Food Policy and Food Security in India

Achieving Rice Price Stability

**Paper intended for India's Ministry of Commerce and Industry and Ministry of Agriculture.*

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*These are hypothetical clients.

Executive Summary

Food security has been a much debated topic in the economics community. Many economists believe that free trade is the right answer and government intervention in the food market simply exacerbates inefficiencies. The food crisis of late 2007- early 2008 brought this issue back to the forefront. At the height of the crisis, in March 2008, India and a number of other countries imposed export controls on rice and other staple food crops to curtail domestic prices and protect consumers at home.

Given the volatility in the rice market over the past two years, this paper examines the question of food security in India and attempts to decipher what would be the optimum policy for the Indian government to achieve rice price stability.

The food security constraint imposed in this paper is keeping the price of staple foods (rice) below a threshold level, above which there would be social unrest. We construct two models to illustrate the impact of government interventions in trade on the international price level of rice.

Our first model assumes the existence of perfect free trade in the world and runs a Monte Carlo simulation to compare the domestic rice price volatility in India if it remains closed to trade (autarky) or allows free trade. The results indicate that India would obtain lower rice price volatility and a lower probability of the price exceeding a threshold level under free trade than under autarky.

Our second model incorporates the imperfect nature of the current world rice market and allows for trade interventions by market participants. We run a Monte-Carlo simulation and conduct step-by-step analysis to examine the impact of Indian trade policy on world rice prices under different scenarios. In particular, we study the impact on prices if India imposes export restrictions before other countries, and if other countries impose export restrictions before India makes any intervention. We find that the international price rises when countries make trade interventions, and that the spikes are particularly significant when a large market player such as India intervenes.

Our simulations imply that under certain circumstances it may be necessary for India to impose export restrictions if other major participants are imposing such controls and driving up the world price. However, if Thailand and India (the two largest rice exporters) refrain from intervening, this keeps the world price stable *even if* other smaller market participants do intervene. Hence, while the first best option would be that no country intervenes, if this is not possible, India's second best option should be to stay out of the market as long as no major participant (in this case, Thailand) intervenes.

In light of India's intervention in the rice market in March 2008, which drove up world prices further, we believe the results of our models hold interesting policy implications that the Indian government may wish to consider next time there is a spike in world rice prices.

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I. Introduction and Motivation

In May 2008, average world rice prices were 104 percent higher than their level a year earlier, wheat prices were 54 percent higher, soybeans had climbed 76 percent and maize was up 60 percent.[1] The rise in food prices was unprecedented, and according to the World Bank would drive an estimated 100 million more people to hunger and deprivation.[2]

Although prices subsequently fell in the latter half of the year owing to good harvests and world recession, the debate on what factors led to the surge in food prices in early 2008 was heated. The International Food Policy Research Institute (IFPRI) declared that 30 percent of the rise in grain prices was due to biofuels. Other sources suggested that even this was an underestimate of how much prices had been impacted by biofuels.[3] One third of US corn is currently used for producing ethanol and about half of vegetable oil production in the EU goes towards producing biodiesel.[4] IFPRI estimated that a freeze on grain-based biofuels could lower maize prices by 20 percent and wheat prices by about 10 percent.[5] On the other hand, the US and EU argued that the higher food prices were a result of increased demand from developing countries such as India and China. Still others claimed that the price surge was because of a lack of food reserves across countries and the concentration of food production in the hands of a few large producers.[6]

In reality, it is likely that a combination of these reasons led to the rise in food prices. Droughts in major wheat-producing countries in 2005-2006, high oil prices, low grain reserves, a large increase in per capita meat consumption in developing countries and the use of grains to produce biofuels are all factors that probably contributed to the crisis.[7] The more interesting issue is that the crisis was made worse by the policies of many countries such as India to impose export restrictions on rice and grains in their attempt to curtail price pressures at home. This increased world prices further, tarnished the credibility of these countries as suppliers and damaged confidence in the world trading system. In fact, the FAO estimated that the 'food problem' was not one of supply at all—there was more than enough food in the world to feed everyone and with record grain harvests in 2007, supply was at least 1.5 times demand.[8] The problem was getting the food to the people who were starving because they were priced out of the market.

Taking the case of rice, India, Egypt, Vietnam, Brazil and Indonesia all put export restrictions on rice in early 2008, ranging from suspension of exports of certain grades of rice to complete bans on all rice exports. As a result, the world price of rice doubled and in some countries tripled in the first four months of 2008.[9] Moreover, only 7 percent of global rice production is traded internationally, so government interventions in the export and import markets for rice can have a tangible impact on supply and world prices.[10] As the second largest producer of rice in the world, India's actions in particular brought on a lot of criticism from the US and other trading partners.[11]

The question going forward is how governments should respond to such food crises, given the export restrictions and barriers that are put in place by key players. If all countries agreed to remove export and import restrictions on food, this would increase the stability of world food prices. According to IFPRI, it could have reduced prices by as much as 30 percent in 2007-2008.[12] The restrictions artificially lower the price of food in countries that impose them, discouraging the capacity of farmers to produce more and thereby increasing future food insecurity.

The market for food and farming of agricultural products is particularly interesting as it is marked by moral hazard and market distortions that prevent private players from responding to price signals in the way they do for other businesses.[13] In the case of an extreme event or crisis in the food market, private producers know that the government will not let people starve and will intervene in the market. In fact, governments often intervene in the food market and impose price controls even *without* a crisis. This presents a clear disincentive for private producers to stockpile ex-ante. As a result, there is not as much stockpiling of reserves as there would be if the market operated "normally". This was made clear by the lack of grain reserves observed across the board in the 2007-08 crisis. According to certain sources, there were less than 54 days worth of grain reserves, globally.[14]

So what should governments do to ensure food security? Apart from imposing trade restrictions on food grains, one possible solution could be for governments to take on the task of physically stockpiling food and raising reserves, rather than leaving this to private players. Another policy option could be to buy food on the futures market—although this may be a controversial route: some attributed part of the reason for high grain prices in 2008 to excessive speculative activity on futures markets for food crops. Finally, governments could subsidize the production of staple crops such as rice and wheat to incentivize farmers to enter these sectors and build food security at home. While this last option may be contrary to basic trade theory on comparative advantage, food insecurity (and the risk of major producers closing up their markets) is too important an issue to leave this alternative unexplored.

This SYPA examines the question of food security from the perspective of the Indian government. India's food security and food policy is extremely relevant at both the international and domestic levels. Internationally, India is the world's second largest producer of rice, wheat, groundnuts and sugarcane, as well as many fruits and vegetables. India's trade policies on food crops are therefore pertinent to the rest of the world in so far as these policies can impact world prices and supply (as in the case of rice in 2008). Domestically, India is a land of over a billion people, with approximately 290 million living below the poverty line; the large numbers of urban and rural poor make food policy an absolutely critical issue. A rise in food prices can lead to a high degree of social unrest and starvation among the poorest.

For the purposes of this paper, we define food security as keeping the prices of staple foods (rice and wheat) below a certain threshold level, above which, we hypothesize, there would be social unrest. With this definition in mind, we consider what policy measures the Indian government should take to ensure food security. How can the government reduce food price volatility and keep staple food prices within a socially sustainable threshold? To answer this question, we examine different policy alternatives: government stockpiling of food; subsidization of staple food farmers; imposing export/import restrictions on food grains; and finally, signing a collective international agreement not to impose any trade restrictions on food but instead using free trade and a combination of domestic price policies to attain food security.

Our SYPA has two sections. First, assuming a collective agreement were possible between countries not to impose any restrictions on agricultural commodities, we examine whether it would be in the interest of India to participate in this agreement. In other words, we examine whether free trade among all countries would be the best option for India (and other countries) to ensure food security and reduced price volatility. Second, in the absence of an international agreement to ban trade restrictions on food, we examine what policy approach the Indian government should take to ensure food security on the presumption that other countries may impose restrictions. Would it still be in the interest of India to keep its borders open and use other policies rather than trade restrictions on grains to achieve food security?

We attempt to study these scenarios by constructing two basic models that will be described in detail further ahead.

II. Policy History and Background

A. Indian Agricultural Policy: 1947-2008

Following independence in 1947, India essentially pursued a policy of attaining self-sufficiency in food, boosting production of rice and wheat in particular (the two crops together account for about 80 percent of grain production in India).[15] After 1965, the introduction of high yielding varieties (HYV) of food grains, increased use of fertilizers and pesticides, and improvements in irrigation technologies resulted in a huge jump in India's agricultural productivity, and came to be known as the Green Revolution (GR) in Indian agriculture.[16]

Between 1970 and 1990, India experienced an increase in yields of approximately 65 percent.[17] Total factor productivity (TFP) growth also accelerated during this period, with some empirical studies indicating that technological change accounted for as much as one-third of agricultural output growth. Although crop prices were decreasing in this period up to 1990, high yields and productivity were enough to incentivize farmers and ensure profitability.[18]

Post-1990, however, many studies find that TFP growth in agriculture has been on the decline, with marginal productivities decreasing due to slower technological change. In fact, today, India's average crop yields for a number of crops are well below the world averages.[19] One possible reason for this turn around in the 1990s is that once the initial explosion in yields and technology provided by the GR slowed down, rather than continuing to invest in technological improvement, the Indian government instead opted to heavily subsidize farmers. Thus, farming profitability in the 1990s came as a result of heavy input subsidies (for fertilizer, power, water) and rising support prices for farmers rather than from increases in productivity.[20] Not only did this result in a burgeoning subsidy bill for the Government, but it also came at the expense of fewer public investments in agricultural infrastructure, irrigation and research. Hence, the Indian government's agricultural policy in the 1990s may have actually *contributed* to the drop in farm productivity during this period.

By 2002-2003, the Government's subsidy outlays for agriculture amounted to about $12 billion[21] and the administration faced "a perverse combination of high domestic prices, slowed growth in production and consumption, record grain surpluses, and soaring budgetary costs."[22] A key reason for this was the continual increase in minimum support prices paid to farmers in the post-1990 period.[23] The rising producer support prices would eventually translate to higher retail prices faced by consumers, resulting in a slowdown in consumption and hurting the same low-income masses the Government aimed to help. In order to further clarify this situation, it is useful to describe the mechanisms and channels through which the Indian government administered its food policy during this period and the main objectives of the policy.

The fundamental objectives of Indian food policy have long been two-sided—on the one hand, the Government aims to provide low-priced food to poor consumers; on the other, it tries to support farmers by guaranteeing them minimum support prices for their produce.[24] The Government works through two main channels to administer its food policy: the Food Corporation of India (FCI) is the organization responsible for procuring food grains from farmers at the **minimum support price (MSP)**, and also for transporting and storing these grains; the

Public Distribution System (PDS) is the body in charge of delivering food grains to low-income consumers at subsidized prices.[25]

The Government's producer support policies have played a role in buttressing the growth of India's grain output since the advent of the Green Revolution. However, in the 1970s and '80s, it was higher yields that ensured farming profitability as MSPs and consumer prices for grains actually declined in real terms during this period.[26] The situation changed in the 1990s when in the absence of yield gains, the MSPs paid to farmers were constantly escalating and these higher prices eventually passed through to consumers both in the retail market as well as through the PDS.[27] As a result, production of grain increased but consumption fell, poor consumers' access to food was impeded, and the Government's grain stockpiles began to swell. This situation was unworkable not only because of high storage costs to the Government and the fact that India lacked the facilities to properly store so much grain, but most scandalously because while these buffer stocks lay rotting, people were starving! According to certain reports, by July 2001, India's grain stocks amounted to about 62 million tonnes and the cost of storing all this grain represented a high proportion of the Government's food policy bill.[28]

In order to understand why MSPs rose through the 1990s and the vicious cycle the Government found itself in at the turn of the millennium, it is important to examine Indian agricultural policy in the context of India's overall economic policy in the '90s. Post-independence, a host of protectionist measures (including tariffs, licenses, quotas and bans) made India one of the world's most closed economies in terms of agricultural and non-agricultural products alike. In 1991-93, India began a process of liberalizing its closed regime by removing some of these restrictive measures and opening up its borders to trade.[29] Agricultural liberalization also began at this time, although complete elimination of quantitative restrictions (QRs) in agricultural goods was not achieved until 2001.[30]

Liberalizing trade set India on a path towards higher growth, with per capita incomes rising through the 1990s, and GDP growth averaging 6 percent in the past two decades. A consequence of the higher per capita income was "the strengthening and diversification of food demand."[31]

According to a 2006 USDA Research report, higher incomes led to a surge in demand growth for "fruits, vegetables, fats and oils, and animal products such as dairy, poultry, and eggs" rather than simply for rice and wheat.[32] This in itself was probably enough to require a revamping of Indian agricultural policy, which had historically focused solely on the two staple grains.

Moreover, the gradual removal of QRs on grains beginning in the mid-1990s left the Indian market vulnerable to world prices for these grains. In 1995-96, Indian exporters benefitted as world prices for grains were relatively high. However, by the late 1990s, world prices dropped and the Government faced pressure to compensate farmers for this drop in prices by increasing MSPs.[33] Thus, MSPs—which were usually set based on cost of production estimates provided by India's Commission on Agricultural Costs and Prices (CACP)—began an upward trend (in real terms) in the 1990s that was based more on politics than on economics or market conditions.[34] The political economy element played a particularly pertinent role here because at the same time that India was making baby steps towards opening up its hitherto heavily protected and closed agricultural market, the country began a period of coalition governments where the farm lobby gained influence and power.[35]

The consequence of rising MSPs through the 1990s, as stated earlier, was an increase in consumer prices that dampened consumption and led to bigger and bigger government stockpiles of grain (as the Government bought all the surplus grain farmers were unable to sell on the market) as well as mounting budgetary costs. The heavy government intervention and involvement in the grain market also served to crowd out and disincentivize private investment in agriculture.[36] As a result, both public and private investment in agricultural infrastructure, technology, research and development has been relatively low over the past two decades, especially when compared to investment rates in India's manufacturing and services sectors. According to a 2006 USDA report, "[w]hile the investment share of GDP for the economy as a whole averaged about 28 percent in 1998-2000, the investment share of agricultural GDP was about half that."[37] This trend has continued over the past decade.

In an address on December 2008, Sharad Pawar, India's Minister of Agriculture, Consumer Affairs, Food and Public Distribution, commented that the share of agriculture in India's GDP has shrunk from 35 percent in 1990-1991 to 18 percent in 2007-2008; however, "population dependence on agriculture has not reduced in the same proportion, and is currently about 60 percent."[38] As a result, he stated that per capita income in the agricultural sector has been relatively low. Given the low levels of investment in Indian agriculture mentioned earlier, these statistics are not surprising.

In terms of output of food grains, the Minister mentioned that 2007-2008 was a record year for India, with grain production increasing to an all-time high of 230.67 million tones.[39] Furthermore, he added that by the end of the 11th five year plan (2007-2012), the country was expected to be producing "about 240 million tonnes of foodgrains against the assessed domestic requirement of about 234 million tonnes."[40] The Minister was therefore quite optimistic on the issue of food security and made the following comment on the Government's grain stockpiles in 2008:

> "We have procured a record 50 million tonnes of foodgrains (27.5 million tonnes of rice and 22.5 million tonnes of wheat) this year. Even after keeping the minimum buffer stock, we have enough foodgrains to intervene in the market to keep prices at a reasonable level. We have also decided to create a Strategic Reserve of 5 million tonnes of foodgrains…out of our domestic procurement. This is in addition to the buffer stock held by FCI every year."[41]

Having made this comment on comfortable buffer stocks, however, the Minister continued to say that export bans had been put in place for wheat and certain varieties of rice in 2008 in order to ensure national food security. He ended his speech by stating that "[t]he intention is to make our agriculture grow faster and find new markets for our products."[42]

The question that begs to be asked then is this: if the Indian government has such vast grain stockpiles, and therefore the ability to intervene in the domestic market to moderate prices, why

did India impose an export ban on rice and wheat in 2008? This action not only prevented Indian exporters from earning valuable income but also caused major damage to India's reputation on the global trading system. While we can surmise that the Government's motivation was mostly political (to instill confidence in the nation that the Government was doing what was needed to ensure food security and stable prices), this paper examines whether putting a ban on exports was the best option for India from an economics perspective. Would such a ban help ensure more domestic price stability and lower prices, albeit at the cost of higher world prices, or would it be better for India going forward to keep its borders open to trade and allow exports in such a situation? Furthermore, does the answer change depending on whether *other* countries are simultaneously in a regime of intervention to block trade when prices are high? In this SYPA, we develop two economic models to examine these important policy questions. Based on our results, we recommend policy options for the Indian government to pursue in the future and discuss the political feasibility of these options.

For the purposes of this SYPA, we have chosen rice as our commodity of focus. Before proceeding with the methodology of our models, the next sections briefly summarize the run up to the Indian ban on rice exports in 2008 and give a brief overview of Thailand's rice intervention history.

B. Indian Food Riots and Rice Export Ban: 2007-2008

In October 2007, riots broke out in India's state of West Bengal as hundreds of hungry villagers accused government food distributors in the state of "stealing and hoarding food meant for the poor."[43] The riots came on the back of spiraling grain prices and a central government investigation that revealed that "most rural poor in eastern and northern India were not getting regular supplies of the [subsidized] food to which they were entitled" due to widespread corruption in the public food distribution system (PDS).[44] An estimated 28 percent of the rural population of West Bengal lives below the poverty line and the poor masses accused grain distributors of "diverting grain to regular markets at huge premiums."[45] The Hindustan Times newspaper reported another government panel had found that "53 percent of wheat meant for the poor in India's capital, New Delhi, was diverted to open markets."[46] The rioters in ransacked

shops as well as homes of distributors, and several hundred people were injured in the clashes. West Bengal was not alone: social unrest spread across many states in northern India.

In the midst of these reports of rampant corruption in the PDS and increasing social strife, India faced rising grain prices and the pressure was on for the Government to take some action. On October 9, 2007, the Government announced a ban on all non-basmati rice exports. This, however, led to protests from rice exporters who argued "that the non-basmati rice category covered a whole gamut of premium varieties, not procured for the PDS."[47] Consequently, the Government lifted the blanket ban and replaced it on October 31, 2007, with a minimum export price (MEP) of $425 per tonne for all non-basmati rice exports (the MEP was later raised to $500 per tonne in December 2007).[48]

With further escalation in rice prices in the first few months of 2008, however, the Indian Government ultimately replaced the MEP with an outright ban on all non-basmati rice exports in March 2008.[49] Other countries such as Vietnam, Cambodia and Egypt also placed export bans on rice in March. As a result, the price of rice on the world market skyrocketed further. The fact that rice is a relatively thinly traded crop on the world market (only about 7-8 percent of total rice production actually trades on the global market) exacerbated the susceptibility of the world price to this supply shock.[50]

C. Thailand's Rice Policy History

Thailand is the world's largest rice exporter (accounting for 30 percent of world rice exports by volume in 2006) and did not restrict rice exports in the 2007-2008 rice price surge.[51] Historically, Thailand has not had a policy of placing quantitative restrictions on rice exports, but rather a policy of taxing rice exports heavily (this tax came to be known as the "rice premium").[52] Following World War II, Thailand's rice export tax became an increasingly important source of government revenue, at one point in 1965 accounting for as much as one-tenth of total government revenue.[53] Adverse distributional effects of the export tax on rural incomes became an issue of increasing concern over time, and the export tax rate was reduced throughout the 1970s and 1980s, until its complete suspension in 1986 (at a time of relatively

low international rice prices).[54] Since the 1986 suspension of the export tax, there have been a few instances where pressures for reintroduction have emerged, such as 1997 when there was a spike in rice prices in the wake of the Asian financial crisis.[55] However, despite these pressures, Thailand has thus far refrained from reintroducing the rice export tax and also from engaging in quantitative restrictions of any sort.

Given the preeminent size of Thailand's rice production and exports, it is the most major participant in the world rice market and its trade policies can have a significant impact on international price and supply. Hence, the importance of Thailand's non-interventionist rice trade policies and the ensuing implications for India and other players in the rice market should not be underestimated. As the second largest rice exporter, it may be worthwhile for India to take a cue from Thailand's rice policy. We will examine this further when we discuss the results of our second model.

III. Methodology

A. Overview

In this section, we aim to illustrate the impact of an export restriction on the price level of a commodity product (rice) using two different models. First, we employ a simple Monte-Carlo simulation model to demonstrate the impact on India's price stability of two polar regimes: autarky and absolute free trade. Based on our simulations, we estimate and compare the probabilities that India's domestic rice price will exceed a certain level under the two regimes. In the absolute free trade regime, we assume that no country, including India, imposes any restriction or subsidy on exports or imports, information is perfect, there are no transaction costs, and there is no material difference in the quality of rice produced and consumed in the world.

Although some of the assumptions we make for the absolute free trade situation are unrealistic, we believe the comparison of perfect free trade to autarky will be useful in highlighting what economic theory would predict about an export ban or any other form of trade intervention, and provide a good basis for us to start discussion of our second model.

The second model we employ is a multi-country model that shows the impact of potential actions taken by major exporters and importers of a commodity product on the international price level of the commodity and on the behaviors of other exporters and importers who participate in the same market. As we observed in several commodity markets in 2008, sharp price rises on the world market can be exacerbated by export restrictions imposed by exporting countries in an attempt to shield their domestic food prices from the international commodity boom. The action of these countries, in turn, induces counter-reactions by other market participants, such as further export restrictions and import subsidies, all of which drive prices even higher.

We use two approaches to demonstrate such interactions and their impact on the international rice price. First, we conduct a Monte-Carlo simulation on a simplified game among exporters and importers and assess how the trade policies of market participants affect the probability of the rice price exceeding a certain threshold level. Second, we analyze the same interaction among countries in a more detailed manner, using a step-by-step approach.

B. Perfect Free Trade Model – Autarky vs. Absolute Free Trade

1. Model structure

The objective of this simple model is to simulate the distributions of price levels given certain production shocks under two regimes: Indian autarky and absolute free trade. In developing this perfect free trade model for our analysis, we relied on a sample for partial equilibrium modeling by Vernon O. Roningen (1997) and simplified it[56]. Our model is structured as follows.

Price is determined at the equilibrium of demand and supply. The demand and supply curves take on the following functional forms:

$$Supply_t = C_s * P_{t-1}^{\varepsilon_s} + \text{random shock}$$

$$Demand_t = C_d * P_t^{\varepsilon_d}$$

Where

C_s: constant terms of supply

P_t: price at time t

ε_s: elasticity of supply

C_d: constant terms of demand

ε_d: elasticity of demand

Supply (production) quantity is determined by the price in the previous period <note: currently, it is set as the average in past years>, own price elasticity of supply, and random shocks. Demand quantity depends on the current price level and own price elasticity of demand. The current price and demand quantity are simultaneously determined so that the market clears.

We then employ a Monte Carlo simulation to estimate the distribution of price levels determined through this simple model, with the random shock term in the supply function as our input variable in the simulation[a]. Based on the distribution of potential price levels generated through the simulation, we can compare price volatility and the probability of prices exceeding a certain threshold level under autarky and absolute free trade.

For simulating the Indian autarky situation, we use Indian domestic data. For simulating absolute free trade, we use world data including production and consumption statistics on rice that is currently not traded in the international market (that is, production for domestic consumption).

2. Input variables

a) Supply function

The own price elasticity of supply is obtained for Indian domestic production and world production. For Indian production, we use 0.16, drawing on Srinivasan's estimate (2001)[57]. For world production, we have used the same elasticity of 0.16 for the sake of simplicity. We believe that rice production is largely inelastic to price in the short-term considering the difficulty in transforming a rice field to or from other purposes.

The constant term of the supply function is calibrated based on the above mentioned numbers for elasticity, actual price, and actual demand (measured as consumption). To be more precise, we

[a] To conduct simulation, we used a software, RiskAMP.

calibrated constant terms using the following equation for each year between 1992 and 2001 and took the simple average. [b]

$$\text{Calibrated constant terms} = S_t/(P_{t-1}\hat{}\ \varepsilon_s)$$

Where

S_{t1}: Supply at time t

P_{t-1}: Price at time t-1

$\varepsilon_{s:}$ Supply elasticity (specified above)

Supply is measured as milled rice production[c] (in thousand tonnes). Price is measured as the domestic, local currency-denominated wholesale price for the Indian autarky simulation, and as FOB (Bangkok), US$-denominated price of Super A Thai rice for the free trade simulation. They are both adjusted for CPI (2000 = 100).

We assume that production responds to the previous year's price. The constant terms for autarky and free trade are calibrated to be 19,005 thousand tonnes and 158,485 thousand tonnes, respectively. Appendix I shows the detailed calculations and data sources.

Based on the above calculations, supply functions (before supply shock) for each regime are specified as follows:

Indian autarky: $\text{Supply}_t = 19{,}005 * P_{t-1}^{0.16} + \text{random shock}$

Free trade: $\text{Supply}_t = 158{,}485 * P_{t-1}^{0.16} + \text{random shock}$

b) Supply shock

A random supply shock is added to the supply function. Random numbers are generated by Simular, and we modeled these random numbers to follow a normal distribution with a mean of

[b] Ideally, we would use more recent data. However, data for 2002 and after was not readily available for India.

[c] Milled rice production volume is estimated by multiplying paddy rice production volume with mill rate (the conversion rate of paddy rice and milled rice equivalent). Same for all milled rice volume referred throughout the report.

zero (i.e., no shock). Standard deviations are calculated based on the historical production volume from 1981 to 2006. For India, the standard deviation is calculated to be 13,083 thousand tonnes (milled rice production) or 17.35 percent of average production volume. For world production, the standard deviation is 43,272 thousand tonnes (milled rice production) or 12.27 percent of average production volume. Appendix I exhibits the calculations and data sources.

c) Demand function

The own price elasticity of demand is obtained for Indian domestic production as well as world production. For Indian demand, we use -0.51, again taken from Srinivasan (2001). For world demand, we estimated the aggregate elasticity to be -0.58 based on the elasticity of demand for cereals estimated for groups of countries in three different income levels, and the rice consumption of each country. The own price elasticity of demand for cereals is estimated to be approximately -0.6 for low and middle income countries and approximately -0.3 for high income countries based on Regmi, Deepak, Seale Jr., and Bernstein (2001).[58] Since total rice consumption in middle and low income countries significantly outweighs that in high income countries, the weighted average of elasticity is very close to -0.6.

The constant term of the demand function is calibrated in the same manner as we did for that of the supply function. The difference is that we assume demand responds to the current price, unlike supply which responds to the previous year's price. To be more precise, we calibrated constant terms using the following equation for each year between 1992 and 2001 and then taking the simple average.

$$\text{Calibrated constant terms} = D_t/(P_t \hat{} \varepsilon_d)$$

Where

D_{t1}: Demand at time t,

P_t: Price at time t,

ε_s: Demand elasticity (specified above)

Demand is measured as milled rice consumption (thousand tonnes). Consumption is measured as production less exports for the Indian autarky case, and measured as equal to production quantity for the free trade case. Price is measured as domestic, local currency-denominated wholesale price for the Indian autarky simulation, and measured as FOB (Bangkok), US$-denominated price of Super A Thai rice for the free trade simulation. Prices are adjusted for CPI (2000 = 100). The constant terms for autarky and free trade are calibrated to be 8,700,004 thousand tonnes and 8,356,680 thousand tonnes, respectively.[d] Appendix I shows the detailed calculations and data sources.

Based on the above calculations, demand functions for each state are specified as follows:

Indian autarky: $Demand_t = 8{,}700{,}004 * P_{t,\ rupee}^{-0.51}$

Free trade: $Demand_t = 8{,}356{,}680 * P_{t,\ US\$}^{-0.58}$

3. Major assumptions

Our analysis described above depends on several major assumptions. First, it assumes perfect free trade with no government intervention, perfect information, and no transaction costs for international trade. These assumptions are relaxed in our second model.

Second, we assume that prices of all other goods remain the same, as well as income of consumers.

C. Multi-Country Model

1. Model structure

a) Overview

The objective of the multi-country model is to depart from the complete free trade situation and incorporate the behaviors of other actors in the international commodity market to illustrate their impact on the international price and implications for Indian policy. We use two analytic approaches here: a Monte Carlo simulation analysis and a step-by-step analysis. The common features of these two analyses are as follows.

[d] Note: these constant terms are not comparable on a one-to-one basis since Indian autarky demand is calculated based on local price while international demand is based on US$ price.

The model includes several players, four exporters and one importer, who participate in the international rice market. In this international market, the price is determined by the supply volume of exporting countries (i.e., their production less domestic consumption) and the demand function of importers so that the market clears.

In each of the two analyses, we demonstrate two scenarios in which we place shocks to either production level or price. Theoretically, the higher the price, the more volume is exported as the domestic consumption decreases. Yet, unlike in the simple model discussed above, this model allows governments to intervene in trade. When the international price exceeds a certain threshold, countries may impose an export quota, ban, or price control. We model this trade intervention by setting a trigger price, the price above which the government places these trade restrictions, for each country. Once a country places a restriction, the international price is re-calculated based on the revised export supply and import demand. After observing this revised price, other countries may also intervene in trade.

b) Countries included in analysis

Both analyses cover four major exporting countries: India, Thailand, Pakistan, and Vietnam. As of 2006, rice exports from these four countries accounted for 72 percent of total world rice exports.[e] The Monte Carlo analysis includes the Philippines as a major importing country. As of 2006, the Philippines was the largest rice importer and accounted for approximately 7 percent of total world imports of the commodity. The step-by-step analysis focuses on the behaviors of exporting countries only.

2. Multi-country Monte Carlo analysis

a) Overview

In our multi-country Monte Carlo analysis, we randomly generate the initial price.[f] In responding to this initial price, each country has a choice of placing a quota or ban (in the case of

[e] Calculated by the authors based on World Rice Statistics November 2008 published by IRRI.

[f] In order to simplify the succeeding steps of simulation, i.e., the recalculation of new international price following the trade intervention, we attribute all of underlying causes of price increase to production shock from non-major

exporting countries), or placing a price control (in the case of importing countries), or not intervening at all. For simplification, the decision of each exporting country is translated as follows in the model. If a country places a quota, this reduces its export quantity by half; if it places a ban, its export becomes zero.[g] In the absence of export intervention, the export quantity remains the same. In other words, world exports are perfectly inelastic to price and do not change *except* through the trade interventions of exporting countries. In the case of importing countries, the model translates the intervention decision as follows. If an importer imposes price controls, its imports become perfectly inelastic to price—however high the price is, this country seizes its original importing quantity from whatever the available export quantity before any other importer touches it. The international price is then re-calculated based on the remaining quantity (i.e., total exports less imports of country with price control) and the international import demand less that of the country with price controls. If an importer does not intervene, its import quantity is determined in the market by the price and demand elasticity.

b) Input variables

(1) Export quantities

As explained above, export quantities vary only according to the trade policy taken by each country. The default quantity for each country is set at its average exports during 2000 to 2006. The difference between the world total exports and the sum of exports from the four major exporting countries is allocated to other countries ("Others" in the spreadsheet).

(2) Import demand function

Total import quantity must equal to total export quantity, and its equilibrium determines the international price. The own price elasticity of import demand is set at -0.58, the same as the aggregate elasticity used in our first model, the perfect free trade model.[h59]

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exporting countries ("Others" column in spreadsheet). In real world, it can be demand shock, speculation, or any other shocks.

[g] It is unlikely in the real world that exporting countries would ban all exports so that its export quantity becomes below average export under normal state. However, if we consider that these countries experienced supply shocks domestically, they may do so to maintain sufficient rice for domestic consumptions.

[h] Another way to estimate the world import demand elasticity was to start from the demand elasticity for the export from particular country. For example, that for Thai rice export is estimated between -1 to -4, and relatively closer to lower side according to Warr (2001). If we assume it to be -2, and adjust it by the proportion of Thai export in the

The constant term of the demand function is calibrated in the same manner as we did in the perfect free trade model, but using data from 2000 to 2006 in order to be consistent with other data used in this model. The constant term is calculated to be 583,358 thousand tonnes. Accordingly, the demand function for world imports is specified as follows:

$$Demand_t = 583{,}358 * P_{t,\ US\$}^{-0.58}$$

Appendix II shows the detailed calculations and data sources.

As for the default import quantity to which the Philippines returns when it places price controls, we used the average imports during 2000 to 2006.

(3) Initial international price

The initial international price that induces the responses of countries is generated randomly. We believe that price movement would not follow a normal distribution but would have concentration around a mean (or mode), almost no probabilities to go below a certain level, and limited but some probabilities to go relatively high. To simulate such movement, we used a beta-PERT distribution. The beta-PERT distribution uses three variables—mode, minimum, and maximum—and generates a distribution that somewhat fits the shape of a normal or lognormal distribution.[60]

In this analysis, we used the monthly export price (US$ per tonne, FOB) of Thai rice 5 percent broken from January 2000 to December 2008, adjusted for CPI (2000=100). We used the median and minimum of this period, US$ 221 and US$ 160 per tonne, as the mode and minimum for our model. As the maximum for our model, we used US$350, the approximate price at the moment when some countries actually placed an export ban in 2008. This is an approximation because the actual maximum price observed in the market was affected by various interventions taken by many countries and thus inappropriate for use as the initial price in our analysis.[i] Appendix III exhibits the monthly rice price data from 2000 to 2008.

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world aggregate export (0.29), it gives a very similar number, -0.58. It is still subjective, and therefore, we performed a sensitivity analysis.

[i] The price mentioned here may differ from international prices announced in media in 2008 due to various factors. First, to simplify our analysis, we only looked at the price of one type of rice, Thai rice 5% broken, assuming that

(4) Trigger Price

When the international price goes beyond the trigger price set by each country, the government intervenes in trade. Our model sets two levels of trigger prices for each exporting country: the first trigger at which countries place a quota, and the second trigger at which countries place a ban. For importing countries, the model sets one trigger price at which the country places price controls.

We experiment with three sets of trigger prices; one that aims to replicate the world rice market in 2007 and 2008, and the other two simulating markets in which countries take different policies than they did in 2008.

In order to replicate the market situation in 2007-2008, we set the trigger price of intervening countries, notably India, Vietnam, and the Philippines, based on the CPI-adjusted world price of Thai 5 percent broken rice at the end of the month succeeding their respective intervention. For India, the first trigger, which invokes the quota, is set based on the country's intervention in 2007, which was eventually lifted. India's second trigger, which invokes the ban, is set based on the export ban it placed in March 2008. For Vietnam, the first trigger is set based on its initial major intervention in March 2008, and the second one is set based on the country's decision to extend the ban.[61] The trigger price of the Philippines is set based on its announcement to guarantee prices for poor people in March 2008.[62] For the countries that did not intervene, i.e., Thailand and Pakistan, we set very high trigger prices such that practically they would not intervene.

For the two experimental scenarios, we modified the trigger prices of some countries. In both scenarios, we raised India's triggers to assess the international price movement when India refrains from intervention. In one of these scenarios, we maintained the trigger prices of all other countries to observe the price movement when India alone changes its policy. In the other scenario, we lowered the trigger prices of Pakistan, another big exporter though smaller than India, to assess the price movement when other countries intervene in the absence of Indian intervention.

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prices of other types moved proportionately to this type. Second, the prices mentioned in this analysis are CPI-adjusted to 2000 level.

The following table summarizes the trigger prices set in each scenario we conducted in our analysis.

Trigger prices used in multi-country Monte Carlo simulation analysis

(US$/ton)

Country	India		Thailand		Pakistan		Vietnam		The Philippines
	quota	ban	quota	ban	quota	ban	quota	ban	price control
Scenario 1	275	370	1,000	1,500	1,000	1,500	300	475	370
Scenario 2	370	450	1,000	1,500	1,000	1,500	300	475	370
Scenario 3	370	450	1,000	1,500	275	370	300	475	370

3. Multi-country step-by-step analysis

a) Overview

In this analysis, we go through the behaviors of major exporting countries step-by-step in order to better understand the underlying behaviors behind the simulation results obtained in our Monte-Carlo analysis.

We demonstrate three scenarios in each of which we place shocks to the production of one exporting country in order to observe its impact on the international price. In the absence of intervention, the export quantity of each country varies according to domestic consumption volume, which in turn depends on the international price.

The three scenarios in this analysis correspond to those in the multi-country Monte Carlo simulation analysis, i.e., each scenario sets different trigger prices. The quota of each country is set so that the domestic price remains at the trigger price for each respective country. The ban of each country is set so that the country does not export at all (or maintains the average domestic consumption level in the case where India experiences a production shock). Once a country places export restrictions, the international price is re-calculated based on the revised export supply. After observing this revised higher price, another country may impose additional export restrictions to shield its consumers.

b) Input variables

(1) Production by each country

Since the exports from each country are calculated as production less domestic consumption calculated based on the demand curve, we used production quantity rather than export quantity in this analysis. The production by each country is assumed to be constant apart from shocks (i.e., supply is assumed inelastic in the short-run). For each country, the average production volume between 1995 and 2000 is used as the constant.[j] The world total export supply is also assumed to be equal to the average world exports in the same time period. The difference between total world exports and total exports from the four major countries is allocated to all other exporting countries (column "Others" in spreadsheet).

In all three scenarios, the size of the shock is set at 6.5 percent, which is one standard deviation of annual production in the world during 1991 to 2006.

c) Domestic demand and export supply by each country

The export supply of each country is calculated as respective domestic production quantity less domestic demand. The domestic demand is calculated in the same manner as in the simple model under perfect free trade. The own price elasticity of demand for each country is obtained from existing literature, and the constant terms in the demand functions are calibrated based on historical prices, consumption and elasticity.

The own price elasticity of demand is obtained for each country in our analysis as well as for overall world export demand. For Indian domestic demand, we use 0.51, drawing from Srinivasan (2001).[63] For Pakistan, Thailand, and Vietnam, we use -0.34, -0.41, and -0.41, respectively, drawing from Seale et al. (2001).[k64] For the rest of the exporting countries (i.e., the column "Others" in the spreadsheet), we assume that their export supply is constant regardless of the price.

[j] We chose time periods for which domestic price and production data for all four major exporting countries were readily available. Having a complete dataset was important to obtain a functioning model that connects domestic price, international price, domestic consumption, and export quantities.

[k] These are the price elasticity of food subcategory of bread and cereal and not that of rice alone.

The constant term of the demand function for each country is calibrated by using the price and consumption (measured as production less exports) from 1995 to 2000, and taking the simple average.

The price elasticity of domestic demand assumes the price to be denominated in each country's respective local currency. In addition, there are some factors that differentiate domestic wholesale price and international price even under perfect free trade. One such factor is transaction costs. Another factor is the difference in quality or type of rice. For simplicity, we name all of these factors collectively as "export margin" and estimate this margin for each country by comparing the actual domestic wholesale price to the international price. The domestic demand quantities of the four countries in the model are calculated based on the price denominated in the respective local currency, with adjustment for export margin.

d) Demand by importing countries

The own price elasticity of import demand is set as the same level as in the multi-country Monte Carlo simulation analysis. The constant terms of the import demand function are also calibrated in the same manner, but using data from 1995 to 2006, which yielded 604, 317 thousand tones.

Accordingly, the demand function for world imports is specified as follows:

$$Demand_t = 604{,}317 * P_{t,\ US\$}^{-0.58}$$

e) Trigger price for each country

This analysis sets the trigger prices at the same level as in the corresponding scenarios in the multi-country Monte Carlo simulation.

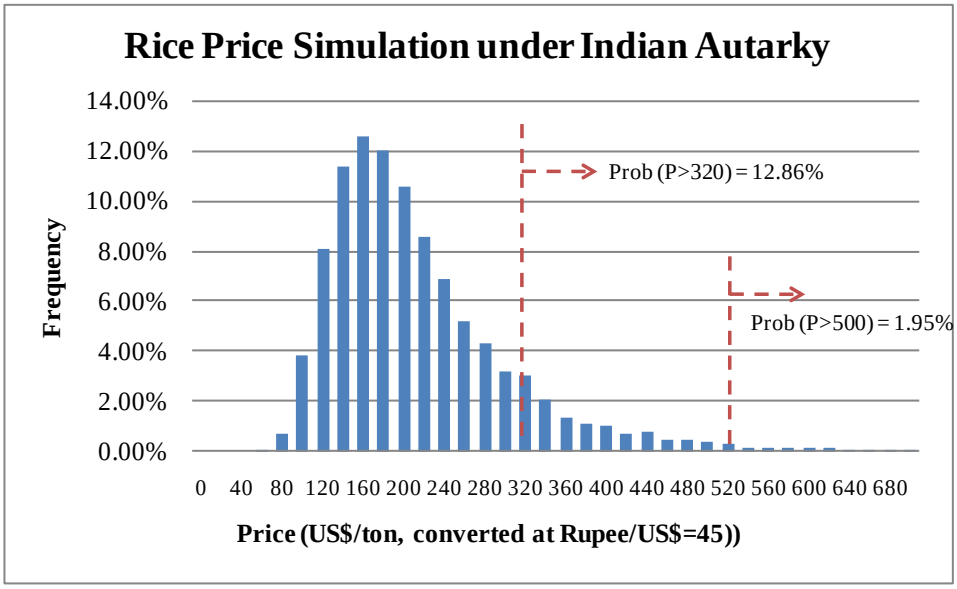
IV. Results of Analysis

A. Perfect Free Trade Model

We repeat 10,000 iterations of random supply shocks, under autarky and free trade, to obtain the distribution of price level given such shocks. The results for each state are as follows.

1. Indian autarky state

Based on the domestic elasticity of supply and demand as well as domestic production volatility, the rice price under Indian autarky ranges from US$ 60 to 2,240 per tonne, with an average price of US$ 226 per tonne.[1] The probability of the autarky price exceeding US$ 320 per tonne, a price approximately 50 percent higher than the average Indian domestic price in the past decade (1992-2001), is estimated to be 12.86 percent. The probability of the price exceeding US$ 500 per tonne is approximately 1.95 percent. The following exhibit depicts the distribution of price obtained in the simulation and the summary statistics.



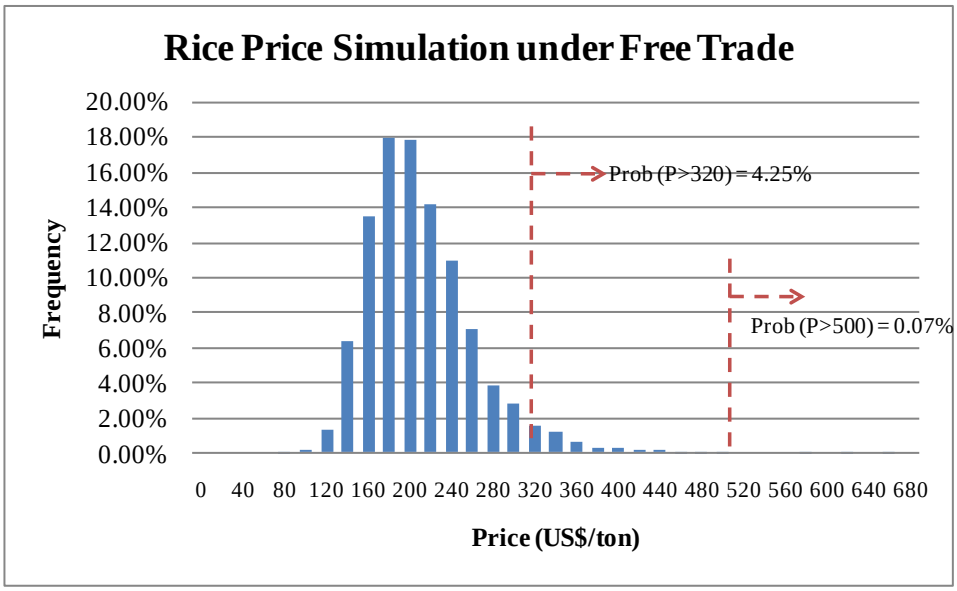
Simulation is run 10,000 times.
Source: prepared by authors using RiskAMP Monte-Carlo Add-In in Microsoft® Excel®.

2. Absolute free trade state

Given the world elasticity of supply and demand, and world production volatility, the rice price under absolute free trade ranges from US$ 80 to 660 per tonne, with an average price of US$ 220 per tonne. The probability of the free trade price exceeding US$ 320 per tonne is estimated to be 4.25 percent. The probability of the price exceeding US$ 500 per ton is 0.07 percent. The

[1] The price is first obtained in local currency, INR, and then converted to US$ at the rate of 45 Rupees per US$. The annual average INR/US$ rate ranges from 22.74 to 48.61 between 1991 and 2006.

following exhibit shows the distribution of price obtained in this simulation as well as the summary statistics.



Simulation is run 10,000 times.
Source: prepared by authors using RiskAMP Monte-Carlo Add-In in Microsoft® Excel®.

3. Comparison

The comparison of the two simulations yields a result consistent with what classic trade theory would predict. The Indian domestic price is much more stable under free trade than under autarky (the standard deviation is US$ 38 per tonne under free trade, compared to US$ 95 per tonne under autarky). Also, the probability of the domestic price exceeding a certain threshold is much lower under free trade. For example, while the probability of the price exceeding a level 50 percent higher than the 10 year average is substantive (13 percent) under autarky, it is fairly limited under free trade (4 percent).

4. Sensitivity analysis

Since it is very difficult to accurately estimate the aggregate elasticity under free trade, we performed a sensitivity analysis to check the robustness of our findings. We believe that it is reasonable to assume that rice production is relatively inelastic to price in the short-term, and therefore focused our sensitivity analysis on elasticity of demand. We ran the same simulation

by changing price elasticity of demand under free trade from -0.35 to -0.55 and obtained the probabilities of the equilibrium price exceeding US$ 320 per tonne and US$ 500 per tonne for each level of elasticity. The following tables restate the results under Indian autarky and exhibit the results of our sensitivity analysis for the free trade simulation.

Indian Autarky (price elasticity of demand fixed at -0.51)

Probability of exceeding $320/ton	12.86%
Probability of exceeding $500/ton	1.95%

Free Trade

	Price elasticity of demand under free trade					
	-0.30	-0.35	-0.40	-0.45	-0.50	-0.55
Probability of exceeding $320/ton	16.57%	12.53%	9.42%	7.27%	5.90%	3.87%
Probability of exceeding $500/ton	3.37%	1.47%	0.67%	0.28%	0.13%	0.07%

The above tables show that the probability of the equilibrium price exceeding certain thresholds under free trade becomes approximately the same as that under autarky when price elasticity of demand in the world is at -0.35. The probability becomes higher than that for autarky as world demand gets even less elastic. Considering that the majority of rice consumers live in low and middle income countries where the own price elasticity of demand for cereals is assumed to be around -0.6, we believe that there is little chance that demand elasticity under free trade is as low as to make autarky a better choice for Indian rice price stability. In addition, even when the world demand elasticity is as low as -0.35, the probability that the price exceeds a very high level, US$ 500 per ton, is still lower under free trade than under Indian autarky.

B. Multi-Country Model

This section presents the results of our multi-country analyses that incorporate, to some extent, the imperfect nature of the current international rice market. Both the multi-country Monte-Carlo analysis and the multi-country step-by-step analysis examine three scenarios. Based on the comparison of the results of these scenarios, we derive some implications for Indian rice trade policy.

1. Multi-country Monte-Carlo analysis

We repeat 10,000 iterations of random movement of the initial price under three scenarios to obtain the distribution of price level after trade interventions of market-participating countries. The results for each scenario are as follows.

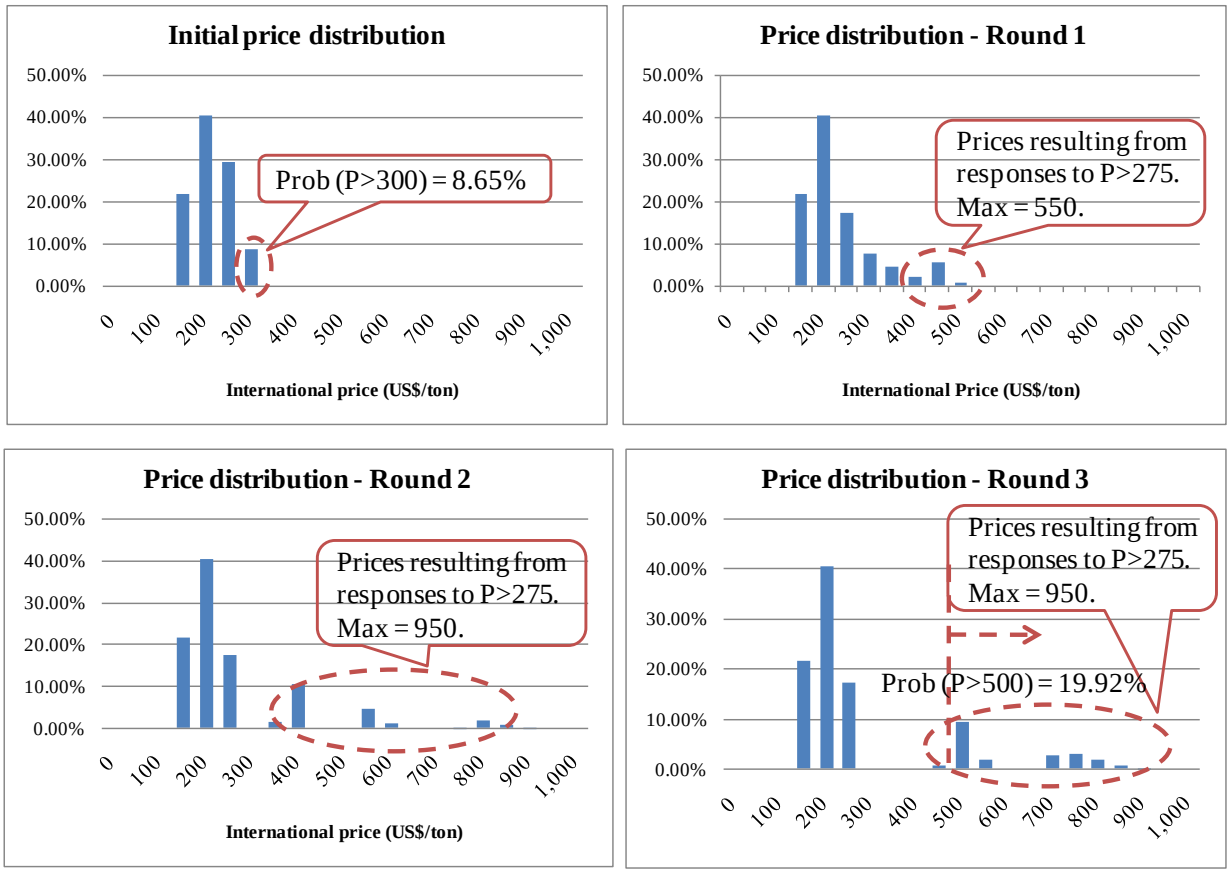
a) Scenario 1: World rice market in 2007 – 2008

The initial price distribution was generated by a random simulation based on the beta-PERT distribution. The probability of the initial price exceeding US$ 300 per tonne is approximately 9 percent and the price never goes beyond US$350 (as we restricted this is as the maximum level in the distribution specification).

Due to the interventions taken in response to initial price, the distribution of price after the preliminary interventions (i.e., round 1) expands to a higher level with maximum price reaching around US$ 550. In response to the resulting price in round 1, other countries introduce a quota or shift from a quota to a ban, which leads to even higher prices in rounds 2 and 3. The maximum price in these rounds is approximately US$ 950, and the probability that the price exceeds US$ 500 at the end of round 3 is as high as 20 percent. The charts in the next page exhibit the price distributions at the initial stage and for rounds 1 through 3.

The underlying mechanism of rising price in this scenario is as follows. It is only India or India and Vietnam that initially intervene since all other countries have trigger prices beyond the level that price can naturally reach without government interventions (i.e., US$ 350 in our model). Their quotas raise the international price above the second trigger prices of India and Vietnam themselves as well as above the trigger price of the Philippines. Due to the secondary interventions of these three countries, the international price becomes even higher. Attachment IV exhibits the spreadsheet that describes these steps in detail.

Price distributions from initial to round 3: Scenario 1 – rice market in 2007-2008



b) Scenario 2 – Higher Indian trigger

The initial price distribution was generated in exactly the same manner as in scenario 1. The preliminary intervention takes place *only by the decisions of Vietnam* under this scenario. While price after the preliminary intervention may reach up to around US$ 450, the probability of price exceeding US$ 400 is less than 1 percent at the end of round 1. Due to subsequent interventions that follow Vietnam's action, price may reach up to US$ 950 but only in very rare cases. The probability of the price exceeding US$ 500 by the end of round 3 is approximately 5 percent, much lower than in scenario 1. If Vietnam also raises trigger prices to the level of India's new trigger prices, the market price would not generate any intervention, and the resulting price and its distribution would become closer to what we observed in the perfect free trade model. The

following charts exhibit the price distributions of scenario 2 at the initial stage and for rounds 1 through 3.

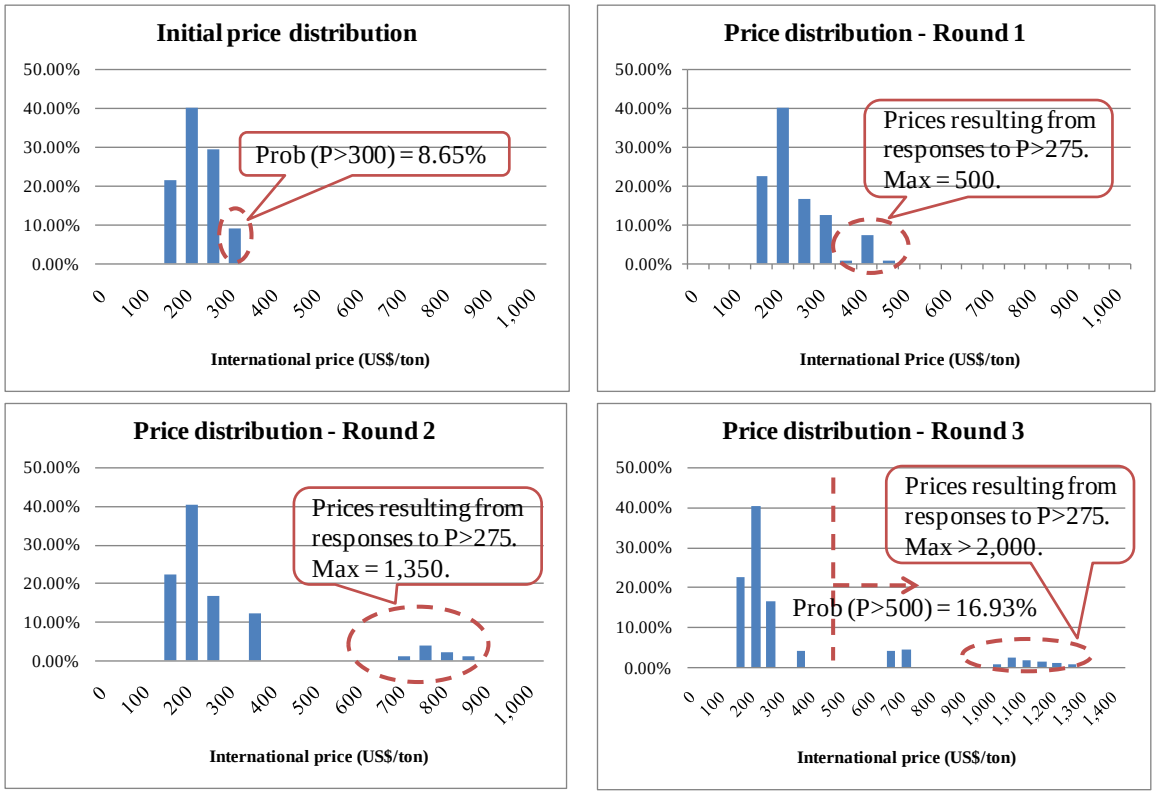
Price distributions from initial to round 3: Scenario 2 - higher Indian trigger

c) Scenario 3 – Higher Indian trigger and lower Pakistani trigger

The initial price distribution was generated in exactly the same manner as in scenarios 1 and 2. Due to Pakistan's interventions in response to the initial price, the distribution of price after the preliminary interventions in round 1 expands to a higher level with maximum price reaching approximately US$ 500 (as in scenario 1). In response to the resulting price in round 1, other countries introduce quotas or shift from a quota to a ban, which leads to even higher prices in rounds 2 and 3. The maximum price at the end of round 3 may exceed US$ 2,000 in very rare cases. Still, the probability that the price exceeds US$ 500 at the end of round 3 is 17 percent,

which is lower than the probability we obtained in scenario 1. This is probably due to the smaller export volume of Pakistan compared to India. The following charts exhibit the price distributions at the initial stage and for rounds 1 through 3.

Price distributions from initial to round 3: Scenario 3 – Higher Indian, Lower Pakistani



d) Sensitivity analysis

(1) Aggregate price elasticity of world demand for rice

Since it is very difficult to accurately estimate the aggregate demand elasticity for the world, we performed a sensitivity analysis to check the robustness of our findings. For the same reason as stated for the perfect free trade model discussed above, we focused our sensitivity analysis on elasticity of demand. We ran the same simulation by changing price elasticity of demand under free trade from -0.40 to -1.0 and obtained the probabilities of equilibrium price exceeding

US$ 500 per ton at the end of round 3 for each level of elasticity. The following table shows the results of our sensitivity analysis.

Probability of price exceeding US$ 500 at the end of round 3

	Price elasticity of demand in the world				
	-0.40	-0.80	-1.00		-0.58 (baseline)
Scenario 1	21.02%	8.28%	6.79%		19.92%
Scenario 2	8.83%	1.94%	0.59%		4.98%
Scenario 3	21.01%	9.24%	6.87%		16.93%

The above table shows that the probability of equilibrium price exceeding US$ 500 is around the same for scenarios 1 and 3, and much lower for scenario 2 regardless of the world elasticity of demand. Although the exact probability varies according to the level of elasticity, the results support our contention that less intervention leads to more price stabilization.

(2) Initial price distribution

Since we set the distribution of initial price (i.e., the price without any intervention) somewhat arbitrarily, we ran the simulation using a different possible maximum price. Particularly, we tested the result of scenario 2 when we allow the initial price to reach a higher range.

We found that the price starts to reach much higher levels at any round once we allow the initial price to go beyond US$ 370, the trigger price of India under scenario 2. For example, if we allow the price to reach US$ 400, the probability of price exceeding US$ 500 is estimated to be 15.12 percent. This result implies that the factor that affects the spikes of international rice price is not the absolute trigger price. It is whether a country sets the trigger price at a level which the international price can easily reach in the absence of interventions.

2. Multi-country step-by-step analysis

The purpose of this analysis is to describe the process through which government interventions impact the international price. To do so, we demonstrate three scenarios corresponding to those simulated in the Monte Carlo analysis above.

a) Scenario 1

The model first calculates the international price based on free trade (that is, no intervention by any country), which turns out to be US$ 346 per ton after the production shock. As this price exceeds the first trigger price of India and Vietnam, the governments of these countries place export quotas so that their domestic price remains at their trigger price, US$ 275 and US$ 300 per tonne, respectively. This decreases the rice supply to the international market, which further increases the world price. In this scenario, the revised international price after the Indian and Vietnamese export quotas jumps up to US$ 739 per tonne, above the second trigger prices of India and Vietnam. Now, they both place a ban. Although the rise in price increases the exports from Thailand and Pakistan as their domestic demand decreases in response to the higher price, the decrease in exports from India and Vietnam outweighs this increase. Consequently, the world price climbs even higher. After the bans placed in round 2, the price reaches US$ 1,480, which induces Thailand and Pakistan to place quotas. By the end of round 3, the world price reaches US$ 1,803 per tonne. The following table exhibits the detailed steps of this process. Appendix VI contains full assumptions and notes to this table.

Multi-country step-by-step analysis: Scenario 1

Scenario 1		India	Thailand	Pakistan	Vietnam	Others	Total exp. countries	Int'l price
Trigger prices	quota	275	1,000	1,000	300			
	ban	370	1,500	1,500	475			
Average production		87,037	18,250	4,883	22,418			
Average domestic consumption		82,508	10,155	2,415	18,457			
Average export		4,529	8,095	2,467	3,961	9,194	28,246	
Shock to production						(25,691)		
Revised domestic demand		72,105	8,477	2,169	12,989			
Without intervention								
Actual export		14,932	9,773	2,714	9,428	(16,497)	20,350	
International price without any intervention								346
Round 1								
Intervention		Quota	None	None	Quota			
Revised domestic demand		81,071	6,550	1,589	13,772	-		
Export after intervention		5,966	11,700	3,293	8,645	(16,497)	13,108	
International price with intervention in Round 1								739
Round 2								
Intervention		Ban	None	None	Ban			
Revised domestic demand		82,508	5,171	1,195	18,457			
Actual export after ban		4,529	13,079	3,688	3,961	(16,497)	8,759	
International price with intervention in Round 2								1,480
Round 3								
quota (yes or no?)		Ban	Quota	Quota	Ban			
Revised domestic demand		82,508	5,909	1,404	18,457			
Actual export after ban		4,529	12,341	3,479	3,961	(16,497)	7,812	
International price with intervention in Round 3								1,803

b) Scenario 2

The starting international price in scenario 2 is the same as in scenario 1, i.e., US$ 346 per tonne. As it exceeds the first trigger price of Vietnam, the Vietnamese government places an export quota to maintain its domestic price at its trigger price, US$ 300. Vietnamese exports decrease accordingly, yet, this decrease is mostly offset by the increases in exports from India, Thailand and Pakistan as their domestic demands decrease in response to the higher world price. Consequently, the Vietnamese intervention moves the world price up only slightly, and does not lead to any subsequent interventions by other countries. The price remains at US$ 351 through

round 3. The following table exhibits the detailed steps of this process. Appendix VI contains full assumptions and notes to this table.

Multi-country step-by-step analysis: Scenario 2

Scenario 2		India	Thailand	Pakistan	Vietnam	Others	Total exp. countries	Int'l price
Trigger prices	quota	370	1,000	1,000	300			
	ban	450	1,500	1,500	475			
Average production		87,037	18,250	4,883	22,418			
Average domestic consumption		82,508	10,155	2,415	18,457			
Average export		4,529	8,095	2,467	3,961	9,194	28,246	
Shock to production						(25,691)		
Revised domestic demand		72,105	8,477	2,169	12,989			
Without intervention								
Actual export		14,932	9,773	2,714	9,428	(16,497)	20,350	
International price without any intervention								346
Round 1								
Intervention		None	None	None	Quota			
Revised domestic demand		71,555	8,434	2,155	13,772	-		
Export after intervention		15,482	9,816	2,727	8,645	(16,497)	20,174	
International price with intervention in Round 1								351
Round 2								
Intervention		None	None	None	Quota			
Revised domestic demand		71,555	8,434	2,155	13,772			
Actual export after ban		15,482	9,816	2,727	8,645	(16,497)	20,174	
International price with intervention in Round 2								351
Round 3								
quota (yes or no?)		None	None	None	Quota			
Revised domestic demand		71,555	8,434	2,155	13,772			
Actual export after ban		15,482	9,816	2,727	8,645	(16,497)	20,174	
International price with intervention in Round 3								351

c) Scenario 3

The starting international price in scenario 3 is the same as in scenarios 1 and 2, i.e., US$ 346 per tonne. As this exceeds the first trigger price of Pakistan and Vietnam, these governments place export quotas to maintain their domestic prices at their respective trigger prices, US$ 275 and US$ 300. While the decrease in total export supply here is more significant than in scenario 2, as

Pakistan also places a quota in this scenario, the magnitude of the impact added by the Pakistani intervention is very limited compared to the impact of India's intervention in scenario 1. The decrease in total export supply caused by the Vietnamese and Pakistani interventions is mostly offset by the increase in exports from India and Thailand. As a result, the world price remains at US$ 354 through the end of round 3 without invoking any further interventions. The following table exhibits the detailed steps of this process. Appendix VI contains full assumptions and notes to this table.

Multi-country step-by-step analysis: Scenario 3

Scenario 3		India	Thailand	Pakistan	Vietnam	Others	Total exp. countries	Int'l price
Trigger prices	quota	370	1,000	275	300			
	ban	450	1,500	370	475			
Average production		87,037	18,250	4,883	22,418			
Average domestic consumption		82,508	10,155	2,415	18,457			
Average export		4,529	8,095	2,467	3,961	9,194	28,246	
Shock to production						(25,691)		
Revised domestic demand		72,105	8,477	2,169	12,989		0	
Without intervention								
Actual export		14,932	9,773	2,714	9,428	(16,497)	20,350	
International price without any intervention								346
Round 1								
Intervention		None	None	Quota	Quota			
Revised domestic demand		71,392	8,421	2,383	13,772	-		
Export after intervention		15,645	9,829	2,500	8,645	(16,497)	20,122	
International price with intervention in Round 1								353
Round 2								
Intervention		None	None	Quota	Quota			
Revised domestic demand		71,392	8,421	2,383	13,772			
Actual export after ban		15,645	9,829	2,500	8,645	(16,497)	20,122	
International price with intervention in Round 2								353
Round 3								
quota (yes or no?)		None	None	Quota	Quota			
Revised domestic demand		71,392	8,421	2,383	13,772			
Actual export after ban		15,645	9,829	2,500	8,645	(16,497)	20,122	
International price with intervention in Round 3								353

The difference in the magnitude of the impact caused by Indian and Pakistani interventions is mostly attributable to the fact that Pakistan is a much smaller producer, consumer, and exporter of rice. Compared to India, Pakistan's production, consumption, and exports of rice are 6 percent, 3 percent, and 54 percent, respectively. Consequently, the impact of Pakistan's trade intervention in the world rice market is much less significant than that of India.[m]

3. Comparison of Multi-country scenarios

The analyses of our multi-country models confirm what was discussed during the commodity boom in 2008 and provide some important policy implications for India.

First, the results confirm that government intervention can cause spikes in the international price in the absence of other types of significant shocks to prices. Our model set the ceiling of the initial price at US$350 in the Monte-Carlo simulation analysis and at US$ 346 in the step-by-step analysis. Yet, the simulation predicted the possibility of prices reaching US$ 900 or higher due to sequential interventions by exporters and importers. A similar result was obtained in the step-by-step analysis.

Second, the comparison between scenarios 1 and 2 suggests that a much lower international price may be achieved if India refrains from intervening too early, without any accompanying changes in the behavior of other countries. The only difference between these two scenarios is that India's trigger prices are higher in scenario 2. However, the two scenarios resulted in vastly different price distributions at the end of round 3. A similar result was obtained in the step-by-step analysis. Furthermore, our sensitivity analysis implies that the stable price observed in scenario 2 is achievable but only when *large* exporters set their trigger prices higher than the level that international prices could reach naturally in the absence of any government interventions.

Third, close comparison of the results of scenario 3 obtained in the Monte-Carlo simulation analysis and the step-by-step analysis provides an important insight. The step-by-step analysis

[m] We also considered the difference in price elasticity of domestic demand for rice as a source of difference in the magnitude of impact. However, the results of the analysis did not change materially even when we changed Pakistani elasticity of demand to the same level as India.

that better incorporated the *size* of Pakistani rice production demonstrated that the intervention by Pakistan, a relatively small rice producer, does not impact the international rice price significantly. On the contrary, the Monte-Carlo simulation analysis predicted a relatively significant price spike as a result of the Pakistani intervention due to the limited capacity of the model to incorporate the size of the country's production and to consider the increase in export supply from the countries that do not intervene. Hence, the simulation overestimated the magnitude of the impact caused by the Pakistani intervention. The results of scenario 3 in these two analyses suggest that India may be best advised to intervene only if other *considerably large* market participants intervene at a relatively early stage. As the Pakistani intervention showed, even when certain participants place trade restrictions, as long as their influence on the international market is limited, India may still be better-off by refraining from intervention as we observed in the step-by-step analysis.

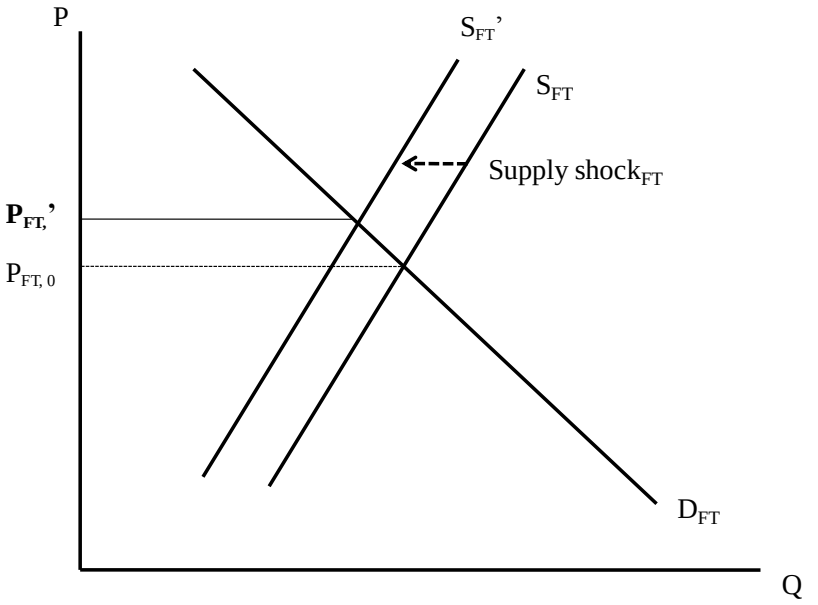
C. Summary of Analysis

Based on the two models, we have observed the potential impact of Indian rice trade policy on rice price stability. In summary, we have simulated the following four combinations of state of the world market and Indian trade policy:

- Under Perfect free trade – No intervention (join free trade) or intervention (autarky)
- Under Imperfect free trade – No (or limited) intervention or intervention.

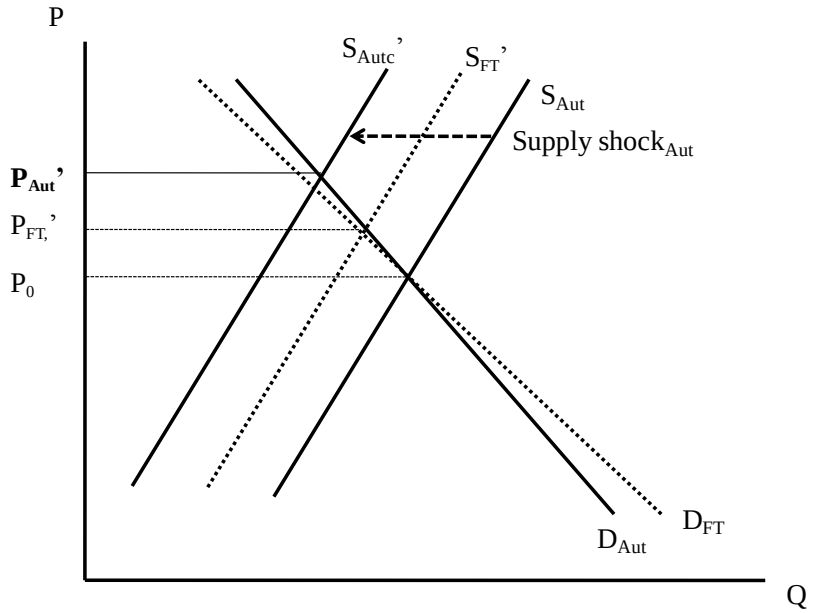
Under perfect free trade, we concluded that India would achieve greater price stability by opening to trade rather than engaging in autarky. The following charts graphically depict the price impact of free trade versus autarky.

Price under perfect free trade – No trade intervention



$S_{FT.}$:supply under free trade, $S_{FT.}$': supply under free trade after supply shock,
D_{FT} : demand under free trade, $P_{FT, 0}$: price under free trade,
$P_{FT,}$': price under free trade after supply shock

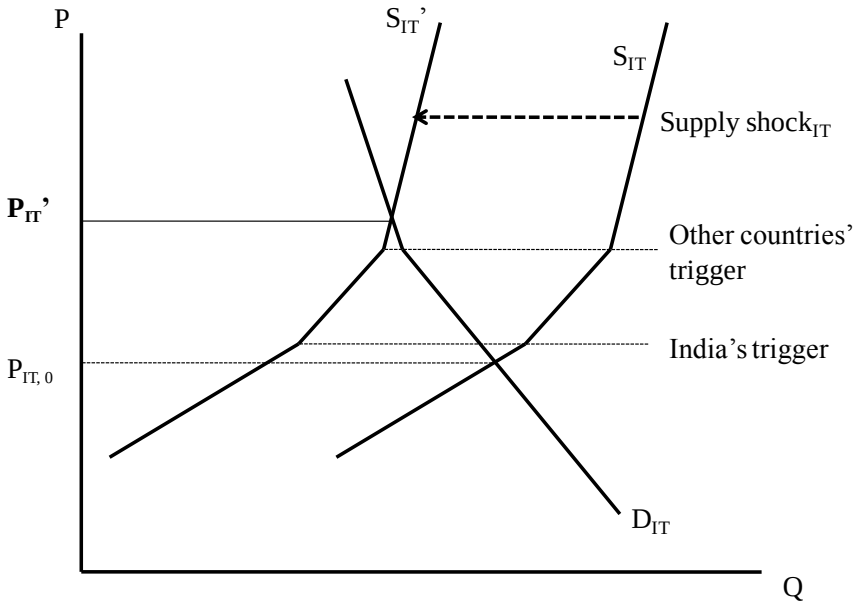
Price under perfect free trade – Autarky



$S_{Aut:}$:supply under autarky, $S_{Aut:}$': supply under autarky after supply shock,
D_{Aut} : demand under autarky, $P_{FT, 0}$: price before supply shock,
$P_{FT,}$ ': price under free trade after supply shock
$P_{Aut,}$': price under autarky after supply shock

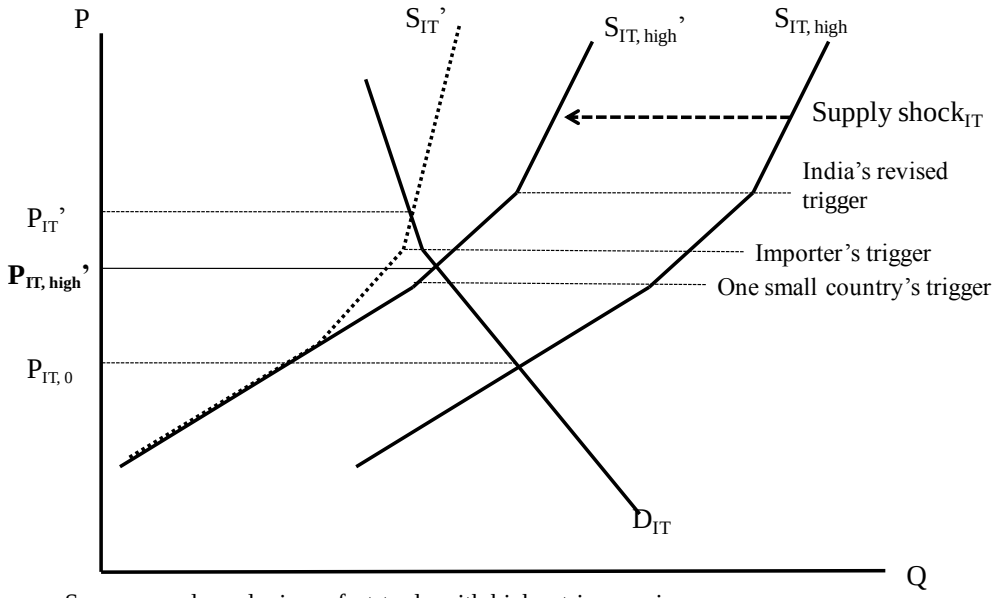
Under imperfect free trade, we concluded that India's best policy to stabilize prices depends on the behaviors of other major participants in the international rice market. If we assume that all other countries maintain their rice trade policy as we observed in 2007-2008, a lower international price is achievable only if India refrains from trade intervention. The following charts graphically depict the impact of different trigger price levels.

Price under imperfect free trade – Intervention



S_{IT}:supply under imperfect trade, S_{IT}': supply under imperfect trade after supply shock,
D_{IT} : demand under imperfect trade, $P_{IT,0}$: price before supply shock,
P_{IT}': price under imperfect trade after supply shock

Price under imperfect free trade – Less intervention (higher trigger)



$S_{IT, high:}$:supply under imperfect trade with higher trigger price,
$S_{IT:}$': supply under imperfect trade with higher trigger price after supply shock,
D_{IT} : demand under imperfect trade, $P_{IT, 0}$: price before supply shock,
$P_{IT,}$ ': price under imperfect trade after supply shock
$P_{IT, high}$ ': price under imperfect trade with higher trigger price after supply shock

V. Initial Recommendations

Based on the results of our models, we can set forth the following points for consideration.

1. Our first model comparing free trade to autarky shows that in a situation with perfectly free trade, it would be in India's best interest to keep its borders open to trade rather than closed, in order to lessen domestic price volatility and keep prices below a certain threshold level.

2. Our second multi-country model shows that in an iterated game scenario that mirrors the global trading system, each country's actions depend on what other countries in the system do. The model provides the following implications:

(a) In order to keep international rice prices stable and low, it would be in India's interests not to intervene as long as other *major* market participants don't, because due to the large size of India's rice production and market, once it does intervene this sets into motion a pattern of intervention among all players that leads to ever-escalating world prices.

(b) As a follow on from point (a), in the event that relatively small participants in the rice market (such as Pakistan) do intervene, it may still be in India's best interest not to follow up with its own intervention in order to keep the international rice price stable and avoid escalation.

(c) If a major market participant such as Thailand (the largest rice exporter) were to intervene in the future, this could certainly have a large impact on world rice prices and lead to a situation where India was also forced to intervene to contain its domestic rice price. However, since Thailand has historically refrained from restricting exports, the onus may lie on India as the second largest exporter of rice to pull back its reins and increase its trigger price so as not to exacerbate the situation next time there is a price surge.

(d) Politically, it may be beneficial for the major exporting and importing countries to enter a trade agreement to deter all parties from taking first action (that is, intervention). Given its past behavior, India would have to show a strong commitment to this in order to regain credibility.

VI. Political Feasibility

Trade policy is a relatively easy tool for governments to use when faced with food crises or rising food prices because of the psychological impact on the population that the government is taking action to ensure national food security, and the administrative ease of implementing trade

interventions as compared to certain domestic policy alternatives (for example, production taxes and consumption subsidies).

However, the food riots that took place in West Bengal in October 2007 were *not* a result of international trade and exposure to rising world prices, but rather a reaction to domestic corruption within the Indian public food distribution system.

Furthermore, our analysis shows that it may actually be in India's interest from a price volatility and food security standpoint *not* to intervene in rice trade policy. Keeping borders open would reduce overall price volatility, help keep rice prices below a certain threshold, ensure farmers valuable export income and preserve India's reputation internationally as a reliable trading partner. Moreover, the fact that Thailand, the largest participant in the international rice export market, has traditionally *not* intervened in this market, makes it even more worthwhile and safe for India as the second largest player to examine its own policies and carefully weigh the pros and cons of intervention.

The big advantage of a regional trade agreement would be if it would tie the hands of the countries involved in a way that new political administrations in individual countries could not simply come in and disregard. Without such a mechanism in place, it would be very difficult for countries to establish credibility and trust because even if a particular government or administration in a country were committed to non-interventionist policies, there would be no guarantee that the next government to win elections would share this commitment. By entering a binding agreement with other countries, it might be possible to avoid policy fluctuations and inconsistencies caused by the political business cycle.

Another noteworthy point is that it may not be necessary to have a trade agreement with *all* players in the market, but merely the *major* players. As the analysis in our step-by-step multi-country model showed, the actions of a relatively small player in the rice market (Pakistan) did not impact world prices enough to instigate further interventions by other countries as long as the trigger prices of major players were sufficiently high. Therefore, while it would be imperative

for India and Thailand to co-sign a trade agreement for rice, it is unclear whether the cooperation and commitment of other smaller players in the market would be absolutely essential from an economics standpoint. From a political standpoint, the more parties involved in the agreement, the more difficult it would be for the government of any one country to ignore it or not take part.

In sum, given the benefits of a regional trade agreement, it may be possible for the Indian government to overcome domestic political hurdles and push for such an agreement to take place. It would, however, require a strong political will—and whether that will exists is open to question.

Appendix I

Table 1: Calibration of Indian demand and supply curve constant terms

Year	Domestic wholesale price$_a$	CPI adjusted price (2000=100)$_b$	Supply (milled rice production)$_c$	Net export$_d$	Domestic demand$_e$	Constant (supply w/ 1yr lag)$_f$	Constant (Demand)$_f$
	(LCU/ton)	(LCU/ton)	(k ton)	(k ton)	(k ton)	(k ton)	(k ton)
1991	5,270	10,979	75,068	596	70,531		
1992	5,800	10,741	73,031	652	68,494	16,482	7,788,947
1993	6,510	11,421	80,668	734	76,131	18,270	8,932,883
1994	6,930	11,000	82,169	4,162	77,632	18,428	8,936,139
1995	6,900	10,000	77,345	3,676	72,808	17,451	7,983,217
1996	7,795	10,257	82,075	2,087	77,538	18,802	8,612,434
1997	8,169	10,085	82,879	4,666	78,342	18,910	8,627,271
1998	9,518	10,346	86,467	2,752	81,930	19,782	9,140,473
1999	9,705	10,109	90,112	1,449	85,575	20,532	9,435,341
2000	8,904	8,904	85,358	1,936	80,821	19,520	8,352,426
2001	9,207	8,853	93,733	6,650	89,196	21,876	9,190,912
Average						19,005	8,700,004

Sources: a: FAO STAT, b: CPI informaiton from EIU, c: see Table 3,
d: IRRI World Rice Statistics (WRS), e: Calculated as production less net export
f: Calculated based on elasticity of 0.16 (supply) and -0.51 (demand)

Table 2: Calibration of world demand and supply curve constant terms

Year	Super A Thai rice, FOB Bangkok $_a$	CPI adjusted price (2000=100)$_b$	Supply (milled rice production)$_c$	Net export$_d$	Domestic demand$_e$	Constant (supply w/ 1yr lag)$_f$	Constant (Demand)$_f$
	($/ton)	($/ton)	(k ton)	(k ton)	(k ton)	(k ton)	(k ton)
1991	178	226	342,335	(596)	342,931		
1992	180	222	348,848	(652)	349,500	146,571	8,027,051
1993	160	191	349,735	(734)	350,469	147,320	7,369,085
1994	186	216	355,688	(4,162)	359,850	153,521	8,139,404
1995	269	305	361,305	(3,676)	364,981	152,836	10,075,303
1996	234	257	375,478	(2,087)	377,565	150,339	9,439,681
1997	214	230	380,811	(4,666)	385,477	156,698	9,035,276
1998	215	226	382,263	(2,752)	385,015	160,121	8,941,282
1999	191	197	403,253	(1,449)	404,702	169,345	8,677,860
2000	143	143	395,270	(1,936)	397,206	169,685	7,063,827
2001	135	131	394,703	(6,650)	401,353	178,417	6,798,029
Average						158,485	8,356,680

Sources: a: FAO STAT, b: CPI informaiton from EIU, c: see Table 3,
d: IRRI World Rice Statistics (WRS), e: Calculated as negative of Indian net export
f: Calculated based on elasticity of 0.16 (supply) and -0.58 (demand)

Table 3: Production volatility in India and World

Year	India		World	
	Paddy rice production	Milled rice equivalent	Paddy rice production	Milled rice equivalent
	(k ton)	(k ton)	(k ton)	(k ton)
1981	79,883	53,522	410,075	270,650
1982	70,772	47,417	421,949	278,486
1983	90,048	60,332	448,016	295,691
1984	87,553	58,660	465,343	307,126
1985	95,818	64,198	468,165	308,989
1986	90,779	60,822	468,675	309,326
1987	85,339	57,177	461,440	304,550
1988	106,369	71,267	487,458	321,722
1989	110,311	73,908	514,422	339,518
1990	111,517	74,717	518,556	342,247
1991	112,042	75,068	518,689	342,335
1992	109,001	73,031	528,558	348,848
1993	120,400	80,668	529,902	349,735
1994	122,640	82,169	538,921	355,688
1995	115,440	77,345	547,432	361,305
1996	122,500	82,075	568,906	375,478
1997	123,700	82,879	576,986	380,811
1998	129,055	86,467	579,187	382,263
1999	134,496	90,112	610,989	403,253
2000	127,400	85,358	598,894	395,270
2001	139,900	93,733	598,036	394,703
2002	107,730	72,179	569,228	375,690
2003	132,789	88,969	584,822	385,983
2004	124,697	83,547	607,741	401,109
2005	137,690	92,252	631,868	417,033
2006	139,137	93,222	644,116	425,117
Average	112,577	75,427	534,553	352,805
Std	19,527	13,083	65,564	43,272
(%)	17.35%	17.35%	12.27%	12.27%
Std (1991-2006)				6.49%

Sources:
IRRI World Rice Statistics (WRS). Milled rice equivalent was calculated by authors by applying 0.67 and 0.66 for Indian and world production, respectively, based on mill rate obtained from IRRI.

Appendix II - Rice production, rice price, domestic demand of rice in selected countries and world

Table 1a - India

Year	Domestic wholesale price (nominal)[a]	Domestic wholesale price (CPI (2000=100) adjusted)[b]	Paddy rice production[c]	Production - milled rice equivalent[d]	Net export of milled rice[e]	Domestic demand (Production - export)
	(rupee/ton)	(rupee/ton)	(k ton)	(k ton)	(k ton)	(k ton)
1995	6,900	9,933	115,440	77,345	3,676	73,669
1996	7,795	10,297	122,500	82,075	2,087	79,988
1997	8,169	10,070	123,700	82,879	4,666	78,213
1998	9,518	10,362	129,055	86,467	2,752	83,715
1999	9,705	10,094	134,496	90,112	1,449	88,663
2000	8,904	8,904	127,400	85,358	1,936	83,422
2001	9,207	8,880	139,900	93,733	6,650	87,083
2002	-	-	107,730	72,179	4,421	67,758
2003	-	-	132,789	88,969	3,172	85,797
2004	-	-	124,697	83,547	4,687	78,860
2005	-	-	137,690	92,252	4,537	87,715
2006	-	-	139,137	93,222	6,301	86,921

Table 1b - India Summary

	Domestic wholesale price (CPI (2000=100) adjusted)	Production - milled rice equivalent (kilo ton)	Net export of milled rice (kilo ton)	Domestic demand (Production - export)
2000-2006		**87,037**	**4,529**	**82,508**
1995-2000	9,943	84,039	2,761	81,278
Demand curve constant (wei. Ave.1995-2000)				**8,886,246**

Sources:

a: IRRI World Rice Statistics (WRS)

b: Calculated by authors based on CPI obtained from WDI for (1995-2004) and EIU (for 2005-2006). EIU data converted to 2000=100 basis.

c: FAOSTAT Database, 2008.

d: Calculated by authors based on Indian mill rate, 0.67, (conversion rate from paddy rice to milled rice), published by IRRI.

e: USDA

Table 2a - Thailand

Year	Domestic wholesale price (nominal)[a]	Domestic wholesale price (CPI (2000=100) adjusted)[b]	Paddy rice production[c]	Production - milled rice equivalent[d]	Net export of milled rice[e]	Domestic demand (Production - export)
	(baht/ton)	(baht/ton)	(k ton)	(k ton)	(k ton)	(k ton)
1995	7,344	9,037	22,016	14,530	5,281	9,249
1996	7,824	9,097	22,332	14,739	5,216	9,523
1997	8,423	9,274	23,580	15,563	6,367	9,196
1998	11,647	11,865	23,450	15,477	6,679	8,798
1999	8,586	8,721	24,172	15,954	6,549	9,405
2000	7,332	7,332	25,844	17,057	7,521	9,536
2001	7,040	6,927	26,523	17,505	7,245	10,260
2002	7,681	7,511	26,057	17,198	7,552	9,646
2003	7,636	7,335	27,038	17,845	10,137	7,708
2004	8,968	8,382	28,538	18,835	7,274	11,561
2005	11,144	9,963	30,292	19,993	7,376	12,617
2006	11,169	9,543	29,269	19,318	9,557	9,761

Table 2b - Thailand Summary

	Domestic wholesale price (CPI (2000=100) adjusted)	Production - milled rice equivalent (kilo ton)	Net export of milled rice (kilo ton)	Domestic demand (Production - export)
2000-2006		**18,250**	**8,095**	**10,155**
1995-2000	9,221	15,553	6,269	9,284
Demand curve constant (wei. Ave.1995-2000)				**206,907**

Sources:

a: IRRI World Rice Statistics (WRS)

b: Calculated by authors based on CPI obtained from WDI for (1995-2004) and EIU (for 2005-2006). EIU data converted to 2000=100 basis.

c: FAOSTAT Database, 2008.

d: Calculated by authors based on Indian mill rate, 0.66, (conversion rate from paddy rice to milled rice), published by IRRI.

e: USDA

Appendix II - Rice production, rice price, domestic demand of rice in selected countries and world

Table 3a - Pakistan

Year	Domestic wholesale price (nominal)[a]	Domestic wholesale price (CPI (2000=100) adjusted)[b]	Paddy rice production[c]	Production - milled rice equivalent[d]	Net export of milled rice[e]	Domestic demand (Production - export)
	(rupee/ton)	(rupee/ton)	(k ton)	(k ton)	(k ton)	(k ton)
1995	7,875	11,177	5,950	3,986	1,668	2,318
1996	7,886	10,141	6,457	4,326	1,775	2,551
1997	9,052	10,451	6,500	4,355	1,994	2,361
1998	10,328	11,226	7,011	4,698	1,838	2,860
1999	8,813	9,198	7,733	5,181	2,026	3,155
2000	7,875	7,875	7,204	4,827	2,417	2,410
2001	8,740	8,473	5,823	3,901	1,603	2,298
2002	9,427	8,848	6,718	4,501	1,958	2,543
2003	11,229	10,241	7,271	4,872	1,986	2,886
2004			7,537	5,050	3,032	2,018
2005			8,321	5,575	3,579	1,996
2006			8,137	5,452	2,696	2,756

Table 3b - Pakistan - Summary

	Domestic wholesale price (CPI (2000=100) adjusted)	Production - milled rice equivalent (kilo ton)	Net export of milled rice (kilo ton)	Domestic demand (Production - export)
2000-2006		**4,883**	**2,467**	**2,415**
1995-2000	10,011	4,562	1,953	2,609
Demand curve constant (wei. Ave.1995-2000)				**113,947**

Sources:

a: IRRI World Rice Statistics (WRS)

b: Calculated by authors based on CPI obtained from WDI for (1995-2004) and EIU (for 2005-2006). EIU data converted to 2000=100 basis.

c: FAOSTAT Database, 2008.

d: Calculated by authors based on Indian mill rate, 0.67, (conversion rate from paddy rice to milled rice), published by IRRI.

e: USDA

Table 4a - Vietnam

Year	Domestic Retail price (nominal)$_a$	Estimated domestic wholesale price (nominal)$_b$	Estiated domestic wholesale price (CPI (2000=100) adjusted)$_c$	Paddy rice production$_d$	Production - milled rice equivalent$_e$	Net export of milled rice$_f$	Domestic demand (Production - export)
	(k dong/ton)	(k dong/ton)	(k dong/ton)	(k ton)	(k ton)	(k ton)	(k ton)
1995	2,761	2,540	3,042	24,964	16,226	3,039	13,187
1996	3,057	2,812	3,186	26,397	17,158	3,326	13,832
1997	2,817	2,592	2,845	27,524	17,891	3,776	14,115
1998	3,516	3,235	3,311	29,146	18,945	4,495	14,450
1999	3,389	3,118	3,066	31,394	20,406	3,330	17,076
2000	3,032	2,789	2,789	32,530	21,144	3,488	17,656
2001	-	-	-	32,108	20,870	3,205	17,665
2002	-	-	-	34,447	22,391	3,755	18,636
2003	-	-	-	34,569	22,470	3,995	18,475
2004	-	-	-	36,149	23,497	4,854	18,643
2005	-	-	-	35,791	23,264	4,355	18,909
2006	-	-	-	35,827	23,287	4,072	19,215

Table 4b - Vietnam Summary

	Domestic wholesale price (CPI (2000=100) adjusted)	Production - milled rice equivalent (kilo ton)	Net export of milled rice (kilo ton)	Domestic demand (Production - export)
2000-2006		**22,418**	**3,961**	**18,457**
1995-2000	3,040	18,628	3,576	15,053
Demand curve constant (wei. Ave.1995-2000)				**403,269**

Sources:

a: IRRI World Rice Statistics (WRS)

b: Wholesale price is estimated to be 92% of retail price.

c: Calculated by authors based on CPI obtained from WDI for (1995-2004) and EIU (for 2005-2006). EIU data converted to 2000=100 basis.

d: FAOSTAT Database, 2008.

e: Calculated by authors based on Indian mill rate, 0.65, (conversion rate from paddy rice to milled rice), published by IRRI.

f: USDA

Appendix II - Rice production, rice price, domestic demand of rice in selected countries and world

Table 5 - World import

Elasticity	-0.58

Year	Thai 2nd Grade 100%a	CPI-adjusted price$_b$	import - all rice (kilo ton)c	Constant terms (Demand)
	($/ton)	(k ton)	(k ton)	(k ton)
2000	207	207	23,119	509,603
2001	177	172	25,954	514,081
2002	197	189	25,865	540,155
2003	201	188	25,769	537,389
2004	244	222	26,145	600,823
2005	291	257	26,832	669,951
2006	311	266	27,930	711,500
Average (2000-2006)				583,358
Average (1995-2000)				604,317

Source:

a: IRRI World Rice Statistics (WRS)

b: Calculated by authors based on CPI obtained from WDI for (2000-2004) and EIU (for 2005-2006). EIU data converted to 2000=100 basis.

c: IRRI World Rice Statistics (WRS)

Table 6 - The Philippines

Year	Paddy rice production$_a$	Milled-rice equivalent$_b$	Milled rice Import$_c$
	(k ton)	(k ton)	(k ton)
2000	12,389	8,053	1,175
2001	12,955	8,421	1,250
2002	13,271	8,626	1,300
2003	13,500	8,775	1,100
2004	14,497	9,423	1,890
2005	14,603	9,492	1,791
2006	15,327	9,962	1,900
Average	13,792	8,965	1,487

Sources:

a: IRRI World Rice Statistics (WRS)

b: Calculated by authors based on Philippines' mill rate, 0.65, (conversion rate from paddy rice to milled rice), published by IRRI.

c: IRRI World Rice Statistics (WRS)

Appendix III - Montly export price of Thai rice 5% brokens

Table 1 - Monthly export price (nominal, US$/ton)

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	241	241	226	215	199	196	189	187	179	188	185	184
2001	184	185	175	164	164	168	169	168	173	171	174	179
2002	192	195	189	190	198	203	200	190	187	186	187	186
2003	201	199	197	195	198	203	199	195	198	196	193	197
2004	213	213	238	241	232	229	231	239	235	244	259	278
2005	287	290	293	297	294	285	277	283	285	286	278	281
2006	291	302	304	302	308	313	315	313	309	301	296	305
2007	313	315	323	317	318	323	329	328	325	329	342	361
2008	376	465	594	907	902	757	732	694	684	609	552	531

Source: IRRI World Rice Statistics (WRS)

Table 2 - Monthly export price (CPI - adjusted, 2000=100, US$/ton)

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	241	241	226	215	199	196	189	187	179	188	185	184
2001	179	180	170	160	160	163	164	163	168	166	169	174
2002	184	187	181	182	190	194	191	182	179	178	179	178
2003	188	186	184	183	185	190	186	183	185	183	181	184
2004	194	194	217	220	211	209	211	218	214	222	236	253
2005	253	256	258	262	259	251	244	250	251	252	245	248
2006	249	258	260	258	263	267	269	267	264	257	253	261
2007	262	264	270	265	266	270	275	274	272	275	286	302
2008	301	372	476	727	723	606	586	556	548	488	442	426

Calculated by authors based on CPI obtained from WDI for (2000-2004) and EIU (for 2005-2006).
EIU data converted to 2000=100 basis.

Ave(2000-2008)	251
Std(2000-2008)	111
Median	221
Minimum	160
Maximum	727

Appendix III Export Margins of Selected Countries

Table 1 - India

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	6,900	32.43	213	63.3%
1996	352	7,795	35.43	220	62.5%
1997	316	8,169	36.31	225	71.2%
1998	315	9,518	41.26	231	73.2%
1999	253	9,705	43.06	225	89.1%
2000	207	8,904	44.94	198	95.7%
2001	177	9,207	47.19	195	110.2%
2002	197	n/a			
2003	201	n/a			
2004	244	n/a			
2005	291	n/a			
2006	311	n/a			
Average (1995 and after)					80.8%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Table 2 - Thailand

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	7,344	24.92	295	87.7%
1996	352	7,824	25.34	309	87.7%
1997	316	8,423	31.36	269	85.0%
1998	315	11,647	41.36	282	89.4%
1999	253	8,586	37.81	227	89.8%
2000	207	7,332	44.43	165	79.7%
2001	177	7,040	42.96	164	92.6%
2002	197	7,681	41.49	185	94.0%
2003	201	7,636	40.22	190	94.5%
2004	244	8,968	40.22	223	91.4%
2005	291	11,144	37.88	294	101.1%
2006	311	11,169	33.6	332	106.9%
Average (1995 and after)					91.6%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Table 3 - Pakistan

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	7,875	31.64	249	74.1%
1996	352	7,886	36.08	219	62.1%
1997	316	9,052	41.11	220	69.7%
1998	315	10,328	45.04	229	72.8%
1999	253	8,813	49.5	178	70.4%
2000	207	7,875	53.65	147	70.9%
2001	177	8,740	59.72	146	82.7%
2002	197	9,427	57.75	163	82.9%
2003	201	11,229	58.26	193	95.9%
2004	244				
2005	291				
2006	311				
Average (1995 and after)					75.7%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Table 4 - Vietnam

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	2,540	11038	230	68.5%
1996	352	2,812	11032	255	72.4%
1997	316	2,592	11683	222	70.2%
1998	315	3,235	13268	244	77.4%
1999	253	3,118	13943	224	88.4%
2000	207	2,789	14167	197	95.1%
2001	177				
2002	197				
2003	201				
2004	244				
2005	291				
2006	311				
Average (1995 and after)					78.7%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Appendix IV - Multi-country Monte Carlo Simulation: Example - Scenario 1

simulation input variable Simulation output variable

Assumptions

	India	Thailand	Pakistan	Vietnam	others	total	Philippines	Others	Total	Note
Average production	87,037	18,250	4,883	22,418		358,817	8,965			milled rice, ton ('000). Average 2000 - 2006
Average export	4,529	8,095	2,467	3,961	9,194	28,246				milled rice, ton ('000). Average 2000 - 2006
Average import							1,487	24,458	25,945	milled rice, ton ('000). Average 2000 - 2006
Trigger price 1 (quota)	275	1,000	1,000	300						Set around the price at then end of the month before
Trigger price 2 (ban)	370	1,500	1,500	475			370			ban was implemented during 2007 and 2008

Assumptions for initial price distribution

mode	221	- 5% broken thai rice, FOB, 2000-2008 monthly average
maximum	350	- CPI adjusted (2000=100)
minimum	160	
Int'l price	183	

(of importing countries)

Elasticity	-0.58
constant	583,358

(calibrated based on 2000-2006 data)

	Exporers						Importers			Note
Without intervention	India	Thailand	Pakistan	Vietnam	others	total	Philippines	Others	Total	
Average export	4,529	8,095	2,467	3,961	9,368	28,419				Total export/import calibrated from demand function
Average import							1,628	26,791	28,419	Reduction equally allocated by import share
Intervention - Round 1	India	Thailand	Pakistan	Vietnam	others	total	Philippines	Others	Total	
Quota/Ban/Subsidy	None	None	None	None	n/a		None			
Revised export	4,529	8,095	2,467	3,961	9,368	28,419				
Revised import							per market		28,419	
Export available to importing countries without intervention						28,419				Revised export less revised import of intervening importer
Revised price	183									'=(supply/constant (demand))^(1/ε(demand))
Intervention - Round 2	India	Thailand	Pakistan	Vietnam	others	total	Philippines	Others	Total	
Quota/Ban	None	None	None	None	n/a		None			
Revised export	4,529	8,095	2,467	3,961	9,368	28,419				
Revised import							per market		28,419	
Export available to importing countries without intervention						28,419				Revised export less revised import of intervening importer
Revised price	183									'=(supply/constant (demand))^(1/ε(demand))
Intervention - Round 3	India	Thailand	Pakistan	Vietnam	others	total	Philippines	Others	Total	
Quota/Ban	None	None	None	None	n/a		None			
Revised export	4,529	8,095	2,467	3,961	9,368	28,419				
Revised import							per market		28,419	
Export available to importing countries without intervention						28,419				Revised export less revised import of intervening importer
Revised price	183									'=(supply/constant (demand))^(1/ε(demand))

Appendix V Export Margins of Selected Countries

Table 1 - India

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	6,900	32.43	213	63.3%
1996	352	7,795	35.43	220	62.5%
1997	316	8,169	36.31	225	71.2%
1998	315	9,518	41.26	231	73.2%
1999	253	9,705	43.06	225	89.1%
2000	207	8,904	44.94	198	95.7%
2001	177	9,207	47.19	195	110.2%
2002	197	n/a			
2003	201	n/a			
2004	244	n/a			
2005	291	n/a			
2006	311	n/a			
Average (1995 and after)					80.8%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Table 2 - Thailand

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	7,344	24.92	295	87.7%
1996	352	7,824	25.34	309	87.7%
1997	316	8,423	31.36	269	85.0%
1998	315	11,647	41.36	282	89.4%
1999	253	8,586	37.81	227	89.8%
2000	207	7,332	44.43	165	79.7%
2001	177	7,040	42.96	164	92.6%
2002	197	7,681	41.49	185	94.0%
2003	201	7,636	40.22	190	94.5%
2004	244	8,968	40.22	223	91.4%
2005	291	11,144	37.88	294	101.1%
2006	311	11,169	33.6	332	106.9%
Average (1995 and after)					91.6%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Table 3 - Pakistan

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	7,875	31.64	249	74.1%
1996	352	7,886	36.08	219	62.1%
1997	316	9,052	41.11	220	69.7%
1998	315	10,328	45.04	229	72.8%
1999	253	8,813	49.5	178	70.4%
2000	207	7,875	53.65	147	70.9%
2001	177	8,740	59.72	146	82.7%
2002	197	9,427	57.75	163	82.9%
2003	201	11,229	58.26	193	95.9%
2004	244				
2005	291				
2006	311				
Average (1995 and after)					75.7%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Table 4 - Vietnam

Year	World price ($)	Domestic price			Dom/ World
		Nominal price	Exchange rate	$ Equivalent	
1995	336	2,540	11038	230	68.5%
1996	352	2,812	11032	255	72.4%
1997	316	2,592	11683	222	70.2%
1998	315	3,235	13268	244	77.4%
1999	253	3,118	13943	224	88.4%
2000	207	2,789	14167	197	95.1%
2001	177				
2002	197				
2003	201				
2004	244				
2005	291				
2006	311				
Average (1995 and after)					78.7%

Source: IRRI WRS.
$ equivalent and ratio calculated by the authors

Appendix VI - Multi-country model **Scenario 1**

Scenario 1	India	Thailand	Pakistan	Vietnam	Others	Total exp. countries	Int'l price	Note	Import demand	export-import
Average export	4,529	8,095	2,467	3,961	9,194	28,246				
Shock to production					(25,691)			1 std of average world production 1991-2006		
Revised domestic demand	72,105	8,477	2,169	12,989				simulataneously calculated as int'l price		
Without intervention										
Actual export	14,932	9,773	2,714	9,428	(16,497)	20,350		average + shock - revised domestic demand		
International price without any intervention							346	using solver to make export-import=0	20,350	(0)
Round 1										
Intervention	Quota	None	None	Quota						
Revised domestic demand	81,071	6,550	1,589	13,772	-			quota keeps the domestic price below trigger		
Export after intervention	5,966	11,700	3,293	8,645	(16,497)	13,108		ban keeps the domestic consumption at average	13,108	(0)
International price with intervention in Round 1							739			
Round 2										
Intervention	Ban	None	None	Ban						
Revised domestic demand	82,508	5,171	1,195	18,457				export quota is set to keep the domestic		
Actual export after ban	4,529	13,079	3,688	3,961	(16,497)	8,759		price below trigger price	8,759	0
International price with intervention in Round 2							1,480			
Round 3										
quota (yes or no?)	Ban	Quota	Quota	Ban						
Revised domestic demand	82,508	5,909	1,404	18,457				export quota is set to keep the domestic		
Actual export after ban	4,529	12,341	3,479	3,961	(16,497)	7,812		price below trigger price	7,812	0
International price with intervention in Round 3							1,803			

Assumptions

		India	Thailand	Pakistan	Vietnam	others	Total exp. countries	Note
domestic demand	elasticity	-0.51	-0.34	-0.41	-0.41			
	constant	8,886,246	206,907	113,947	403,269			calibrated for 1995-2000
Average production		87,037	18,250	4,883	22,418		395,253	milled rice, ton ('000). 2000-2006
Average export		4,529	8,095	2,467	3,961	9,194	28,246	milled rice, ton ('000). 2000-2006
Exchange rate (LCU/$)		45	38	60	16,000		n/a	approximate rate as of 2000 - source IRRI WRS
Export margin		81%	92%	76%	79%			Domestic/int'l price, average 1995 and after
Trigger price	quota	275	1,000	1,000	300			See report
	ban	370	1,500	1,500	475			

Import demand

Elasticity	-0.58
constant	604,317

If quota placed,

	India	Thailand	Pakistan	Vietnam
Domestic supply	87,037	18,250	4,883	22,418
Trigger price	275	1,000	1,000	300
Corresponding domestic demand	81,071	5,909	1,404	13,772
Corresponding export quota	5,966	12,341	3,479	8,645

Appendix VI - Multi-country model **Scenario 2**

Scenario 2	India	Thailand	Pakistan	Vietnam	Others	Total exp. countries	Int'l price	Note	Import demand	export-import
Average export	4,529	8,095	2,467	3,961	9,194	28,246				
Shock to production					(25,691)			1 std of average world production 1991-2006		
Revised domestic demand	72,105	8,477	2,169	12,989				simulataneously calculated as int'l price		
Without intervention										
Actual export	14,932	9,773	2,714	9,428	(16,497)	20,350		average + shock - revised domestic demand		
International price without any intervention							346	using solver to make export-import=0	20,350	0
Round 1										
Intervention	None	None	None	Quota						
Revised domestic demand	71,555	8,434	2,155	13,772	-			quota keeps the domestic price below trigger		
Export after intervention	15,482	9,816	2,727	8,645	(16,497)	20,174		ban keeps the domestic consumption at average	20,174	0
International price with intervention in Round 1							351			
Round 2										
Intervention	None	None	None	Quota						
Revised domestic demand	71,555	8,434	2,155	13,772				export quota is set to keep the domestic		
Actual export after ban	15,482	9,816	2,727	8,645	(16,497)	20,174		price below trigger price	20,174	0
International price with intervention in Round 2							351			
Round 3										
quota (yes or no?)	None	None	None	Quota						
Revised domestic demand	71,555	8,434	2,155	13,772				export quota is set to keep the domestic		
Actual export after ban	15,482	9,816	2,727	8,645	(16,497)	20,174		price below trigger price	20,174	0
International price with intervention in Round 3							351			

Assumptions

		India	Thailand	Pakistan	Vietnam	others	Total exp. countries	Note
domestic demand	elasticity	-0.51	-0.34	-0.41	-0.41			
	constant	8,886,246	206,907	113,947	403,269			calibrated for 1995-2000
Average production		87,037	18,250	4,883	22,418		395,253	milled rice, ton ('000). 2000-2006
Average export		4,529	8,095	2,467	3,961	9,194	28,246	milled rice, ton ('000). 2000-2006
Exchange rate (LCU/$)		45	38	60	16,000		n/a	approximate rate as of 2000 - source IRRI WRS
Export margin		81%	92%	76%	79%			Domestic/int'l price, average 1995 and after
Trigger price	quota	370	1,000	1,000	300			See report
	ban	450	1,500	1,500	475			

Import demand

Elasticity	-0.58
constant	604,317

If quota placed,

	India	Thailand	Pakistan	Vietnam
Domestic supply	87,037	18,250	4,883	22,418
Trigger price	370	1,000	1,000	300
Corresponding domestic demand	69,685	5,909	1,404	13,772
Corresponding export quota	17,352	12,341	3,479	8,645

Appendix VI - Multi-country model **Scenario 3**

Scenario 3	India	Thailand	Pakistan	Vietnam	Others	Total exp. countries	Int'l price	Note	Import demand	export-import
Average export	4,529	8,095	2,467	3,961	9,194	28,246				
Shock to production					(25,691)			1 std of average world production 1991-2006		
Revised domestic demand	72,105	8,477	2,169	12,989		0		simulataneously calculated as int'l price		
Without intervention										
Actual export	14,932	9,773	2,714	9,428	(16,497)	20,350		average + shock - revised domestic demand		
International price without any intervention							346	using solver to make export-import=0	20,350	0
Round 1										
Intervention	None	None	Quota	Quota						
Revised domestic demand	71,392	8,421	2,383	13,772	-			quota keeps the domestic price below trigger		
Export after intervention	15,645	9,829	2,500	8,645	(16,497)	20,122		ban keeps the domestic consumption at average	20,122	0
International price with intervention in Round 1							353			
Round 2										
Intervention	None	None	Quota	Quota						
Revised domestic demand	71,392	8,421	2,383	13,772				export quota is set to keep the domestic		
Actual export after ban	15,645	9,829	2,500	8,645	(16,497)	20,122		price below trigger price	20,122	0
International price with intervention in Round 2							353			
Round 3										
quota (yes or no?)	None	None	Quota	Quota						
Revised domestic demand	71,392	8,421	2,383	13,772				export quota is set to keep the domestic		
Actual export after ban	15,645	9,829	2,500	8,645	(16,497)	20,122		price below trigger price	20,122	0
International price with intervention in Round 3							353			

Assumptions

		India	Thailand	Pakistan	Vietnam	others	Total exp. countries	Note
domestic demand	elasticity	-0.51	-0.34	-0.41	-0.41			
	constant	8,886,246	206,907	113,947	403,269			calibrated for 1995-2000
Average production		87,037	18,250	4,883	22,418		395,253	milled rice, ton ('000). 2000-2006
Average export		4,529	8,095	2,467	3,961	9,194	28,246	milled rice, ton ('000). 2000-2006
Exchange rate (LCU/$)		45	38	60	16,000		n/a	approximate rate as of 2000 - source IRRI WRS
Export margin		81%	92%	76%	79%			Domestic/int'l price, average 1995 and after
Trigger price	quota	370	1,000	275	300			See report
	ban	450	1,500	370	475			

Import demand

Elasticity	-0.58
constant	604,317

If quota placed,

	India	Thailand	Pakistan	Vietnam
Domestic supply	87,037	18,250	4,883	22,418
Trigger price	370	1,000	275	300
Corresponding domestic demand	69,685	5,909	2,383	13,772
Corresponding export quota	17,352	12,341	2,500	8,645

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