_{t-1} \\
\Delta VN_{t-1}
\end{bmatrix} + \begin{bmatrix}
.0703 & .1331^{**} \\
-.1071 & .0908
\end{bmatrix}
\begin{bmatrix}
\Delta WMP_{t-2} \\
\Delta VN_{t-2}
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
.0368 & .0149 \\
.5335^{**} & .0978
\end{bmatrix}
\begin{bmatrix}
\Delta WMP_{t-3} \\
\Delta VN_{t-3}
\end{bmatrix} + \begin{bmatrix}
-.0119 \\
.0315
\end{bmatrix}
[seasonal dummy]
\]

\[
+ \begin{bmatrix}
.0014 \\
-.0001
\end{bmatrix}
\begin{bmatrix}
\varepsilon_{WP} \\
\varepsilon_{VN}
\end{bmatrix}
\]

(18)

Although the result above portrays a cointegration between Vietnamese rice and USDA adjusted world price, the size of the estimated price transmission elasticity for the Vietnamese rice price significantly larger than one, suggesting that, in the long run, the USDA adjusted world price accelerates much faster than the Vietnamese rice price. Lacking clear justification of what drives the relationship, it becomes clear that the USDA adjusted world price might not represent a good proxy for the actual world price. Added to the fact that we fail to establish long-run relationships with the other two leading rice exporting countries, the overall result does not provide adequate evidence in my view. This conclusion reinforces Taylor, Bessler, Waller, and Rister’s (1996)’s skepticism that other considerations besides market force are in place for formulation of the USDA adjusted world price.

(e) Spot-futures of U.S. rough rice

In this subsection, the following analysis considers whether there is a convergence of spot and futures price of rough rice in the United States domestic market. The estimated bivariate error correction model between spot price of rough rice and rough rice futures is shown below.
\[
\begin{bmatrix}
\Delta SP_t \\
\Delta FT_t
\end{bmatrix}
= 
\begin{bmatrix}
-.1827^{**} \\
.0807
\end{bmatrix}
\begin{bmatrix}
SP_{t-1} \\
FT_{t-1}
\end{bmatrix}
+ 
\begin{bmatrix}
.1348^* \\
.1421^{**}
\end{bmatrix}
\begin{bmatrix}
\Delta SP_{t-1} \\
\Delta FT_{t-1}
\end{bmatrix}
+ 
\begin{bmatrix}
.0008 \\
.0018
\end{bmatrix}
\begin{bmatrix}
\hat{\epsilon}_{SP} \\
\hat{\epsilon}_{FT}
\end{bmatrix}
\]
\[ + \left[ season\text{al}\ dummy \right]
\]
\[ 14 \]

From (19), the cointegrating equation, or \( \beta \) vector, between the cash price and futures of rough rice shows a coefficient of -1.02 on the futures rice price with a 95% confidence interval between -1.09 and -0.95. This is a welcomed result, as the cointegrating equation above extracts the long-run co-movement of cash and futures rice prices\(^{15}\) and the market efficiency hypothesis is not rejected since the interval also includes -1. The price discovery measure also reveals that 31% of permanent value is associated with the cash price, while 69% is associated with the future price.\(^{16}\) This evidence seems to suggest that the rice future price is a dominant source of uncovering new information. This finding is also consistent with the literature on price discovery of commodities (see Figuerola-Ferretti, and Gilbert, 2005)

\[^{15}\text{From the cointegrating equation } SP = 1.026FT -.0917 + \hat{\epsilon}, \text{ we have} \]
\[ln P_{SP} = 1.02ln P_{FT} -.09 + \hat{\epsilon}\]
\[dln P_{TH}/dln P_{VN} = 1.02\]
\[dP_{TH}/dP_{VN} = 1.02\]

\[^{16}\frac{0.0807}{(0.1827+0.0807)} = 31\%, \frac{0.1827}{(0.1827+0.0807)} = 69\%\]
Figure 4 Predicted Cointegrated Equation between Spot and Future market of U.S. rough rice

Table 5 Price Discovery of Spot-Future market of U.S. rough rice

<table>
<thead>
<tr>
<th>Time period (1998:1-2010:2)</th>
<th>Spot-Future Price Discovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spot</td>
</tr>
<tr>
<td>Price Discovery</td>
<td>0.31</td>
</tr>
<tr>
<td>p-value</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Source: Author’s calculation
### (f) Vertical markets

We now shift focus to the question of the degree of price discovery between two levels of market. The estimated bivariate error correction model between the F.O.B export price of U.S. milled rice and the spot price of rough rice is as follows:

\[
\begin{bmatrix}
\Delta AK_t \\
\Delta SP_t
\end{bmatrix}
= 
\begin{bmatrix}
-0.1768^{**} \\
0.0818
\end{bmatrix}
\begin{bmatrix}
AK_{t-1} \\
SP_{t-1}
\end{bmatrix}
+ 
\begin{bmatrix}
0.8483^{**} \\
1.1205
\end{bmatrix}
\begin{bmatrix}
\Delta AK_{t-1} \\
\Delta SP_{t-1}
\end{bmatrix}
+ 
\begin{bmatrix}
0.0252 \\
-0.0611
\end{bmatrix}
\begin{bmatrix}
AK_{t-2} \\
SP_{t-2}
\end{bmatrix}
+ 
\begin{bmatrix}
-0.1605^{**} \\
-0.3530^{*}
\end{bmatrix}
\begin{bmatrix}
\Delta AK_{t-3} \\
\Delta SP_{t-3}
\end{bmatrix}
+ 
\begin{bmatrix}
0.006 \\
-0.0098
\end{bmatrix}
\begin{bmatrix}
\Delta AK_{t-4} \\
\Delta SP_{t-4}
\end{bmatrix}
+ 
\begin{bmatrix}
0.0417 \\
1.1109
\end{bmatrix}
\begin{bmatrix}
\Delta AK_{t-5} \\
\Delta SP_{t-5}
\end{bmatrix}
+ 
\begin{bmatrix}
0.0186 \\
-0.0037
\end{bmatrix}
\begin{bmatrix}
\Delta AK_{t-6} \\
\Delta SP_{t-6}
\end{bmatrix}
+ 
\begin{bmatrix}
\hat{e}_{AK} \\
\hat{e}_{SP}
\end{bmatrix}
\]

The cointegrating relationship between the Arkansas milled rice and spot rough rice shows a coefficient of -.85 on spot rough rice price, with a 95% confidence interval between -90 and -.79. The significance of this finding is that it not only reveals a long-run co-movement between two marketing levels, but also provides evidence of a variable marked-up price structure, in contrast to a cost-plus structure. The price discovery measure reveals that only 32% of permanent value is associated with the F.O.B export price of milled-rice while 68% is associated with the spot price of rough rice. Together with results from the last section, it becomes clear that, for the U.S. domestic rice market, the first dominant price discovery process take place in the futures market, and this is followed by the cash market of the rough rice, and then, finally, is filtered through to the export market.
Figure 5 Predicted Cointegrated Equation between rough and milled rice

Table 6 Price Discovery of the Vertical U.S. Rice Markets

<table>
<thead>
<tr>
<th>Time period (1998:1-2010:2)</th>
<th>Vertical Market Price Discovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milled</td>
</tr>
<tr>
<td>Price Discovery</td>
<td>0.32</td>
</tr>
<tr>
<td>p-value</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Source: Author’s calculation
7 POLICY IMPLICATIONS

The findings in the previous section establish that there exist long-term price co-movements among the three major rice-exporting countries examined in this study. Estimated price transmission elasticity also provides us with a preliminary tool to gauge the impact from price transmission when the price in one market changes. These estimates should be used with the possibility that deviation from long-run equilibrium can be sustained for a long time. The dominant role of price discovery of Thai and United States rice markets when compared to that of Vietnam underscores the importance of Thailand as the world’s largest rice exporter and the United States’ dominance in high-quality rice and high-income markets. Within the United States domestic markets, the success of the Chicago Board of Trade rough rice futures as a dominant source of price discovery also highlights the importance of the futures market as a hedging tool to farmers.

Recognizing that rice as a staple food is especially crucial for low income populations. Given the trajectory of population growth and climate change, together with scarcer land and waters, it is clear that rice supply will continue to be under pressure for the foreseeable future. The current thin market condition for rice does not allow room for a significant supply shock. To prevent malnutrition and improve food security means the more efficient role of rice market is required.

Since market inefficiency that arose from supply shock could be averted if the market infrastructure allows more rice to be traded. The first step would be to invest in viable storage technology in the rice growing emerging countries, allowing these countries to accumulate stocks that can be used as a buffer in the event of supply shock. This in effect would incur less degree of rice price volatility as well.

Secondly, governments must continue to support and nurture a viable centralized trading platform. In 2004, Thailand launched a trading of rice futures in the Agricultural Futures Exchange of Thailand (AFET) but the volume trade currently is dismal. Governments can
engage more systematically through the exchange to accumulate or lower national rice stocks in order to boost and draw international traders to the market.

8 CONCLUSION

To summarize the main findings previously discussed. First through three bivariate cointegrated systems, this study found that from 1998m1 to 2010m2, long-run price co-movements exist among the three major rice-exporting countries, namely Thailand, Vietnam, and US (Arkansas). In addition to this anticipated finding, the hypothesis of market efficiency, as captured by the price transmission elasticity, or $\beta_2$ equals to one, are rejected in two of the three pairs, namely Thai-Vietnam and Thai-US(Arkansas) respectively. Based on the findings, the magnitudes of the estimated price transmission elasticities reveal higher acceleration of the Thai and United States rice price in the long-run co-movement than that of the Vietnamese rice.

Nonetheless, contrary to this result, the separate estimations with the data prior to 2008 show supporting evidence to the market efficiency hypothesis on all three price-pairs. This striking revelation highlights an effective mechanism of international rice market from 1998m1 up to 2008m1 and underscores the importance of further investigation on the 2008’s period as a root cause of the market inefficiency.

Building on the 1998m1-2010m2 linkages, the Gonzalo & Granger common factor decomposition technique shows the dominant sources of price discovery are Thailand and Arkansas, while the role of Vietnamese rice market appears to be the informational laggard of the three. This finding is sensible as Thailand is the world’s largest rice exporter while the United States dominates high-quality rice and high-income markets.

To evaluate the performance of the USDA adjusted world price relative to other major rice exporting countries, this study looks for evidence of long-run relationship of the adjusted world price with Thailand, Vietnam, and United States (Arkansas). In this regard, the USDA adjusted world price shows only a long-run linkage with Vietnamese market. The size of the estimated coefficient far from one also pinpoints that there could be other factors influencing the USDA
world price. In combination with the fact that we fail to establish long-run price relationships between the USDA world rice price with the other two leading rice exporting markets, underscores a weakened argument to support validity and transparency of the USDA’s methodology. This conclusion reinforces Taylor, Bessler, Waller, and Rister’s (1996)’s skepticism that other considerations besides market force are in place for formulation of the USDA adjusted world price.

For the US domestic rice markets, the result shows efficient linkage between spot and future prices of rough rice, demonstrated by Chicago Board of Trade rough rice futures converging to USDA rough rice prices in a cash market. In the vertical markets, the result also reveals the significant price linkage between two marketing level of rough and milled rice in the United States. Building on these linkages, the Gonzalo & Granger’s decomposition characterizes the dominant source of the price discovery process in the futures market followed by the cash market of the rough rice and then the milled rice export price.

Going forward, as the issue of food security becomes increasingly essential due to scarcer area of arable land due to competing demand for food as well as for energy, the understanding of the relationship among the major rice exporting countries remains key necessities especially to rice-importing countries to safeguard the failure of international rice supply as a transfer from rice-surplus countries to the rice-deficit countries has a meaningful welfare implication.

The advantage of our model’s simplistic design also reveals its inherent shortcoming. The drawback of the model’s reliance on price information is the limited interpretation of the estimated elasticities that precludes other significant factors underlying market force. A plausible explanation for the differences in size of percentage change that defines the co-movement includes fluctuating exchange rates, with exporters incurring costs in local currency but quoting prices in United States dollars, and transportation and transaction costs. Additional study can incorporate the role of traditional versus non-traditional investor in commodities market as well as investigate market efficiency in the context of bilateral, multilateral trade agreements.
REFERENCES


APPENDIX

1. THREE LEADING RICE EXPORTING COUNTRIES VECM IN A SUB-PERIOD 1998m1-2008m1

In this section the result of the VECM estimation from 1998m1 to 2008m1, or the period prior to the 2008’s price spike is provided for Thailand, Vietnam, and US (Arkansas). The hypothesis of market efficiency based on $\beta_2 = 1$ cannot be rejected on all three cases.

\[
\begin{bmatrix}
\Delta TH_t \\
\Delta VN_t
\end{bmatrix} = \begin{bmatrix}
-1.285^* \\
.2210^*
\end{bmatrix} \begin{bmatrix}
TH_{t-1} - 1.054^{**} VN_{t-1} + 2.110 \\
.0548
\end{bmatrix} \\
+ \begin{bmatrix}
.3514^{**} \\
.3111^{**}
\end{bmatrix} \begin{bmatrix}
\Delta TH_{t-1} \\
\Delta VN_{t-1}
\end{bmatrix} + \begin{bmatrix}
-.0101 \\
.0354^{**}
\end{bmatrix} \text{[seasonal dummies]}
\]

\[
\begin{bmatrix}
\Delta TH_t \\
\Delta AK_t
\end{bmatrix} = \begin{bmatrix}
-.0469^* \\
.0484^{**}
\end{bmatrix} \begin{bmatrix}
TH_{t-1} - 1.010^{**} AK_{t-1} + 2.947 \\
.0172
\end{bmatrix} \\
+ \begin{bmatrix}
.2955^{**} \\
.0134
\end{bmatrix} \begin{bmatrix}
\Delta TH_{t-1} \\
\Delta AK_{t-1}
\end{bmatrix} + \begin{bmatrix}
-.1159 \\
-.0297
\end{bmatrix} \text{[seasonal dummies]}
\]

17 * and,** denote 5% and 1% significance level. Standard errors are given in parentheses. The coefficient of the first variable in the cointegrating vector was normalized to one and thus does not have standard errors. The constant term in the cointegrating equation does not have standard errors since it is not directly estimated but is backed out from other estimates.
\[
\begin{bmatrix}
\Delta AK_t \\
\Delta VN_t
\end{bmatrix} = \begin{bmatrix}
-0.0428^* \\
0.0695^{**}
\end{bmatrix} \begin{bmatrix}
AK_{t-1} - 1.041^{**} VN_{t-1} - 0.977 \\
(.1651) (.0240)
\end{bmatrix}
\]
\[
+ \begin{bmatrix}
0.5347^{**} \\
0.1215
\end{bmatrix} \begin{bmatrix}
\Delta AK_{t-1} \\
\Delta VN_{t-1}
\end{bmatrix}
+ \begin{bmatrix}
0.0487 \\
0.1527
\end{bmatrix} \begin{bmatrix}
\Delta AK_{t-2} \\
\Delta VN_{t-2}
\end{bmatrix}
\]
\[
+ \begin{bmatrix}
0.1981^* \\
-0.4180^*
\end{bmatrix} \begin{bmatrix}
\Delta AK_{t-3} \\
\Delta VN_{t-3}
\end{bmatrix}
+ \begin{bmatrix}
0.0029 \\
0.0171
\end{bmatrix} \begin{bmatrix}
[ seasonal dummies ] \\
[ seasonal dummies ]
\end{bmatrix}
\]
\[
+ \begin{bmatrix}
0.0016 \\
0.0009
\end{bmatrix} + \begin{bmatrix}
\hat{e}_{AK} \\
\hat{e}_{VN}
\end{bmatrix}
\]  
(A3)
### 2. SUMMARY OF THE COINTEGRATED EQUATIONS AND TEST OF MARKET EFFICIENCY HYPOTHESIS AMONG THREE LEADING RICE EXPORTING COUNTRIES

| Cointegrated Price Relationships | 1998m1-2008m1 | Original | Treated Data\(^{18}\) |
|---------------------------------|---------------|---------|----------------|---|
| TH-VN                           | \(TH_{t-1} = 1.054** (0.0470)VN_{t-1} - 0.054\) | \(TH_{t-1} = 1.1676** (0.0381)VN_{t-1} + 0.8145\) | \(TH_{t-1} = 1.300** (0.0548)VN_{t-1} = 5.662\) |
| AK-VN                           | \(AK_{t-1} = 1.041** (0.1651)VN_{t-1} - 0.0977\) | \(AK_{t-1} = 0.9703** (0.0982)VN_{t-1} - 0.852\) | \(AK_{t-1} = 1.1880** (0.1012)VN_{t-1} = 5.881\) |
| TH-AK                           | \(TH_{t-1} = 1.016 (1587)AK_{t-1} + 0.2947\) | \(TH_{t-1} = 1.2930** (1298)AK_{t-1} + 1.9043\) | N/A |

Source: compiled from the findings

<table>
<thead>
<tr>
<th>Hypothesis of Market Efficiency</th>
<th>1998m1-2008m1</th>
<th>Original</th>
<th>Treated Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH-VN</td>
<td>Not rejected</td>
<td>Rejected</td>
<td>Rejected</td>
</tr>
<tr>
<td>AK-VN</td>
<td>Not rejected</td>
<td>Not rejected</td>
<td>Not rejected</td>
</tr>
<tr>
<td>TH-AK</td>
<td>Not rejected</td>
<td>Rejected</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: compiled from the findings

---

\(^{18}\) The price series were treated to account for non-market intervention in Vietnamese market by i) an OLS regression on dummy variable that indicates that rice exports ban is enforced, ii) then the computed residuals are used to enter the VECM estimation.
3. JARQUE-BERA TEST FOR NORMALITY DISTRIBUTED RESIDUAL TERMS

In this section, we perform misspecification tests to ensure that the underlying statistical assumptions are valid. First, Jarque-Bera test for normally distributed residuals are performed and the results are given below.

For each single-equation, the null hypothesis is that the error term has a univariate normal distribution. For the system with two equations jointly, the null hypothesis is that the disturbances come from bivariate normal distribution.

<table>
<thead>
<tr>
<th>Equation</th>
<th>$\chi^2$</th>
<th>df</th>
<th>Prob &gt; $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_inTH</td>
<td>29.247</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inVN</td>
<td>4287.261</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>ALL</td>
<td>4316.508</td>
<td>4</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inTH</td>
<td>360.662</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inAK</td>
<td>1.295</td>
<td>2</td>
<td>0.52324</td>
</tr>
<tr>
<td>ALL</td>
<td>361.958</td>
<td>4</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inAK</td>
<td>7.819</td>
<td>2</td>
<td>0.02005</td>
</tr>
<tr>
<td>D_inVN</td>
<td>6417.770</td>
<td>2</td>
<td>0.00613</td>
</tr>
<tr>
<td>ALL</td>
<td>6425.589</td>
<td>4</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inWP</td>
<td>91.305</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inVN</td>
<td>6799.894</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>ALL</td>
<td>6891.199</td>
<td>4</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inSP</td>
<td>9.621</td>
<td>2</td>
<td>0.00814</td>
</tr>
<tr>
<td>D_inFT</td>
<td>12.3</td>
<td>2</td>
<td>0.00213</td>
</tr>
<tr>
<td>ALL</td>
<td>21.921</td>
<td>4</td>
<td>0.00021</td>
</tr>
<tr>
<td>D_inAK</td>
<td>203.483</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>D_inSP</td>
<td>41.937</td>
<td>2</td>
<td>0.00000</td>
</tr>
<tr>
<td>ALL</td>
<td>245.42</td>
<td>4</td>
<td>0.00000</td>
</tr>
</tbody>
</table>

Source: Compiled from Stata’s output
4. **LAGRANGE-MULTIPLIER TEST**

Lagrange-multiplier tests are also performed for the possible autocorrelation of the residuals. The formula for the Lagrange-multiplier test statistic at lag $j$ is

$$LM_j = (T - d - .5)\ln\left(\frac{|\hat{\Sigma}|}{|\bar{\Sigma}_s|}\right)$$

where $T$ is the number of observations in the estimation; $\hat{\Sigma}$ is the maximum likelihood estimate of the variance-covariance matrix of the error terms from the estimation; and the $\bar{\Sigma}_s$ is the maximum likelihood estimate of $\Sigma$ from the following augmented regression. First, for the case of 2 equations in the estimation, the error terms is defined to be a $2 \times 1$ vector of residuals. And for each lag $s$, an augmented regression in which the newly created error vector are lagged $s$ times is formed. $d$ is the number of coefficients estimated in the regression. The asymptotic distribution of $LM_j$ in the case of 2-equation-system is $\chi^2$ with $2^2$ degree of freedom.

<table>
<thead>
<tr>
<th>Lag s</th>
<th>$\chi^2$</th>
<th>df</th>
<th>Prob &gt; $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH-VN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4.0299</td>
<td>4</td>
<td>0.40198</td>
</tr>
<tr>
<td>2</td>
<td>3.4184</td>
<td>4</td>
<td>0.49039</td>
</tr>
<tr>
<td>3</td>
<td>2.8971</td>
<td>4</td>
<td>0.57518</td>
</tr>
<tr>
<td>4</td>
<td>2.8238</td>
<td>4</td>
<td>0.58773</td>
</tr>
<tr>
<td>TH-AK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.4615</td>
<td>4</td>
<td>0.65155</td>
</tr>
<tr>
<td>2</td>
<td>4.3421</td>
<td>4</td>
<td>0.36168</td>
</tr>
<tr>
<td>3</td>
<td>4.0289</td>
<td>4</td>
<td>0.40211</td>
</tr>
<tr>
<td>4</td>
<td>2.4307</td>
<td>4</td>
<td>0.65709</td>
</tr>
<tr>
<td>AK-VN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.0583</td>
<td>4</td>
<td>0.72504</td>
</tr>
<tr>
<td>2</td>
<td>2.8825</td>
<td>4</td>
<td>0.57767</td>
</tr>
<tr>
<td>3</td>
<td>2.4107</td>
<td>4</td>
<td>0.66069</td>
</tr>
<tr>
<td>4</td>
<td>3.0352</td>
<td>4</td>
<td>0.55194</td>
</tr>
</tbody>
</table>

Source: Compiled from Stata’s output
The Lagrange-multiplier test does not detect problems of autocorrelation in any systems. Since the likelihood function is derived under the assumption that the residuals are independently, identically, and normally distributed with zero mean and finite variance. If the normality assumption is rejected but the residual is independent and identically distributed, the estimates are consistent but not efficient. This implies that the estimates would converge to the true value in large sample but may not have minimum variance.

<table>
<thead>
<tr>
<th></th>
<th>Lag s</th>
<th>$\chi^2$</th>
<th>df</th>
<th>Prob &gt; $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMP-VN</td>
<td>1</td>
<td>7.0997</td>
<td>4</td>
<td>0.13071</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.4833</td>
<td>4</td>
<td>0.11245</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4.3526</td>
<td>4</td>
<td>0.36038</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.9407</td>
<td>4</td>
<td>0.91864</td>
</tr>
<tr>
<td>SP-FP</td>
<td>1</td>
<td>1.6864</td>
<td>4</td>
<td>0.79318</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.1866</td>
<td>4</td>
<td>0.5271</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.0689</td>
<td>4</td>
<td>0.19406</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5.6022</td>
<td>4</td>
<td>0.23089</td>
</tr>
<tr>
<td>AK-SP</td>
<td>1</td>
<td>1.3858</td>
<td>4</td>
<td>0.84665</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.0438</td>
<td>4</td>
<td>0.28283</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.0384</td>
<td>4</td>
<td>0.7287</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3.2234</td>
<td>4</td>
<td>0.52116</td>
</tr>
</tbody>
</table>

Source: Compiled from Stata’s output
5. **CHRONOLOGY OF THE 2007-08 RICE CRISIS**

This table is an excerpt from Slayton (2009) appendix.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 21&lt;sup&gt;st&lt;/sup&gt;, 2007</td>
<td><strong>NFA</strong> tender 500,000 tons and buys 422,701 tons at an average price of $410 CNF. Vietnam sells 410,701 tons.</td>
</tr>
<tr>
<td>December 31&lt;sup&gt;st&lt;/sup&gt;</td>
<td><strong>Thailand</strong>’s shipments exceed 9.5 million tons, while <strong>India</strong> records 6.3 million tons – including 5.25 million tons of non-Basmati. <strong>Vietnam</strong>’s exports top 4.5 million tons.</td>
</tr>
<tr>
<td>January 14&lt;sup&gt;th&lt;/sup&gt;, 2008</td>
<td>Cold spell begins in northern <strong>Vietnam</strong> which over several weeks destroys 148,000 ha of transplanted rice and 10,000 ha of seedlings.</td>
</tr>
<tr>
<td>January 18&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>Vietnam</strong>’s export target raised from 4.4 million tons to 4.5 million tons, including 700,000 tons January-March, 1.5 million tons each in second and third quarters, and 800,000 tons October-December. Exports are allowed to resume with MEP of $385 for 5% and $360 for 25% for January-February shipment and $400 for 5% for March. Informally, VFA asks that no sales of 25% be made.</td>
</tr>
<tr>
<td>January 29&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>NFA</strong> tenders for 550,000 tons and buys 463,750 tons at an average price of $475 CNF. Vietnam sells 300,000 tons. Facing large losses on unshipped contracts concluded in late 2007, major exporters in <strong>Thailand</strong> stop offering price quotes.</td>
</tr>
<tr>
<td>February 1&lt;sup&gt;st&lt;/sup&gt;</td>
<td><strong>NFA</strong>’s stocks are equivalent to 8 days requirements, just over half of the targeted level of 15 days. (NFA’s stocks are to be at least 30 days during the “lean” season.)</td>
</tr>
<tr>
<td>February 5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Vietnam informally banned new rice exports by revoking MEP and stop issuing any additional MEPs during February 2008.</td>
</tr>
<tr>
<td>March 6&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Export quotas announced in <strong>Vietnam</strong>: January-March 700-800,000 tons, April-June 1.3-1.5 million tons, July-September 1.3-1.4 million tons, and October-December 700-800,000 tons. This effectively bans further sales in March given existing sales to NFA and others.</td>
</tr>
<tr>
<td>March 14&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>Vietnam</strong> Food Association issues letter to members banning exports through April and promises guidance for May shipment at a later time.</td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>March 17&lt;sup&gt;th&lt;/sup&gt;</td>
<td>First arrivals in Bangladesh from initial contract by <strong>India</strong> under promised 500,000 tons. <strong>Vietnam</strong> bans further sales for March and April. Only sales for May allowed.</td>
</tr>
<tr>
<td>March 25&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>Vietnam</strong> extends export ban through June and reduces export target by .5-1.0 million tons to 3.5-4.0 million tons.</td>
</tr>
<tr>
<td>March 26&lt;sup&gt;th&lt;/sup&gt;</td>
<td><strong>Vietnam</strong> decrees that no export contracts will be approved unless exporter is holding as stock 50% of the sale, prices must be in line w/ MEP, and shipment within 60 days; Export quotas revised: January-June 2.25 million tons (50% of total exports in '06 and '07); 3.5 million tons through September; MOU with the Philippines for 1.5 million tons announced.</td>
</tr>
<tr>
<td>March 28&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Commerce minister in <strong>Thailand</strong> told press that export prices would reach $1,000/ton by June and that farmers should not be in a hurry to sell.</td>
</tr>
<tr>
<td>March 29&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Export tax proposed in <strong>Vietnam</strong>.</td>
</tr>
<tr>
<td>April 1&lt;sup&gt;st&lt;/sup&gt;</td>
<td><strong>India</strong> bans non-Basmati exports, Basmati MEP rises to $1,200. Head of All India Rice Exporters’ Association forecasts a 5.25 million ton drop in exports over the next twelve months. In an effort to quell rising domestic prices, the minister of commerce indicates the government in <strong>Thailand</strong> will release up to 650,000 tons from its stockpiles into the domestic market at below-market prices. In the <strong>Philippines</strong>, the government rejects a proposal to reduce the import tariff on rice from its current rate of 50%.</td>
</tr>
<tr>
<td>April 4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>With hoarding underway by rice mills, traders, and public, prime minister in <strong>Thailand</strong> assures there is enough rice for domestic consumption, but indicates a commerce ministry plan to distribute subsidized rice is not necessary. Finance and commerce ministers repeat assurances that the country will not restrict exports. Following a “summit” with government officials and farm experts on how to contain the rice crisis, President Arroyo in the <strong>Philippines</strong> announces the government will spend over $1.0 billion to increase rice production. The agriculture secretary tells press that 2007 imports could reach as high as 2.7 million tons.</td>
</tr>
<tr>
<td>April 8&lt;sup&gt;th&lt;/sup&gt;</td>
<td>In the <strong>Philippines</strong>, the government indicates it will tender for 500,000 tons in May. NFA tenders for 100 TMT of U.S. #2/4%; purchased 72,600 tons for June-Sep shipment at average price of over $1,058.</td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>April 10th</td>
<td><strong>Thailand</strong>’s commerce minister announces that effective from April 14 all retail rice prices will be reduced 10% for two months. Also, head of Internal Trade Department indicates that millers and exporters must report stock levels monthly and that army could be called in to guard rice warehouses. Also, exporters will be required to hold stock of 500 tons. Head of Thai rice exporters’ association predicts 100% B will soon reach $1,000.</td>
</tr>
<tr>
<td>April 11th</td>
<td>In <strong>Thailand</strong>, the commerce minister asks the military to guard the government-held stocks.</td>
</tr>
<tr>
<td>April 14th</td>
<td>U.N. secretary general says global food crisis has reached “emergency proportions.”</td>
</tr>
<tr>
<td>April 17th</td>
<td><strong>NFA</strong> tenders for 500,000 tons and buys 364,000 tons at an average price of $1,075 CNF for 25% (323,375 tons) and $1,129 for 5% (40,625 tons each). Vietnam sells 80,000 tons (not including 20,875 tons sourced out of Pakistan via Long An Food).</td>
</tr>
<tr>
<td>April 22nd</td>
<td>Prime minister of Thailand denies country will restrict exports.</td>
</tr>
<tr>
<td>April 23rd</td>
<td>Head of NFA indicates it is considering holding weekly import tenders.</td>
</tr>
<tr>
<td>April 25th</td>
<td>In <strong>Vietnam</strong> “rice fever” breaks out, prices have doubled in HCMC over the course of a couple of days. <strong>India</strong> announces it will build 5 million ton “strategic reserve” of food grains, including 2 million tons of rice – beyond its stocking norms. U.N. Secretary General Ban calls for concerted and immediate action to solve global food crisis. Head of FAO tells press global food crisis could result in “civil wars.”</td>
</tr>
<tr>
<td>April 28th</td>
<td>Decree against speculators issued in Vietnam.</td>
</tr>
<tr>
<td>April 30th</td>
<td>Thailand’s prime minister revives proposed rice exporter cartel, OREC.</td>
</tr>
<tr>
<td>May 5th</td>
<td><strong>NFA</strong> tender for 675,000 tons fails as only one offer received and it without a sovereign guarantee; the Philippines talks of waiting until fall to buy. It indicates it will not, in any case, pay above $1,200/ton.</td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>May 6&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Following objections from the Philippines and the ADB, Thailand scraps OREC proposal.</td>
</tr>
<tr>
<td>May 13&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Malaysia buys from Thailand 100,000 tons each of 5% at $950 and 15% at $940.</td>
</tr>
<tr>
<td>May 19&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Philippines discloses Japan may also provide 200,000 tons imported rice.</td>
</tr>
<tr>
<td>May 21&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Major exporters in Thailand resume offering price quotes.</td>
</tr>
<tr>
<td>May 23&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Thailand’s visiting prime minister reportedly tells President Arroyo that Bangkok is prepared to sell its stocks to the Philippines at friendship prices.</td>
</tr>
<tr>
<td>June 2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>At FAO summit on food crisis, Japan’s P.M. Fukuda commits “to release in the near future over 300,000 tons of imported rice” to the world market. Japan also discloses Sri Lanka has requested up to 200,000 tons of food aid. Prime minister takes commerce minister’s proposal off cabinet agenda that would authorize Thailand to participate in NFA’s request for G-to-G offers of 600,000 tons by June 13.</td>
</tr>
<tr>
<td>June 10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Prime minister takes commerce minister’s proposal off cabinet agenda that would authorize Thailand to participate in NFA’s request for G-to-G offers of 600,000 tons by June 13.</td>
</tr>
<tr>
<td>June 13&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Philippines receives offers for G-to-G purchase of 600,000 tons.</td>
</tr>
<tr>
<td>June 18&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Vietnam’s export ban lifted; MEP $800 for 5% established.</td>
</tr>
</tbody>
</table>

Source: Slayton (2009)
6. CHARACTERISTICS OF RICE MARKETS

This section provides brief background on rice markets, including a global supply perspective, consumption, and characteristics that define the international rice market.

(a) Global supply and consumption

Global rice production has increased steadily due to both expansion of harvesting areas and yield improvement through technology and modern irrigation systems. According to the USDA grain database, the global harvesting area slowly increased from 147 million hectares in 1990/91 to over 160 million hectares in 2009/10, or a compound average growth rate of 0.43% over 20 years. Yield improvement of rough rice also saw gradual increases from 3.54 metric tons per hectare in 1990/91 to 4.3 metric tons per hectare in 2009/10, or a compound average growth rate of 1.03%. Milled rice production increased to 459 million tons in 2009/10 from 353 million tons in 1990/91, or a compound average growth rate of 1.36%. Over the same period, rice consumption also rose to 449 million tons from 351 million tons, or a compound average growth rate of 1.31%. Faster production growth allows excess rice production each year to be accumulated for next year’s stocks.

(b) Global rice stock-to-use ratio

The gauge to monitor the health of available rice supply is the stock-to-use ratio (figure 3). This ratio compares beginning stock to a year’s consumption. While a slight price decrease during 1997 and 2000 corresponded with the general increase in global stock, and a price increase from 2001 to 2005 corresponded with the decrease in global stock of the same period, the peak in 2008 is not associated with a meaningful decrease in global rice stock. This poses a serious issue concerning the rice market infrastructure as a means to allocate rice efficiently.
**Figure 6 Area Harvested and Rough Rice Yield (rough basis)**

Source: USDA Estimates. Foreign Agricultural Service. Author’s calculation.

**Figure 7 Rice Stocks and Consumption (milled basis)**

Source: USDA Estimates. Foreign Agricultural Service. Author’s calculation.
Figure 8 World Rice Ending Stocks and Stock-to-Use Ratio (milled basis)

Source: USDA Estimates. Foreign Agricultural Service. Author’s calculation.

Figure 9 Milled Rice Prices (Unit in US$/Metric Ton)

Source: USDA Rice briefing room.
Table 7 Milled rice production by country (Unit in Thousand Metric Tons)

<table>
<thead>
<tr>
<th>Production</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010*</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>127200</td>
<td>130224</td>
<td>134330</td>
<td>137000</td>
<td>137500</td>
</tr>
<tr>
<td>India</td>
<td>93350</td>
<td>96690</td>
<td>99180</td>
<td>87500</td>
<td>99000</td>
</tr>
<tr>
<td>Indonesia</td>
<td>35300</td>
<td>37000</td>
<td>38300</td>
<td>38800</td>
<td>40000</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>29000</td>
<td>28800</td>
<td>31000</td>
<td>30500</td>
<td>32300</td>
</tr>
<tr>
<td>Vietnam</td>
<td>22922</td>
<td>24375</td>
<td>24393</td>
<td>24380</td>
<td>24750</td>
</tr>
<tr>
<td>Thailand</td>
<td>18250</td>
<td>19800</td>
<td>19850</td>
<td>20300</td>
<td>20600</td>
</tr>
<tr>
<td>Burma</td>
<td>10600</td>
<td>10730</td>
<td>10150</td>
<td>10597</td>
<td>11000</td>
</tr>
<tr>
<td>Philippines</td>
<td>9775</td>
<td>10479</td>
<td>10753</td>
<td>9757</td>
<td>10800</td>
</tr>
<tr>
<td>Brazil</td>
<td>7695</td>
<td>8199</td>
<td>8569</td>
<td>7820</td>
<td>8400</td>
</tr>
<tr>
<td>Japan</td>
<td>7786</td>
<td>7930</td>
<td>8029</td>
<td>7711</td>
<td>7850</td>
</tr>
<tr>
<td>United States</td>
<td>6088</td>
<td>6149</td>
<td>6400</td>
<td>6917</td>
<td>7809</td>
</tr>
<tr>
<td>Pakistan</td>
<td>5450</td>
<td>5700</td>
<td>6700</td>
<td>6500</td>
<td>6500</td>
</tr>
<tr>
<td>Cambodia</td>
<td>3946</td>
<td>4238</td>
<td>4520</td>
<td>4780</td>
<td>4800</td>
</tr>
<tr>
<td>Korea, South</td>
<td>4680</td>
<td>4408</td>
<td>4843</td>
<td>4916</td>
<td>4600</td>
</tr>
<tr>
<td>Egypt</td>
<td>4383</td>
<td>4385</td>
<td>4402</td>
<td>4300</td>
<td>3900</td>
</tr>
<tr>
<td>Nigeria</td>
<td>2900</td>
<td>3000</td>
<td>3200</td>
<td>3400</td>
<td>3600</td>
</tr>
<tr>
<td>Nepal</td>
<td>2804</td>
<td>2810</td>
<td>2850</td>
<td>2900</td>
<td>2900</td>
</tr>
<tr>
<td>Madagascar</td>
<td>2240</td>
<td>2304</td>
<td>2505</td>
<td>2688</td>
<td>2688</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>2145</td>
<td>2200</td>
<td>2227</td>
<td>2566</td>
<td>2594</td>
</tr>
<tr>
<td>Iran</td>
<td>1724</td>
<td>1850</td>
<td>1500</td>
<td>2000</td>
<td>2050</td>
</tr>
<tr>
<td>Other</td>
<td>22117</td>
<td>22338</td>
<td>24326</td>
<td>25253</td>
<td>25638</td>
</tr>
<tr>
<td>World Total</td>
<td>420355</td>
<td>433609</td>
<td>448027</td>
<td>440585</td>
<td>459279</td>
</tr>
</tbody>
</table>

*2010 number is USDA Forecast.
Table 8 Rice consumption by country (Unit in Thousand Metric Tons)

<table>
<thead>
<tr>
<th>Domestic Consumption</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010*</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>127200</td>
<td>127450</td>
<td>133000</td>
<td>134500</td>
<td>135500</td>
</tr>
<tr>
<td>India</td>
<td>86700</td>
<td>90466</td>
<td>91090</td>
<td>89300</td>
<td>93500</td>
</tr>
<tr>
<td>Indonesia</td>
<td>35900</td>
<td>36350</td>
<td>37090</td>
<td>38100</td>
<td>39500</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>29764</td>
<td>30747</td>
<td>31000</td>
<td>31300</td>
<td>32500</td>
</tr>
<tr>
<td>Vietnam</td>
<td>18775</td>
<td>19400</td>
<td>19000</td>
<td>19150</td>
<td>19500</td>
</tr>
<tr>
<td>Philippines</td>
<td>12000</td>
<td>13499</td>
<td>13650</td>
<td>13614</td>
<td>13700</td>
</tr>
<tr>
<td>Burma</td>
<td>10670</td>
<td>10249</td>
<td>9648</td>
<td>10000</td>
<td>10100</td>
</tr>
<tr>
<td>Thailand</td>
<td>9780</td>
<td>9600</td>
<td>9500</td>
<td>9600</td>
<td>9800</td>
</tr>
<tr>
<td>Brazil</td>
<td>7925</td>
<td>8254</td>
<td>8530</td>
<td>8600</td>
<td>8650</td>
</tr>
<tr>
<td>Japan</td>
<td>8250</td>
<td>8177</td>
<td>8326</td>
<td>8200</td>
<td>8125</td>
</tr>
<tr>
<td>Nigeria</td>
<td>4400</td>
<td>4500</td>
<td>5150</td>
<td>5300</td>
<td>5500</td>
</tr>
<tr>
<td>Korea, South</td>
<td>4887</td>
<td>4670</td>
<td>4788</td>
<td>4750</td>
<td>4740</td>
</tr>
<tr>
<td>United States</td>
<td>3959</td>
<td>3919</td>
<td>3957</td>
<td>4001</td>
<td>4050</td>
</tr>
<tr>
<td>Cambodia</td>
<td>3646</td>
<td>3788</td>
<td>3770</td>
<td>3960</td>
<td>3970</td>
</tr>
<tr>
<td>Egypt</td>
<td>3276</td>
<td>3340</td>
<td>4000</td>
<td>4000</td>
<td>3850</td>
</tr>
<tr>
<td>Iran</td>
<td>3294</td>
<td>3297</td>
<td>3350</td>
<td>3400</td>
<td>3500</td>
</tr>
<tr>
<td>EU-27</td>
<td>2911</td>
<td>3185</td>
<td>2925</td>
<td>3100</td>
<td>3150</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2207</td>
<td>2700</td>
<td>3400</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Nepal</td>
<td>2993</td>
<td>3016</td>
<td>2909</td>
<td>2912</td>
<td>2925</td>
</tr>
<tr>
<td>Madagascar</td>
<td>2400</td>
<td>2499</td>
<td>2615</td>
<td>2838</td>
<td>2838</td>
</tr>
<tr>
<td>Other</td>
<td>37159</td>
<td>37059</td>
<td>38171</td>
<td>39745</td>
<td>40892</td>
</tr>
<tr>
<td>World Total</td>
<td>418096</td>
<td>426165</td>
<td>435869</td>
<td>439370</td>
<td>449290</td>
</tr>
</tbody>
</table>


*2010 number is USDA Forecast.
(c) Rice as a differentiated product

In terms of product differentiation, rice is categorized into four main types, namely *Indica*, *Aromatic*, *Japonica*, and *Glutinous*. In 2009, long-grain *Indica* rice dominated global rice trade with a 75% share. Long-grain *Aromatic*, such as Thai’s Jasmine and India’s Basmati, accounts for a 12%-13% share. Short and medium *Japonica* accounts for around a 10% share of global trade. *Glutinous* accounts for the small remainder. The *Aromatic* rice usually sells at a premium to *Indica* to reflect demand from higher income countries. *Indica* rice is popular in the Middle East, East and Southeast Asia, and Africa. *Japonica* rice is preferred in East Asian countries, the Caribbean, and Eastern European (see Rice:Background, 2009, Bashir, 2002).

(d) Thin market

Although rice is traded globally, rice trade is traditionally viewed as a “thin market” due to low trade volume compared to production volume. This is an inherent characteristic of rice markets when compared to other commodity markets (see Siamwalla & Haykin, 1983, Slayton, 2009). Compared to other commodities, in the 2009/10 marketing year, the average volume of trade per production is only 7% for rice, compared to 19% for corn, and 28% for wheat (see figure 6). Not only is the volume of rice trade thin, but only a few countries have export capacity to impact rice trade. Table 1 shows that the largest rice producer in the world by volume is China, but the equally large share of domestic consumption leaves little to export (see Table 2). Indonesia and Bangladesh are a similar story. Based on 2009/10 data, the top five exporting countries by volume are Thailand, Vietnam, Pakistan, the United States, and India (see Table 3). Altogether, five countries export 81% of total international rice trade volume. The fact that few players control so much trade volume makes a case of collusion seem plausible. Nonetheless, studies of market power in the global rice trade seem to suggest otherwise. Karp & Perloff (1989) found that the oligopoly model fits well with the data, but that the degree of market power is low, and closer to competitive equilibrium than to collusion. More recent literature, accounting for rice differentiation (Bashir, 2002), also found that modeling global rice in a
Bertrand equilibrium model is the better representation compared to a collusion model, as the conjecture variation suggests that market behavior is closer to competitive than collusive 19.

A low degree of market power does not imply that the market functions efficiently. A thin market by itself could pose a big challenge, since we have already witnessed that an abrupt change in tradable supply conditions could create an upswing of price volatility. India’s export restrictions on non-basmati rice and Vietnam’s ban on rice exports to calm domestic food price pressure in 2008 coincided with triple-fold increases in international rice prices leading to a record-setting $1,000 U.S dollars in all major export markets, (see Appendix). Surging rice prices will increase nations’ food price inflation, as they filter through to consumers.

Figure 10 Volume of trade per production (based on weight)

Source: Data from Foreign Agriculture Service and Author’s calculation.

19 Recall that the Bertrand equilibrium represents the case of low market power. For a perfectly substitute product with two players, both would use marginal cost pricing.
Table 9 Rice Exports ranked by country on a milled basis (Unit in Thousand Metric Tons)

<table>
<thead>
<tr>
<th>Exports</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td>9557</td>
<td>10011</td>
<td>8570</td>
<td>9500</td>
<td>10000</td>
</tr>
<tr>
<td>Vietnam</td>
<td>4522</td>
<td>4649</td>
<td>5950</td>
<td>5750</td>
<td>5800</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2839</td>
<td>3000</td>
<td>3000</td>
<td>3300</td>
<td>3600</td>
</tr>
<tr>
<td>United States</td>
<td>2886</td>
<td>3305</td>
<td>3011</td>
<td>3303</td>
<td>3529</td>
</tr>
<tr>
<td>India</td>
<td>5740</td>
<td>4654</td>
<td>2090</td>
<td>2200</td>
<td>2500</td>
</tr>
<tr>
<td>China</td>
<td>1340</td>
<td>969</td>
<td>783</td>
<td>850</td>
<td>900</td>
</tr>
<tr>
<td>Cambodia</td>
<td>450</td>
<td>500</td>
<td>800</td>
<td>850</td>
<td>850</td>
</tr>
<tr>
<td>Uruguay</td>
<td>734</td>
<td>778</td>
<td>987</td>
<td>715</td>
<td>815</td>
</tr>
<tr>
<td>Argentina</td>
<td>452</td>
<td>443</td>
<td>554</td>
<td>625</td>
<td>700</td>
</tr>
<tr>
<td>Burma</td>
<td>31</td>
<td>541</td>
<td>1052</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>Brazil</td>
<td>242</td>
<td>550</td>
<td>569</td>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>Egypt</td>
<td>1203</td>
<td>750</td>
<td>550</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td>Guyana</td>
<td>250</td>
<td>210</td>
<td>210</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Japan</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>EU-27</td>
<td>148</td>
<td>152</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Paraguay</td>
<td>67</td>
<td>79</td>
<td>125</td>
<td>163</td>
<td>127</td>
</tr>
<tr>
<td>Russia</td>
<td>12</td>
<td>21</td>
<td>90</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Ecuador</td>
<td>161</td>
<td>90</td>
<td>15</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Peru</td>
<td>20</td>
<td>20</td>
<td>80</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Australia</td>
<td>166</td>
<td>36</td>
<td>15</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>Other</td>
<td>435</td>
<td>253</td>
<td>273</td>
<td>241</td>
<td>197</td>
</tr>
<tr>
<td>World Total</td>
<td>31455</td>
<td>31211</td>
<td>29064</td>
<td>29817</td>
<td>31483</td>
</tr>
</tbody>
</table>

Source: USDA Estimates. Foreign Agricultural Service
*2010 number is USDA Forecast.
Table 10 Rice Imports ranked by country on a milled basis (Unit in Thousand Metric Tons)

<table>
<thead>
<tr>
<th>Imports</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td>1800</td>
<td>2570</td>
<td>2600</td>
<td>2200</td>
<td>2500</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1500</td>
<td>1800</td>
<td>1750</td>
<td>1800</td>
<td>1900</td>
</tr>
<tr>
<td>Iran</td>
<td>1500</td>
<td>1550</td>
<td>1470</td>
<td>1300</td>
<td>1500</td>
</tr>
<tr>
<td>EU-27</td>
<td>1340</td>
<td>1568</td>
<td>1339</td>
<td>1350</td>
<td>1350</td>
</tr>
<tr>
<td>Iraq</td>
<td>613</td>
<td>975</td>
<td>1089</td>
<td>1100</td>
<td>1150</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>958</td>
<td>961</td>
<td>1166</td>
<td>1049</td>
<td>1100</td>
</tr>
<tr>
<td>Malaysia</td>
<td>886</td>
<td>799</td>
<td>1039</td>
<td>1070</td>
<td>1020</td>
</tr>
<tr>
<td>Cote d'Ivoire</td>
<td>920</td>
<td>845</td>
<td>800</td>
<td>860</td>
<td>900</td>
</tr>
<tr>
<td>South Africa</td>
<td>795</td>
<td>1030</td>
<td>580</td>
<td>800</td>
<td>900</td>
</tr>
<tr>
<td>Japan</td>
<td>675</td>
<td>597</td>
<td>656</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>Senegal</td>
<td>675</td>
<td>820</td>
<td>683</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>United States</td>
<td>653</td>
<td>759</td>
<td>610</td>
<td>635</td>
<td>667</td>
</tr>
<tr>
<td>Brazil</td>
<td>732</td>
<td>422</td>
<td>675</td>
<td>950</td>
<td>650</td>
</tr>
<tr>
<td>Mexico</td>
<td>594</td>
<td>582</td>
<td>588</td>
<td>600</td>
<td>650</td>
</tr>
<tr>
<td>Cuba</td>
<td>574</td>
<td>652</td>
<td>463</td>
<td>565</td>
<td>550</td>
</tr>
<tr>
<td>Vietnam</td>
<td>450</td>
<td>300</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>348</td>
<td>399</td>
<td>395</td>
<td>400</td>
<td>410</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>769</td>
<td>2047</td>
<td>602</td>
<td>90</td>
<td>400</td>
</tr>
<tr>
<td>Guinea</td>
<td>230</td>
<td>175</td>
<td>150</td>
<td>330</td>
<td>375</td>
</tr>
<tr>
<td>Mozambique</td>
<td>335</td>
<td>450</td>
<td>270</td>
<td>350</td>
<td>375</td>
</tr>
<tr>
<td>Other</td>
<td>11883</td>
<td>10083</td>
<td>9734</td>
<td>9831</td>
<td>10370</td>
</tr>
<tr>
<td>Unaccounted</td>
<td>3225</td>
<td>1827</td>
<td>1905</td>
<td>2637</td>
<td>2816</td>
</tr>
<tr>
<td>World Total</td>
<td>31455</td>
<td>31211</td>
<td>29064</td>
<td>29817</td>
<td>31483</td>
</tr>
</tbody>
</table>

*2010 number is USDA Forecast.
Figure 11 Rice Yield (rough basis) metric ton per hectare

Source: Data from the Foreign Agriculture Service and Author’s calculation.