The Global Food Price Crisis and China-World Rice Market Integration: A Spatial-Temporal Rational Expectations Equilibrium Model

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Abstract

In this paper, we examine how China, the world's largest rice producer and consumer, would affect the international rice market if it liberalized its trade in rice and became more fully integrated into the global rice market. The impacts of trade liberalization are estimated using a spatial-temporal rational expectations model of the world rice market characterized by four interdependent markets with stochastic production patterns, constant-elasticity demands, expected-profit maximizing private speculative storers, and government stockpiling authorities. The results show that full entry by China into the world rice market will substantially reduce and stabilize the world rice price, reducing the risk faced by major importers, particularly price spikes caused by restrictive trade policies implemented by major exporters.

Key words: world rice market, China's integration, export bans, government stockpiling

1. Introduction

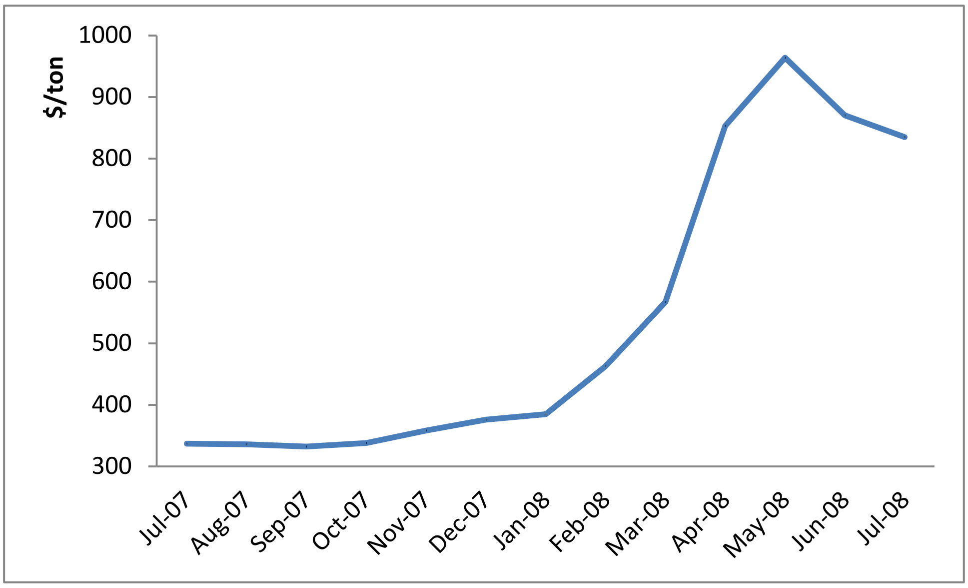
With the world population surpassing seven billion in 2012, food security is once again emerging as a major issue in development economics. Producing adequate supplies of food at a reasonable price is an important issue to everyone, especially those in poverty. The poor spend as much as 40 percent of their income on staple foods and large food price increases, such as those experienced during the recent World Food Price Crisis, have been a severe blow to their purchasing power (FAO, 2011). The World Food Price Crisis also has also created difficulties for many governments, leading to financial crises and social unrest (Lagi et al, 2011).

Rice is one of the world's three major cereals. It is heavily consumed by the populations of Asia, Caribbean, Middle East and Africa. Since large proportions of the population in these countries are living under the poverty line, keeping a stable rice price is of great importance.

The World Food Price Crisis in 2007-8 caught most countries unprepared. As shown in Figure 1, in 2008, the price of Thai White 100% B Second Grade, the benchmark for the world rice price, more than doubled in the five months between January and May, reaching a peak of $963/ton.

The sudden price increase particularly hurt the poor in developing countries. FAO estimates that, mainly as a result of high food prices, the number of chronically hungry people in the world rose by 75 million in 2007 to reach 923 million (FAO, 2008).

Figure 1 Export Prices for Thai White 100%



From: FAO Rice Market Monitor July 2008

Governments responded to the food crisis through a number of measures. Many major rice exporters, including India, Vietnam and Pakistan, implemented export restrictions to limit the increases in the domestic rice price (Childs & Kiawu, 2009). The export restrictions, in turn, stimulated panic buying by several large importers in Asia, Middle East and North Africa. Countries such as the Philippines, Indonesia, Nigeria and Iran sharply reduced or eliminated rice import tariffs to encourage supply and moderate domestic food price inflation. Other measures included administrative price controls and increased spending on safety net programs for the poor (FAO, 2008).

A number or researchers have argued that low global rice stocks contributed heavily to the large price spikes (Childs & Kiawu, 2009; Bobenrieth et al, 2012; Lilliston, 2012; Momagri Agency, 2012). These findings have stimulated interest in establishing domestic and international rice reserves in order to reduce excessive price volatility in the global market as well as to secure source of food for the safety net programs. The Association of Southeast Asian Nations (ASEAN) has discussed the establishment of an East Asia Emergency Rice Reserve (EAERR) with its largest rice trading partners, Japan, South Korea and China (ADB, 2011). It was also proposed that vulnerable countries in the Middle East and North Africa (MENA) region should cooperate and establish a multilateral grain reserve to ensure food security in the face of unexpected instabilities in supply and demand (Wright & Cafiero, 2011).

Despite of the profound impacts of the 2007-8 food price spikes on the world market, China, one of world's largest rice producers and consumers, was not heavily affected. When the benchmark price for rice in international market almost tripled during May 2007 and May 2008, the nominal domestic price of rice in China rose by only 9% for japonica and 12% for indica rice from May 2007 to May 2008 (Fang, 2010).

Chinese policies of grain self-sufficiency, maintenance of large buffer stocks, and insulation from world markets all have contributed to stable domestic food price in China during the 2007-8 World Food Price Crisis. China has consistently kept grain stocks proportionately much larger than the rest of the world in order to insure against domestic shortages. Most rice consumed in China is supplied by domestic production and rice traded in the world market accounts for only a small proportion of China's rice production and consumption, insulating the domestic rice market from the volatile global market (Lilliston, 2012).

Given the size of the Chinese rice market, its integration with the global rice market through expanded trade could have a profound impact on international rice prices and price volatility and, more generally, on international food security. China's integration into the world rice market might increase world price volatility because of the significant size of its rice market; or it might decrease world price volatility by serving as the world's buffer stock of grain.

In this paper, we develop a stochastic spatial-temporal rational expectations model of the international rice market that captures supply, demand and stockpiling dynamics of China and rest-of-world, as well as interregional trade flows and trade policy interventions. With the model, we assess the potential impacts of China's entry to the world market on rice price levels and volatilities in other major players' domestic markets.

In the next section, we discuss the structure of world rice market and the characteristics of China's rice market. In the subsequent section, we formulate a model of the world rice market that explicitly captures supply, demand and stockpiling of China and other major players in the world rice market. In Section 4, we analyze the impact of China's integration on world rice price volatility, under different assumptions regarding the rice stockholding and trade policies of other important rice exporters and importers. In Section 5, we summarize our conclusions and discuss directions for future research.

2. Literature Review

2.1 Global Rice Market

Rice is a vital source of calories of much of Asia, Latin America, the Caribbean, the Middle East and North Africa. Developing countries account for 95% of global rice production, with China and India responsible for nearly half the world output (FAO, 2003). Nine out of the top ten rice producing countries are in Asia. Major rice producers are also typically the major rice consumers.

The global rice market is thin and highly concentrated. Most rice produced is consumed domestically and only about 5%-6% of rice produced is traded in the international market. The largest five exporters – Thailand, India, Vietnam, Pakistan and the United States – accounted for more than 80% of world rice exports in 2012[1]. While few countries export rice, numerous countries in various areas import it. Major rice importers include the Philippines, Indonesia, Malaysia, Nigeria, Iran, Saudi Arabia and various African and Persian Gulf countries.

Since rice is considered to be a strategic staple food by many governments, its international trade has been subject to various controls and interventions. Given the limited trade volume and the substantial market power of major exporters, the global rice market is extremely vulnerable to shocks in production, consumption, stockholdings, and trade policies of major players in the market.

2.2 China's Rice Market

China is world's largest producer and consumer of rice. Rice production accounts for nearly half of total grain production in China. Since rice production demands a large amount of water during the growing season, it is generally grown as a wetland crop in flooded fields in South China and mostly consumed by the population in that area.

China's rice market historically has been strictly controlled by the government. However, the market has been gradually liberalized since the 1980s. Before the market reforms of 1978, urban residents in China relied on the government for their daily rice supply. Rural residents, on the other hand, were expected to grow their own rice and sell their surplus exclusively to the government. The food rationing system in urban

[1] Data available from USDA Foreign Agriculture Service

areas was abandoned after 1990s, allowing urban residents to buy rice in a free market (Rozelle, Park, Huang & Jin, 2000). In rural areas, the government procurement of surplus rice is no longer mandatory and rice exchange, which previously was controlled by state monopolies, has shifted to individuals and private enterprises (Sicular, 1995). The liberalization of China's domestic grain market has been a significant success: production increased, domestic trade expanded and grain flow patterns changed. The market also became more competitive and integrated (Rozelle, Park, Huang & Jin, 2000).

Although the private sector now plays a significant role in the Chinese domestic rice market, the export and import of rice continues to be closely controlled by the government through export quotas and import tariffs and quotas. Annual rice export quotas are typically exclusively decided by the central government and a system of state trading for rice exports has been established (Dawe, 2010). SinoGrain, a state-owned company, is the only rice exporter and private firms are not allowed to sell rice directly in the international market. Contrary to rice exports, qualified Chinese private enterprises can import rice, but the volume of import is restricted. Generally, the majority of imported rice is high quality japonica rice from neighboring countries and sold in large cities such as Beijing and Shanghai.

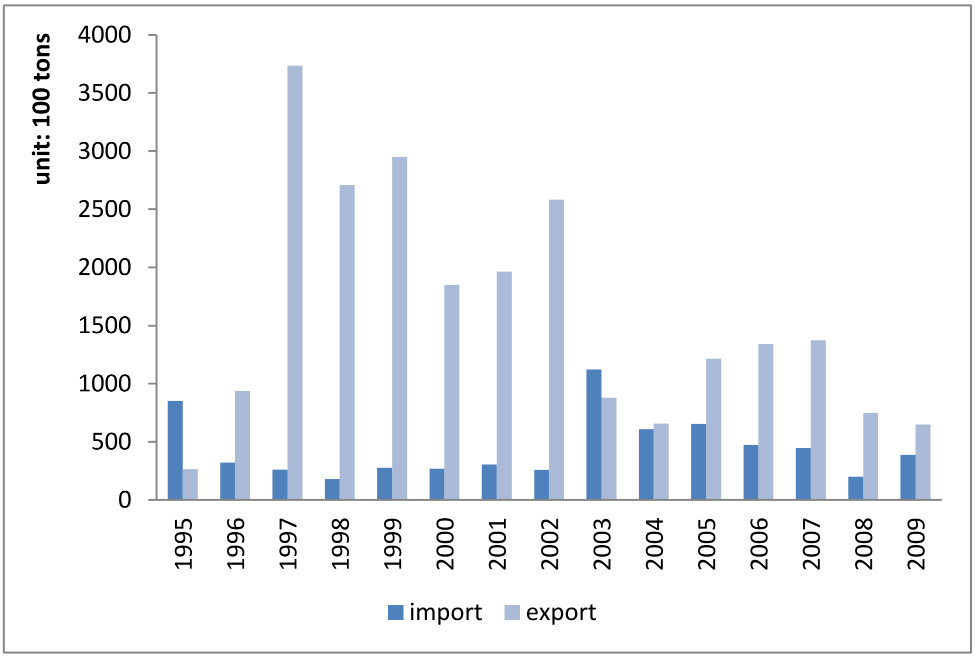
Although China is the world's largest producer and consumer of rice, it has never been a major player in global rice market due to Chinese government grain self-sufficiency policies. In 2009, China exported 790 thousand tons of rice, less than 1% of the country's total production in that year and only a very small proportion of the global rice trade volume of 30 million tons. In 2012, the rice import quota is 5,320 thousand tons, only 3.8% of the annual domestic consumption. As is shown in Figure 2, China's exports and imports fluctuate, but remain an insignificant portion of amounts traded in the world market.

The Chinese government holds a huge grain buffer stocks as insurance against catastrophic crop failure or market disruptions that could threaten China's grain supply. Keeping a stable food price and ensuring a food supply has always been the priority of the government. In 2007–2008, China's rice stock accounted for 53% of global rice stocks. From 2004 to 2009, the ratio of ending stock to domestic utilization in China increased from 45% to 55% for rice, over three times as large as those for the rest of the world, highlighting the importance the Chinese government places on national food security. It is quite clear that the size of Chinese stocks could dramatically affect global rice price levels and volatility (Dawe, 2010).

Self-sufficiency in rice, strict international trade controls, and large rice reserves have combined to insulate China from price fluctuations in the international rice market. Figure 3 compares the nominal rice price in China's domestic market with the price of Thai white rice 100% B, which is generally used as the benchmark in world market, after adjusting for exchange rate from 1989 to 2009. As is shown in figure 3, the rice price in China's domestic market has always remained below prices in the global market and generally does not follow the trend of price volatilities in the international market, especially during the 2007–8 World Food Price Crisis. While the price of Thai white 100%

B rice increased by more than 90% in 2007-8, the price of Indica rice in China increased by only 12% and the price of Japonica rice increased by only 2%.

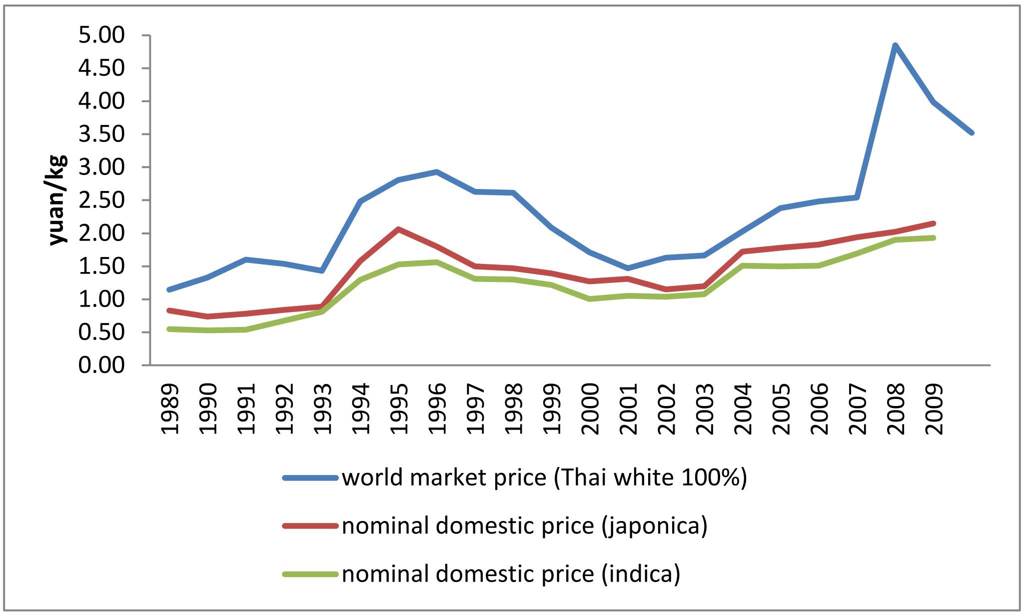
Figure 2 China's Annual Rice Export and Import (1998 - 2009)



From: USDA Foreign Agriculture Service

Figure 3 Annual Average Nominal Rice Price of China and International Market

(1989 – 2009)



From: FAO & USDA Economic Research Service

3. Market model

3.1 Model Description

The model presented in this paper is based upon Makki, Tweeten and Miranda's (1996) three-region world wheat market storage model. In our model, the global rice market consists of four distinct regions: China (c), Major Exporters (x), Major Importers (m) and the Rest of the World (w). Rice is produced and consumed in all four markets. Major Exporters and China may export to the World market, but never import[2]. No storage of rice is assumed for China and Major Exporters for the sake of simplicity. Major Importers may import from the World market and hold rice stocks to insure themselves against food crises, but never export. All trade flows through the world market, and, as such, there are no direct trade flows from China to Major Importers or from Major Exporters to Major Importers. Storage by Major Importers is undertaken by a government stockpiling authority that buys and sells at a prescribed price. Storage in the World market is undertaken by expected-profit-maximizing private storers who store whenever the expected inter-seasonal price spread is sufficient to cover carrying charges.

At the beginning of each period, there is a predetermined amount of rice A_i available in each region $i \in \{ c, x, m, w \}$. Availability of rice in the four markets in each period must satisfy the following material balance relations:

(1) $A_c = C_c + Y_c$

(2) $A_x = C_x + Y_x$

(3) $A_m = C_m + Z_m - Y_m$

(4) $A_w = C_w + Z_w - Y_c - Y_x + Y_m$.

Here C_i denote consumption and Z_i denote ending stocks in market i, Y_c denotes Chinese exports to the World market, Y_x denotes Major Exporter exports to the World market, and Y_m denotes Major Importer imports from the World market.

Consumption in each market is a constant elasticity function of the price P_i in market i:

(5) $C_c = \alpha_c P_c^{-\beta c}$

(6) $C_x = \alpha_x P_x^{-\beta x}$

(7) $C_m = \alpha_m P_m^{-\beta m}$

[2] Since China's export always exceeds import only except for the most recent two years, it is still assumed to be a net exporter in this model.

(8) $C_w = \alpha_w P_w^{-\beta w}$

Here β_i are the price elasticity of demand and α_i are scale factors.

Trade is driven by inter-market arbitrage profit opportunities satisfying the following equilibrium complementarity conditions:

(9) $0 \leq Y_c \leq \bar{Y}_c \perp P_w - P_c - \tau_c$

(10) $0 \leq Y_x \leq \bar{Y}_x \perp P_w - P_x - \tau_x$

(11) $0 \leq Y_m \leq \bar{Y}_m \perp P_m - P_w - \tau_m$

Here, $\bar{Y}_c$ denotes China's maximum export capacity, $\bar{Y}_x$ denotes Major Exporter's maximum export capacity, and $\bar{Y}_m$ denotes Major Importer's maximum import capacity. τ_c denotes the unit cost of transportation between China and the World market, τ_x denotes the unit cost of transportation between the Major Exporter market and the World market, and τ_m denotes the unit cost of transportation between the Major Importer market and the World market, all assumed constant[3].

Storage in Major Importers is managed by a government authority that is prepared to buy and sell stocks at a predetermined price subject to storage capacity constraints:

(12) $0 \leq Z_m \leq \bar{Z}_m \perp \bar{P}_m - P_m$

Here, $\bar{Z}_m$ denotes the storage capacities faced by the stockpiling authority in Major Importers and $\bar{P}_m$ denotes the predetermined prices at which the stockpiling authority is willing to buy and sell rice.

Storage in the World market is undertaken by expected-profit-maximizing private storers, leading to the following inter-temporal equilibrium complementarity condition:

(13) $0 \leq Z_w \leq \bar{Z}_w \perp \delta EP'_w - P_w - K$.

Here, $\bar{Z}_w$ denotes the rest of the World's maximum storage capacity, δ is the per-period discount factor, EP'_w is the expected price in the next period, and K denotes the constant unit cost of storage.

Availability of rice A'_i in market i at the beginning of the following period is new production $\tilde{Q}_i$ for China and Major Exporters and the sum of ending stocks this period Z_i plus new production $\tilde{Q}_i$ for Major Importers and Rest of the World:

(14) $A'_c = \tilde{Q}_c$

(15) $A'_x = \tilde{Q}_x$

[3] The notation $a \leq x \leq b \perp f(x)$ indicates a complementarity condition whose solution x must simultaneously satisfy $a \leq x \leq b$, $f(x) < 0 \Rightarrow x = a$, and $f(x) > 0 \Rightarrow x = b$. In economic applications, f(x) typically indicates the marginal profit from an activity x. In equilibrium the marginal profit may be negative only if x is constrained at its lower bound and may be positive only if x is constrained at its upper bound.

(16) $A'_m = Z_m + \tilde{Q}_m$

(17) $A'_w = Z_w + \tilde{Q}_w$

New production is assumed to be randomly and identically distributed over time, and independently distributed across markets and time. For each market i, we denote expected production by $\tilde{Q}_i$ and production volatility by σ_i.

Equilibrium in any period is characterized by four prices, four consumption levels, two storage levels, and three inter-market flows. Given the predetermined availabilities A_i, the thirteen variables are determined by the thirteen mixed-complementarity conditions (1)-(13). It follows that the market equilibrium prices are functions of the predetermined availabilities

(18) $P_i = P_i(A_c, A_x, A_m, A_w)$.

If the expected world price is "rational" in the sense that it is consistent with the formation of prices implied by the model, it must be that:

(19) $EP'_w = f(Z_m, Z_w) \equiv E_{\tilde{Q}} P_w(\tilde{Q}_c, \tilde{Q}_x, Z_m+\tilde{Q}_m, Z_w+\tilde{Q}_w)$.

Under this assumption, the expected price function f is known to exist and to be unique because it must satisfy a strong contraction in the complete metric space of bounded continuous functions (Miranda and Fackler). Unfortunately, the unique rational expected price function is not known a priori and cannot be derived analytically. It can, however, be computed numerically to any desired degree of accuracy using numerical methods.

3.2 Numerical Solution Strategy

The rational expected price function f can be derived by beginning with a guess $f^{(0)}$ as to what the expected price function might be. Given this provisional guess for the expected price function, it is possible in principle to solve equilibrium conditions (1)-(13) to compute the equilibrium world price for any set of availabilities A_i, allowing us to derive the function (18) that expresses the equilibrium world price in terms of availabilities. This in turn, allows us to compute an updated guess $f^{(1)}$ for the rational expected price function using equation (19). Given $f^{(1)}$, it possible to repeat the process to obtain another an updated guess $f^{(2)}$ for the rational expected price function. The process may be repeated indefinitely until the sequence of iterates converge to the one true rational expected price function f. Convergence is guaranteed by the same Contraction Mapping Theorem that is used to establish the existence and uniqueness of f. Although the expected price function f does not possess a known closed form expression, it may be computed to any desired degree of accuracy using standard projection methods. In particular, we construct a finite-dimensional approximation:

$$f(Z_m, Z_w) \approx \Sigma_{j=1,2,\ldots,n} c_j \phi_j(Z_m, Z_w)$$

where c_j are a set of coefficients to be determined and ϕ_j are selected cubic polynomial spline basis functions (Miranda and Fackler). A Matlab program that uses the CompEcon Toolbox is used to solve and simulate the rational expectations model of the global rice market.

3.3 Model Parameterization

3.3.1 Choice of Countries

Thailand, India, Vietnam, Pakistan, Egypt, and Brazil are included in the "Major Exporter" group since they are major rice exporters in the world rice market. All these countries except for Thailand implemented export restrictions during 2007-8 World Food Price Crisis that were blamed for increasing world rice price volatility. Although the Thai government did not restrict rice exports during the 2007–8 Crisis, Thai exporters speculated that rice prices would rise and thus made few sales despite adequate supplies.

The Major Importers include countries located in Middle East, North Africa and West Africa, which are highly dependent on world market for rice supply and were heavily affected by the 2007–8 Crisis. They include Iraq, Iran, Saudi Arabia, Nigeria, Senegal and Cote d'Ivoire.

The "Rest of the World" consists of countries that are also major players in world rice market, including several large rice importers in Asia such as Indonesia, Philippines, Malaysia and Bangladesh. The United States is also included in this group since it is world's fifth largest rice exporter.

3.3.2 Parameter Calibration

The parameters presented in table 1 are representatives of China, Major Exporters, Major Importers and Rest of the World rice market.

The demand elasticities β_i are taken from FAPRI's Elasticity Database[4]. We calculate the weighted average elasticity for each market based on the demand elasticity and consumption volume for each country included in that market. The scale factors α_i are calibrated by first detrending annual consumption data using OLS:

$$\log c_{it} = a_i + b_i t + \epsilon_i.$$

Then estimate consumption demand $\bar{c}_i$ in each market i for the base year for our simulations, 2013:

$$\log \bar{c}_i = a_i + b_i 2013.$$

Based on the constant elasticity consumption function, we have:

$$\alpha_i = \bar{c}_i \bar{p}_i^{\beta i}$$

4 The FAPRI Elasticity Database can be found at http://www.fapri.iastate.edu/tools/elasticity.aspx

where $\bar{p}_i$ is the prevalent price in market i relative to a normalized world rice price. Since exporters, importers, and ROW are linked through trade, we assume that for these regions $\bar{p}_i$ = 1. However, this assumption is not tenable for China, given that it historically has insulated its domestic market from the global rice market. Estimates from public databases suggest that average rice price in Chinese domestic market during 1990–2010 was 60% of world average price during the same period, so we set $\bar{p}_c$ = 0.6.

Production in each region $\tilde{Q}_i$ is assumed to follow a log-normal distribution. The standard deviation of production is estimated by the standard deviation of the error term of the OLS regression in which log production is the dependent variable and year is the independent variable.

Export capacity is represented by the maximum production of China and Major Exporters during 1960–2012 assuming that these exporters are able to export all the annual production to the world market. And import capacity is represented by the maximum consumption minus minimum production of importers and ROW during 1960 – 2012. None of these capacities, however, were found to be binding in our model simulations, so we effectively assume no export or import capacity limitations in our analysis.

The annual cost of storage is set to be 0.06 based on Brennan's estimate that the annual physical cost of storing rice in Bangladesh in 6% of the market value (Brennan, 2003). International shipping cost is set to be 0.2 based on a report by United Nations Economic and Social Commission for Asia and the Pacific, which estimates that the logistic cost of exporting rice from Thailand to the United States takes 19% of market value of exported rice (UNESCAP, 2011). The interest or discounted rate represents the opportunity cost of holding stocks and is set to 5% in the model.

Table 1: Base-Case Parameter Values

PARAMETER	SYMBOL	BASE-CASE VALUE
Relative Local Price – China	$\bar{p}_c$	0.6
Relative Local Price – Exporters	$\bar{p}_x$	1.0
Relative Local Price – Importers	$\bar{p}_m$	1.0
Relative Local Price – World	$\bar{p}_w$	1.0
Demand Scale Factor – China	α_c	132.34
Demand Scale Factor – Exporters	α_x	140.40
Demand Scale Factor – Importers	α_m	14.69
Demand Scale Factor – World	α_w	96.55
Demand Elasticity - China	β_c	0.10
Demand Elasticity – Exporters	β_x	0.18

Demand Elasticity – Importers	β_m	0.25
Demand Elasticity – World	β_w	0.11
Export Capacity – China	$\overline{Y}_c$	145
Export Capacity – Exporters	$\overline{Y}_x$	160
Import Capacity – Importers	$\overline{Y}_m$	15
Unit Transportation Cost – China	τ_c	0.20
Unit Transportation Cost – Exporters	τ_x	0.20
Unit Transportation Cost – Importers	τ_m	0.20
Storage Capacity – Importers	$\overline{Z}_m$	15
Storage Capacity – World	$\overline{Z}_w$	94
Stockpile Authority Price – Importers	$\overline{P}_m$	1.20
Average Production – China	$\overline{Q}_c$	139.27
Average Production – Exporters	$\overline{Q}_x$	160.82
Average Production – Importers	$\overline{Q}_m$	5.59
Average Production – World	$\overline{Q}_w$	92.74
Production Volatility – China	σ_c	0.03
Production Volatility – Exporters	σ_x	0.05
Production Volatility – Importers	σ_m	0.04
Production Volatility – World	σ_w	0.02
Unit Cost of Storage	K	0.06
Per-Period Discount Factor	δ	0.95

4. Results

4.1 Impact of China's Full Entry into the World Rice Market

The effect of China's full entry into the global rice market is shown in table 2. A Monte Carlo simulation is performed to estimate the steady-state means and variances of variables.

Under full trade liberalization, a significant portion of China's rice output would be exported to the world market, causing China's domestic price to rise by 17% as a result of decreased domestic availability. However, the volatility of China's domestic price would decrease.

Exports from Major Exporters fall by 15% and rice export volatility increases with China's entry, due to increases in the competitiveness of the world rice market. However, the price level and volatility in the exporters' domestic market decrease, since a proportion of rice that otherwise would have been exported to the world market is now sold in the domestic market.

Prices in the Rest of the World are lowered by 6% since the total amount of rice exported increases, but average ending global stocks fall by more than 50% since China's entry would reduce price volatility, reducing speculative storage profit opportunities.

The price of rice in the Major Importers decreases by 5% as a result of China's entry due to the increased availability of rice in the world rice market; their imports rise by 2%. The volatilities of price and import volume both slightly decrease since China's entry increases rice available to the world market and thus lowers the risk of supply deficits.

Table 2 Steady-State of Mean and Variation of Price, Trade and Stocks With and Without China

	Base Case: China Insulated, No Export Ban, No Importers' Storage		China Enters, No Export Ban, No Importers' Storage	
	mean	volatility	mean	volatility
Price - China	0.654	0.191	0.768	0.119
Price - Exporters	0.763	0.147	0.707	0.128
Price - Importers	1.163	0.147	1.107	0.128
Price - World	0.963	0.147	0.907	0.128
Exports - China	0	0	2.717	2.848
Exports - Exporters	12.971	2.719	11.032	3.742
Imports - Importers	8.583	0.496	8.751	0.461
Ending Stocks - Importers	0	0	0	0
Ending Stocks - World	0.533	0.888	0.255	0.663

4.2 Impact of China's Entry with Export Restrictions

During the 2007–8 World Food Price Crisis, many major rice exporters restricted exports to the world market in order to protect their own consumers from high prices and potential food shortages, either by completely banning exports or announcing increasingly high minimum export prices (FAO, 2011). For example, Vietnam, the second largest rice exporter, placed a ban on commercial sales of rice on late September, 2007. India, the third largest rice exporter announced a minimum export price (MEP) for all categories of rice except for its high quality premium basmati rice in early October 2007.

It continued to raise the MEP repeatedly during the rest of the year to effectively ban the rice export. Pakistan, the fourth largest rice exporting country, announced minimum export prices for different grades and types of rice. Other medium size exporters like Brazil and Egypt also implemented official rice export bans in 2008 to ensure adequate domestic grain supplies. These policies amplified market uncertainty and further destabilized the world rice price.

The impact of China's integration into a global market with rice export restrictions implemented by exporter governments on rice price and volatility is shown in table 3. For these simulations, exporters' export capacity $\overline{Y}_x$ is set to 0, indicating the extreme assumption that rice exports are completely banned by governments of major exporting countries and China and United States become the only two remaining large rice exporters .

Compared with average rice prices in the absence of export restriction, which are reported in table 2, average rice prices in the domestic market of major exporters drops from 0.763 to 0.487, or a 36% decrease. Price also becomes less volatile after imposing an export ban, which indicates that export restrictions could ensure supply to the exporters' domestic market and thus successfully lower the domestic price and protect the exporters from sudden rice price increases.

However, rice prices in exporting countries are stabilized domestically at the expense of a higher and more volatile rice price in the world market and among major importers in particular. If China is not involved in the global rice trade, consumers in major importing countries as well as in the rest of the world have to depend mainly on the United States for reliable rice supplies. The supply deficit brought about by export restrictions in other exporting countries pushes the rice price in the importers' market from 1.163 to 2.816, or a 142% increase with a much higher volatility. The rest of the world is also heavily affected as average price more than doubles from 0.963 to 2.616. The volume imported by Major Importers also drops by 33%, which indicates a risk of food deficit in that region.

China's entry into world rice market alleviates the supply shortage created by restrictions imposed by exporters and thus stabilizes market prices. After entering the world market with no export from major exporters, China becomes an important source of rice export and its trade volume more than triples as it replaces much of the demand previously met by the other major exporters. Since more rice is exported from China, the domestic price of rice in China increases significantly by 78% and becomes less stable. But importers and world market benefit from China's involvement, as price in importing countries drops approximately 50% from 2.816 to 1.568 and price in the world market decreases by 47% from 2.616 to 1.369, both with a much lower volatility.

Table 3 Steady-State of Mean and Variation of Price, Trade and Stocks With and Without China under Export Restrictions

	China Insulated, Export Ban Implemented, No Importers' Storage		China Enters, Export Ban Implemented, No Importers' Storage	
	mean	volatility	mean	volatility
Price - China	0.654	0.191	1.169	0.214
Price - Exporters	0.487	0.125	0.487	0.125
Price - Importers	2.816	0.327	1.569	0.214
Price - World	2.616	0.327	1.369	0.214
Exports - China	0	0	8.267	2.173
Exports - Exporters	0	0	0	0
Imports - Importers	5.765	0.354	7.564	0.48
Ending Stocks - Importers	0	0	0	0
Ending Stocks - World	0	0	0.067	0.156

4.3 Impact of China's Entry with Importer Stockpiling

Many rice importing countries announced plans to build up buffer stocks after the 2007-8 World Food Price Crisis. A central coordinated government rice buffer stock is believed to be able to respond more rapidly to the needs of the affected population and avoid speculative hoarding in the private sector in times of food emergencies.

In our dynamic model, we assume that a fixed protection price $\overline{P}_m$ is set by stockpiling authorities of Major Importers. Rice stock would be released to the market when price of rice in these major importing countries is higher than $\overline{P}_m$, and rice would be bought in by stockpiling authorities when market price is lower than $\overline{P}_m$.

The impact of China's entry to a global rice market with a common stockpile managed by governments of major importers on rice price and volatility is shown in table 4, where it is assumed that $\overline{P}_m = 1.2$.

Table 3 Steady-State of Mean and Variation of Price, Trade and Stocks With and Without China under Importers' Stockpiling Policy

	China Insulated, Export Ban Implemented, No Importers' Storage		China Enters, Export Ban Implemented, No Importers' Storage	
	mean	volatility	mean	volatility
Price - China	0.654	0.191	1.169	0.214
Price - Exporters	0.487	0.125	0.487	0.125

Price - Importers	2.816	0.327	1.569	0.214
Price - World	2.616	0.327	1.369	0.214
Exports - China	0	0	8.267	2.173
Exports - Exporters	0	0	0	0
Imports - Importers	5.765	0.354	7.564	0.48
Ending Stocks - Importers	0	0	0	0
Ending Stocks - World	0	0	0.067	0.156

Compared with the base case results presented in table 2, after establishing a government stockpile, the domestic price of rice of Major Importers slightly increases by 6% from 1.163 to 1.171. However, volatility drops dramatically from 0.147 to 0.086, which indicates a much more stable domestic rice market. The price level in the world market and Major Exporters stay essentially unchanged, but volatility of both decreases from 0.147 to 0.086, as the buffer stock of Major Importers reduces the possibility of panic buying in case of a food price crisis, and thus keeps a relatively stable price in the world market. The trends in these markets are consistent with the assumption that a government-managed rice stock is able to protect markets from sudden price hikes and large fluctuations.

China's entry into the world market raises the price level in its domestic market, but decreases the price in other three markets. Average prices of major exporters, importers and rest of the world drop by 6%, 4.7% and 5% respectively. However, domestic price volatilities increase, except for China.

Ending stocks of Major Importers increases dramatically by 40% from 8.756 to 12.307, which shows that major importers would purchase and store more rice after China's integration into the international rice market as a result of increased supply and lowered price. They would also experience less volatility in trade volumes and stocks.

5. Conclusion

This paper illustrates how China, the world's largest rice producer and consumer, would affect the international rice market if it liberalized its trade in rice and became more fully integrated into the global rice market. The impacts of trade liberalization are estimated using a model of the world rice market characterized by four interdependent markets with stochastic production patterns, constant-elasticity demands, expected-profit maximizing private speculative storers, and government stockpiling authorities. The major findings are summarized below.

First, China's entry generally amplifies an otherwise thin world rice market, effectively reducing the rice price level and volatility, both in the world market and in markets of other major importers and exporters.

Second, an export restriction implemented by major exporters destabilizes the global market, greatly inflating the world price level and its volatility. China's entry into the global rice trade in the presence of export restrictions has a much more dramatic effect than in the absence of export restrictions, alleviating the greater global supply deficit created by export restrictions, lowering prices and stabilizes the market to a greater degree.

Third, rice stock managed by major importers results in a more stable domestic rice price, but pushes up price levels both domestically and internationally. China's export of rice to the world market in the presence of importer stockpiling lowers the market prices of importers and ROW, while slightly increases the price volatility in these markets. China's involvement also enables importers to expand their stock, which ensures the food supply in these countries.

The model used in this model is subject to numerous limitations, many of which should be obvious, but some of which are more serious than others. Perhaps the most restrictive assumption used to build this model is that of purely exogenous production. Clearly, the amount of land devoted to rice production in different markets will be affected by changes in general rice price levels and volatilities. Also, official and private stocks in major exporting countries and China are not included in the model. By assuming stationarity of demand and supply, we also fail to consider the possibility that China could evolve into a rice net importer as incomes begin to grow. These extensions will be more fully explored in future work.

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