HYBRID RICE AND ITS IMPACT ON FOOD SECURITY AND THE PATTERN OF GLOBAL PRODUCTION AND TRADE

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Abstract

The hybrid rice technology is one of the many ways in which productivity of scarce resources devoted to rice production could be enhanced, with the consequent alleviation of food insecurity. The findings of this study show that the hybrid rice technology has so far made some sizable contributions to per-capita availability of rice in adopting countries with marginal spillover effects to other regions. However, at forecasted population growths, a massive intensification of adoption would be needed to maintain per-capita availability of rice at baseline levels. But even with adoption rates climbing significantly, much higher equilibrium prices are expected, which will represent a challenge for the hungry in many parts of the world. While hybrid rice has the potential to contribute significantly to improve production and food security, more efforts are needed to improve the productivity of the constraining production resources.

Keywords: hybrid rice, food security, technology change.

JEL Classification codes: Q16, Q55

Introduction

Forecasts point to a steady increase in the global demand for rice of around 1 percent a year over the next decade. Demand increase is based primarily on population growth in important rice-consuming areas such as Asia, Africa, Central America, and the Middle East, since per-capita consumption is predicted to remain flat or even decrease in most rice consuming regions. At the same time, total rice production is projected to increase but at a slower pace than demand, based solely on yield improvements since total area is projected to decrease slightly over the next decade (FAPRI, 2009; USDA, 2010).

The forecasted rice deficit is troublesome from a food security standpoint, primarily in Asia, where rice remains the primary caloric source, and where undernourishment is prevalent (FAO, 2010).

The only way to cope with increasing demand given growing constraints on land and water is to increase the productivity of these constraining factors. Approaches to improve rice land productivity include higher investment in irrigation infrastructure and machinery, increasing the rate of and/or efficiency in the use of fertilizers and pesticides, and adopting new seed technologies with higher productivity potentials. In this regard, the hybrid rice seed technology is seen by many as a great tool to ameliorate the forecasted rice supply shortage (Yuan, 2004).

Reports on trial and commercial experiences from a number of primarily Asian countries highlight the yield improvements that the hybrid technology provides vis-à-vis most inbred varieties. In China, for instance, where hybrid rice accounted for roughly 18.5 million hectares or 63 percent of the acreage in 2008, the yield advantage over inbred rice cultivars ranged from 17.0 percent to 53.2 percent from 1976 to 2008, which equates to a 30.8 percent higher average yield (Li, Xin, and Yuan, 2009). There are differences in adoption of hybrids between *indica* and *japonica* types. While roughly 85% of the *indica* rice grown in China is hybrid, the adoption rate only amounts to 3% for *japonica* rice (Barclay, 2010).

Improvements in hybrid technology are allowing not only for higher output yields but also higher seed yields which contributes to a lower cost of adoption. Early three-line hybrids launched commercially in 1976 offered a significant boost in output yield over semi-dwarf varieties, but their low seed yield (0.5 MT/ha) resulted in significantly higher seed costs. Two-line hybrids released during the early 1990s not only offer higher output yields (5 to 10 percent) but also much better seed yields (between 3.0 and 3.5 MT/ha) than the earlier hybrid releases (Li, Xin, and Yuan, 2009). Improvements in seed yields have resulted in lower seed prices, which together with the much lower (roughly 4 times) seeding rate of hybrids vis-à-vis inbred varieties results in a more moderate increase in the production cost of hybrid relative to inbred rice, which is facilitating the adoption of the former (Li, Xin, and Yuan, 2009). Two-line hybrids accounted for around 18 percent of the acreage devoted to hybrids in China in 2002. One-way “super” hybrids obtained during the last decade exhibit even further increases in productivity (around 20 percent) and significantly better seed yields (above 3.0 MT/ha) compared to three-line hybrids (Yuan, 2004).

Outside China, the hybrid technology is spreading into some Asian countries such as India, Vietnam, Philippines, Indonesia and Bangladesh. However, despite positive yield differentials vis-à-vis inbred varieties, hybrid adoption rates still remain low, as shown in the table below. In some cases such as Bangladesh, where the government encouraged importation rather than local development of the seed industry, the main reason for the low adoption rate seems to be the high cost of hybrid seeds. In other regions, such as India and the Philippines, governments have invested in the development of the hybrid seed industry (in India, for instance, some 45 hybrid varieties have been released for commercial use), but adoption has been constrained by factors such as lack of awareness among farmers, high cost of inputs such as fertilizers needed for the positive yield differential of hybrids to be expressed; poor adaptation of hybrids to some particular environments such as shallow lowlands and boro (dry-season) rice; and also poor grain quality (Vien and Nga, 2009; Barclay, 2010, Janaiah and Xie, 2010).

Table 1. Hybrid rice area in major hybrid rice countries

Country	Hybrid Rice (1,000 hectares)	Percent to Total Rice Area
Bangladesh[a]	735	7.6%
India[a]	1,400	3.2%
Indonesia[b]	62	0.5%
Philippines[a]	346	10.2%
Vietnam[a]	645	9.0%
U.S.[b]	175	14.5%
Subtotal	***3.363***	***6.5%***
China[b]	17,000	57.6%

a. Figures for year 2008. Source: Janaiah and Xie, 2010.
b. Figures for year 2009. Source: Barclay, 2010.

Despite the low adoption rates observed among many Asian countries, contributions of hybrid rice technology to aggregate supply are not negligible. For instance, Vien and Nga (2009) estimate that the hybrid technology contributes 600,000 mt annually in Vietnam, sufficient to feed 1.9 million people a year. In India, it is estimated that hybrids have contributed to 1.5 to 2.5 mmt of additional rice, and experts forecast that hybrid rice might expand up to 5 million hectares by 2015 (Barclay, 2010).

Outside Asia, the hybrid rice technology has spread significantly in the U.S. over the last few years. According to experts, hybrids accounted for around 15 percent of the U.S. long-grain production in 2005 and increased to nearly 50 percent in 2008. Adoption rates in the Southern Cone (Brazil, Argentina, and Uruguay) remain low after several years of marketing the technology.

Despite its productivity boost and better adaptability to stress environments, the adoption of hybrid rice technology has been delayed by the challenges it entails. Developing the technology implies significant and steady investment in a seed program by either public or private agents. At the farm level, the technology might represent insurmountable financial and managerial constraints particularly for small impoverished farmers, due to the higher seed cost and more precise cultural techniques associated with this technology. Initial hybrid milling quality concerns seem to have been overcome by newly developed hybrids. In the U.S., for instance, milling rates are reported to be higher, and milling durations shorter (to obtain a certain degree of milling) for hybrids than conventional rice cultivars (Siebenmorgen, Matsler, and Earp, 2006).

Technological changes, such as the adoption of hybrid rice, have the potential to change the regional patterns of production, trade, and consumption, and consequently affecting the availability of a staple commodity on which a large portion of the world population relies as a source of caloric intake. This study attempts to answer two questions:

- What has been so far the impact of the hybrid rice technology on the pattern of production, consumption, trade, and the implications for food security in some key regions?;
- What is the potential contribution of the hybrid technology to help us cope with the forecasted shortage and rising cost of rice?

Answering each question entails running different scenarios, namely, an ex-post and ex-ante assessment, both of which are described in the following section.

METHODOLOGY

The RICEFLOW model (Durand-Morat and Wailes, 2010) is used in this study. RICEFLOW is a multi-region, multi-product, spatial partial equilibrium framework describing the rice world market. The production sector is specified as a two-stage budgeting process; the first production stage determines the conditional demand functions for intermediate inputs and the value-added composite, and the second stage determines the derived demands for factors of production. A number of technology variables associated with the productivity of factors and inputs are included. Final consumption is represented by a demand function, which depending on the functional form chosen, might account for both substitution as well as income effects. Import demand is specified according to Armington (1969); that is, the import composite substitutes for domestic goods in the production of a composite commodity according to a constant elasticity of substitution.

The model is flexible with regard to the specification of production technologies and consumer preferences. Production can be specified as a CES, Cobb-Douglas, or Leontief technologies. Furthermore, consumer preferences can be represented by a constant-difference- elasticity (CDE), CES, Cobb-Douglas, or Leontief functional form.

For this study, the two stages of production are specified as Leontief, thus ignoring the potential substitution effects between factors and inputs that might actually occur. In a scenario of inelastic supply of resources, this specification can be understood as the worst-case scenario in the sense that no substitution is allowed, thus magnifying the impact of scarce resources.

Furthermore, we assume a perfectly elastic supply of inputs (fertilizers, pesticides, energy, and seeds), highly elastic supplies of labor and capital, and perfectly inelastic supply of land in all regions; this specification we believe describes well the future scenario in most regions. The inelasticity of land supply, together with the assumption of no-substitution in production, stresses the importance of that factor as a constraint to the expansion of production.

Regarding the mobility of factors of production, labor and capital are specified as perfectly mobile across activities, while land is a sluggish factor with unitary elasticities of transformation. Finally, unitary elasticities of substitution between the imports and domestic commodities are assumed.

Demand for final consumption is specified as a non-homothetic, CDE function. Data on price and income elasticities from most regions come from the Arkansas Global Rice Model database (Wailes and Chavez, 2010); otherwise, default values for price and income elasticities are set at -0.15 and 0.15, respectively.

The database used to calibrate the model represents the global rice market situation in calendar year 2008[1]. It includes data on production (cost of production, market value of production, value

[1] Calendar year 2008 was chosen as a baseline because this is the latest year for which data is available and systematically organized for most regions included in the database. It is important to bear in mind that 2008 was marked by the rice crisis, which reached its peak on April 2008. The price of Thai 100% B rice tripled between October 2007 and April 2008, reaching a historical record high of USD 1,000 per metric ton. Rice prices by the end of 2008 had declined significantly from the peak reached during the peak of the crisis. For a detailed analysis of the 2007-2008 rice crisis see Dawe (2010).

of domestic support), changes in inventories, bilateral trade, final and intermediate consumption, and trade policies (tariffs and tariff-rate-quotas), all by rice type (long grain, medium grain, and fragrant rice) and milling degree (paddy, brown, and milled rice), for the top 65 regions involved in rice trade during that period of time.

This study takes into consideration the behavior of the hybrid rice technology in Bangladesh, China, India, the U.S., and Vietnam. The assessment is constrained to these five countries due to access to reliable cost of production data. The changes in the rates of adoption of hybrid rice are implemented through a series of shocks to the technology variables describing the efficiency in the use of intermediate inputs and factors of production, and shocks to the input price variables, primarily the price of seeds[2].

The ex-post assessment aims at estimating the realized contributions of hybrid rice to production, consumption, and trade. The ex-post analysis entails running a single scenario in which the efficiency and cost effects of producing hybrid rice are removed according to (1) the rates of adoption, (2) the changes in resource efficiencies, and (3) the changes in input prices reported for each of the five countries taken into consideration.

The ex-ante assessment attempts to forecast the potential effects of the hybrid rice technology on the global rice market and its contribution to food security in specific countries. The ex-ante assessment entails running three scenarios, namely, (1) a benchmark or status-quo scenario, which entails shocking the model to account for the forecasted behavior of some key exogenous variables such as population, gross domestic product, and fuel and energy prices up to the year 2020; (2) a technology 1 scenario, which differs from the benchmark scenario (1) in that it assumes that adoption rates of hybrid rice will double in the five countries under consideration, and (3) a technology 2 scenario, which differs from the benchmark scenario (1) in that it attempts to find the adoption rates of hybrid rice that will maintain per-capita availability in the five countries under consideration at the 2008 level.

[2] Recall that the study does not break production by inbred and hybrid rice, but rather takes the aggregate figures reported by countries. For instance, China's volume and value of production of long grain in 2008 is roughly 116 mmt and USD 26,219 million, respectively. From the literature consulted we can infer that 85% of the volume of long grain production corresponds to hybrid rice. This share is taken into consideration when estimating the change in the efficiency in the use of factors and inputs as well as changes in input prices.

RESULTS AND DISCUSSION

EX-POST ASSESSMENT

Production

The rice market in some countries in 2008 would have looked quite different in the absence of hybrid rice (see Appendix Table 1 for nominal volumes and values of production for the selected countries). As expected, all adopters of hybrid rice would have obtained lower production, with the largest impact estimated for China. Rice production in China would have been 18.2 mmt or 9.3% lower than actually reported as a result of a decrease in the production of both long grain (12.2 mmt or 10.4%) and medium grain rice (6 mmt or 7.9%).

Without hybrids, global rice production would have been 15.3 mmt or 2.3% lower, driven primarily by reductions in long grain (12.5 mmt or 2.2%) and, to a lesser extent, reductions in medium grain (2.8 mmt or 2.7%) and fragrant rice (50 tmt or 0.5%). Differences in the impact across rice types result primarily from the different rates of adoption of hybrids by type. Most of the hybrid rice production comes from long grain, with minor adoption in the medium grain and fragrant segments[3].

Table 2. The ex-post impact of hybrid rice technology on the volume and value of rice production

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Production Volume -- Paddy	**-2.3%**	**-1.6%**	**-9.3%**	**-0.8%**	**-2.0%**	**-2.4%**
Long Grain Paddy	*-2.2%*	*-1.6%*	*-10.4%*	*-0.8%*	*-1.9%*	*-2.4%*
Medium Grain Paddy	*-2.7%*	--	*-7.9%*	--	*-2.1%*	--
Fragrant Paddy	*-0.5%*	--	--	*-2.0%*	--	--
Producer Prices						
Long Grain Paddy	--	*1.8%*	*14.3%*	*1.0%*	*2.2%*	*3.0%*
Medium Grain Paddy	--	--	*10.5%*	--	*2.7%*	--
Fragrant Paddy	--	--	--	*2.6%*	--	--
Value of Production*	**1,160.5**	**38.8**	**976.2**	**80.3**	**11.6**	**54.9**
Long Grain Paddy	*816.3*	*38.8*	*643.8*	*73.7*	*6.9*	*54.9*
Medium Grain Paddy	*337.5*	--	*332.4*	--	*4.8*	--
Fragrant Paddy	*6.7*	--	--	*6.7*	--	--

*. Change expressed in USD million.

[3] Janaiah and Xie (2010) highlight the production potential of new basmati hybrid rice. Reports on commercial production suggest yields similar to non-basmati rice, and much higher than conventional basmati varieties. Despite the commercial hurdles that remain to be solved, these developments have great potential to change the behavior of the fragrant rice markets.

Farm prices in all hybrid-adopting countries would have been higher than observed. In China, farmers would have been paid 14.3% and 10.5% higher prices for their long grain and medium grain output. Increases in farm prices in all other hybrid-adopting countries would have been more modest (3% or less). Notice that the percentage increases in prices are larger than the percentage decreases in production for all countries, evidence of the inelastic nature of aggregate demand for rice.

As a result of the changes in volumes and prices discussed above, the aggregate value of paddy rice production in the hybrid-adopting countries would have been USD 1,160 million higher, but yet marginal compared to the estimated value of production of USD 236.5 billion realized in those five countries in 2008.

The effects of the removal of hybrid rice on the pattern of production would have been largely confined to hybrid-rice adopting countries, with no significant changes in the patterns of rice production volumes and prices in other countries.

Final Consumption

Higher costs of production and consequently higher farm prices resulting from the absence of hybrid rice would have carried throughout the supply chain and resulted in higher consumer prices, which at 2008 level of income would have yielded lower consumption volumes in the hybrid-adopting countries (see table below). The largest contraction in consumption would have happened in China, equivalent to 12.8 mmt (9.4%) of total consumption, or roughly 14 kg per capita consumption. This reduction would have been particularly significant for poor households who rely on rice for up the 50% of their calories. The reduction in consumption would have meant reductions in per-capita consumption of around 10 kg in Vietnam, 5 kg in Bangladesh, and less than 1 kg in other countries.

Table 3. The ex-post impact of hybrid rice technology on the pattern of rice consumption

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Consumption Volume	**-2.4%**	**-1.5%**	**-9.4%**	**-0.8%**	**-1.7%**	**-2.5%**
Long Grain	*-2.3%*	*-1.5%*	*-10.5%*	*-0.8%*	*-1.8%*	*-2.5%*
Medium Grain	*-3.0%*	--	*-7.9%*	--	*-2.3%*	--
Fragrant	*-0.7%*	--	*0.0%*	*-1.9%*	*-0.4%*	--
Consumer Prices						
Long Grain		*1.6%*	*11.6%*	*0.8%*	*1.8%*	*2.5%*
Medium Grain		--	*8.7%*	--	*2.6%*	--
Fragrant		--	*0.0%*	*2.3%*	*0.3%*	--

Trade

The findings suggest that, in aggregate, the hybrid rice technology had impacted international rice trade only marginally (see table below). Overall, total rice trade would have been around 255 tmt or 1.1% lower than actually reported in 2008. Trade of long grain rice, which represents roughly 80% of total rice trade, would have been 0.9% lower, while trade of medium grain (6% of total rice trade) and fragrant rice (14% of total trade) would have been 2.9% and 1.0% lower than actually reported.

China, the sixth largest exporter of rice in 2008 (10th and 2nd largest exporter of long grain and medium grain rice, respectively) would have traded 7.9% less rice than reported. Vietnam, India, and the U.S. (the 2nd, 3rd, and 4th largest rice exporters in 2008) would have also reported less trade, primarily of long grain rice.

Table 4. The impact of hybrid rice technology on international rice trade.

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Volume Exports	**-1.1%**	**0.0%**	**-7.9%**	**-1.4%**	**-1.9%**	**-2.2%**
Long Grain	*-0.9%*	--	*-10.7%*	*-0.8%*	*-1.8%*	*-2.2%*
Medium Grain	*-2.9%*	--	*-6.8%*	--	*-2.1%*	--
Fragrant	*-1.0%*	--	--	*-2.0%*	--	--
Volume Imports	**-1.1%**	**-1.1%**	**-0.1%**	**0.0%**	**-0.7%**	**-8.8%**
Long Grain	*-0.9%*	*-1.1%*	*-0.2%*	*0.0%*	*-0.5%*	*-8.8%*
Medium Grain	*-2.9%*	--	--	--	*-4.3%*	--
Fragrant	*-1.0%*	--	*0.0%*	--	*-0.4%*	--
Export Prices (f.o.b.)	**1.2%**	**0.0%**	**10.1%**	**1.6%**	**2.1%**	**2.6%**
Long Grain	*1.1%*	--	*12.6%*	*0.8%*	*2.0%*	*2.5%*
Medium Grain	*3.5%*	--	*8.8%*	--	*2.4%*	--
Fragrant	*1.1%*	--	--	*2.3%*	--	--

On a bilateral basis, and taking into consideration that the U.S. and China are the two largest exporters of medium grain rice, accounting for roughly 75% of the international market of this type, we should expect that imports by medium grain deficit nations such as Japan, South Korea, and Turkey would have felt the spillover effects of the technology change in exporting countries. Yet our findings suggest small reductions in medium grain imports of around 2.5%, 4.5%, and 1% for Japan, South Korea, and Turkey, respectively.

The rice export price index[4] would have been 1.2% higher, with the largest (but still marginal) percentage increase in export prices reported for medium grain rice (3.5%). China again would have experienced the largest increase in export prices, estimated at around 12.6% and 8.8% for long grain and medium grain rice, respectively. Price increases in other countries would have remained within 3% of the price actually realized in 2008.

The results of this study suggest that the absence of hybrid rice in 2008 would have had no impact on either total trade by commodity, that is, by milling degree and type, or aggregate volume of rice trade by non-adopting countries. This is the same as saying that the estimated reductions in domestic production as a consequence of the absence of hybrid rice would have been restricted to impacting primarily the domestic market in those same countries, with only minor adjustments to imports from abroad and, consequently, minimal spillovers into other regions[5].

Ex-Ante Assessment[6]

Production

Doubling the adoption of hybrid rice (scenario technology 1) in Bangladesh, China, India, the U.S., and Vietnam have the potential of marginally increasing net global rice production by

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[4] It is estimated as an aggregate trade-weighted average of the change in bilateral f.o.b. prices.

5 Recall that imports and domestic production are specified as imperfect substitutes, with an assumed elasticity of substitution equal to 1. When assuming perfect substitution between domestic products and imports, the main changes from the reported results are less dramatic reductions in consumption in hybrid-adopting countries; the effects of domestic production remain close to what is reported in this study. Consult the authors for more details on results from this alternative scenario.

6 The results presented in this section must be interpreted as the difference generated by the technology scenario 1 relative to the benchmark or *status quo* scenario.

around 6.0 mmt or 0.9%. The expansion of hybrid rice would translate into gains in production of around 5.0 mmt in China (primarily long grain), 1.3 mmt in India, 1.0 mmt in Vietnam, 0.8 mmt in Bangladesh, and 0.2 mmt in the U.S.

The additional volume of production is expected to translate primarily into more than proportional reductions in farm prices, again owing to the inelasticity of aggregate demand for paddy rice in these countries. For instance, Chinese rice farmers will realize 8.1% and 1.2% lower prices for long grain and medium grain paddy, respectively, which will lower the value of production by USD 212 million. Vietnamese rice farmers will also observe significant reductions of nearly 6% in producer price, while rice producers from India and the U.S, will see a decline below 3.0%.

Table 5. The impact of doubling the adoption of hybrid rice technology on the volume and value of rice production by year 2020

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Production Volume -- Paddy	**0.9%**	**1.6%**	**1.8%**	**0.9%**	**1.9%**	**2.5%**
Long Grain Paddy	*1.1%*	*1.6%*	*2.7%*	*1.0%*	*2.1%*	*2.5%*
Medium Grain Paddy	*0.3%*	--	*0.5%*	--	*1.6%*	--
Fragrant Paddy	*0.1%*	--	--	*0.2%*	--	--
Producer Prices						
Long Grain Paddy	--	*-3.0%*	*-8.1%*	*-2.4%*	*-2.9%*	*-5.6%*
Medium Grain Paddy	--	--	*-1.2%*	--	*-2.2%*	--
Fragrant Paddy	--	--	--	*-1.3%*	--	--
Value of Production*	**-430.2**	**-41.5**	**-211.5**	**-108.5**	**-11.8**	**-56.6**
Long Grain Paddy	*-480.8*	*-41.5*	*-264.9*	*-108.4*	*-8.8*	*-56.6*
Medium Grain Paddy	*50.4*	--	*53.4*	--	*-3.0*	--
Fragrant Paddy	*0.1*	--	--	*-0.1*	--	--

*. Change in value expressed in USD million.

Consumption

As expected, doubling the adoption of the hybrid rice technology will lead to a new equilibrium with lower consumer prices and marginally higher consumption levels. Again the largest changes are estimated for China, where the long grain market will balance at a volume of 3.5 mmt or 2.8% higher than the benchmark, and at 6.6% lower consumer prices. Vietnamese consumers will also expand their consumption by around 1.0 mmt and pay roughly 5% lower prices as a result of the expansion in the adoption of hybrid rice.

Table 6. The impact of doubling the adoption of hybrid rice technology on the pattern of rice consumption by year 2020

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Consumption Volume	**0.9%**	**1.6%**	**1.8%**	**1.0%**	**1.6%**	**2.6%**
Long Grain	*1.1%*	*1.6%*	*2.8%*	*1.0%*	*2.1%*	*2.6%*
Medium Grain	*0.3%*	*--*	*0.5%*	*--*	*1.5%*	*--*
Fragrant	*0.1%*	*--*	*0.0%*	*0.3%*	*0.2%*	*--*
Consumer Prices						
Long Grain		*-2.9%*	*-6.6%*	*-2.1%*	*-2.4%*	*-4.7%*
Medium Grain		*--*	*-1.0%*	*--*	*-2.0%*	*--*
Fragrant		*--*	*0.0%*	*-1.2%*	*-0.1%*	*--*

Trade

The findings suggest that, in aggregate, the expansion in the adoption of hybrid rice will impact the international rice market very marginally from the benchmark (see table below). Vietnam is expected to benefit the most, increasing total rice trade by around 100 tmt or 2.4%, but receiving an equally proportional lower price for its exports, yielding a value of exports similar to that estimated for the benchmark.

The value of global rice trade is estimated to be marginally lower as a result of the expansion of the hybrid rice technology because of lower export prices that offset only marginally the increase in global volume of trade.

Table 7. The impact of doubling the adoption of hybrid rice technology on trade of selected countries by 2020.

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Volume Exports	**0.6%**	**0.0%**	**1.1%**	**0.7%**	**1.8%**	**2.4%**
Long Grain	*0.7%*	*--*	*2.9%*	*0.9%*	*2.0%*	*2.4%*
Medium Grain	*0.6%*	*--*	*0.4%*	*--*	*1.5%*	*--*
Fragrant	*0.1%*	*--*	*--*	*0.5%*	*--*	*--*
Volume Imports	**0.6%**	**1.0%**	**0.0%**	**0.0%**	**0.3%**	**2.2%**
Long Grain	*0.7%*	*1.0%*	*0.0%*	*0.0%*	*0.5%*	*2.2%*
Medium Grain	*0.6%*	*--*	*0.0%*	*--*	*0.2%*	*--*
Fragrant	*0.1%*	*--*	*0.0%*	*0.0%*	*0.2%*	*--*
Export Prices (f.o.b.)	**-0.8%**	**0.0%**	**-1.1%**	**-0.7%**	**-2.0%**	**-2.4%**
Long Grain	*-1.0%*	*--*	*-2.9%*	*-1.0%*	*-2.1%*	*-2.4%*
Medium Grain	*-0.8%*	*--*	*-0.4%*	*--*	*-1.6%*	*--*
Fragrant	*-0.2%*	*--*	*--*	*-0.4%*	*--*	*--*

The findings of this assessment with regard to production, consumption, and trade, suggest that the impacts of the technology scenario are confined primarily to the five countries where the technological change is assumed to happen.

IMPLICATIONS FOR FOOD SECURITY

Achieving food security implies guaranteeing access (physical availability and affordability) to safe and nutritious food to the entire population. Improving food security is the key goal of the World Food Summit of 1996 and the first Millennium Development Goal[7].

Food security assessments have traditionally been done either at the macro level (market stability) or micro level (household access). Although the methodology used in this study constrains us to focus on the macro level, it can help us shed some light on the potential contribution of the hybrid rice technology to regional and global rice supply and, thus, to market stability.

According to FAO (2010), roughly 60% of the close to one billion undernourished people live in Asia, where rice is the main staple food. This fact highlights the importance of rice and the Asian region in matters related to food security. As Timmer (2010) states, “it is impossible to improve food security in the short run or long run without providing adequate supplies of rice that are accessible to the poor” (p. 2).

The findings from the ex-post assessment suggest that the hybrid technology has made some sizeable contribution towards improving food security, but only in regions where the technology has been extensively embraced (see table below). Contributions to production on a per-capita basis range from around 14 kg or 9.5% in China, 11 kg or 2.5% in Vietnam, and 5 kg or 1.6% in Bangladesh, which translate closely into similar changes in per-capita consumption (with the exception of Vietnam, whose contribution to per-capita consumption is estimated at 9 kg).

The findings from the ex-ante assessment point to a significant decrease in the per-capita availability of rice, which might be ameliorated only slightly by the further expansion of hybrid rice. Per-capita rice availability in Bangladesh and Vietnam is estimated to decline dramatically by 51 kg and 46 kg from the 2008 level, respectively, and the expansion of hybrid rice might

[7] The World Food Summit goal is to halve the number of undernourished people between 1990-92 and 2015. The Millennium Development Goal 1, target 1C, is to halve the proportion of people suffering hunger between 1990 and 2015 (FAO, 2010).

improve availability relative to the benchmark only slightly. Smaller reductions are forecasted for India and China.

Table 8. Impact of the hybrid rice technology on per-capita rice availability and prices in selected regions and scenarios

	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
2008-2020 Population Growth	**12.7%**	**21.0%**	**5.1%**	**16.3%**	**12.2%**	**12.7%**
Per-cap Rice Production[1] (Kg)						
Baseline Year 2008	123.4	310.0	146.8	130.0	30.4	442.3
No Hybrid Rice Year 2008	120.5	305.2	133.1	128.9	29.8	431.7
Benchmark Scenario Year 2020	110.4	259.1	140.1	113.6	27.1	396.5
Tech 1 Scenario Year 2020	111.4	263.3	142.7	114.6	27.6	406.2
Per-cap Rice Consumption[1] (Kg)						
Baseline Year 2008	121.8	322.2	145.2	121.4	19.4	362.6
No Hybrid Rice Year 2008	118.8	317.2	131.6	120.4	19.0	353.6
Benchmark Scenario Year 2020	108.0	268.4	139.4	108.1	17.6	343.9
Tech 1 Scenario Year 2020	109.1	272.6	141.9	109.1	17.9	352.4
Real Price of Rice[2]						
No Hybrid Rice Year 2008	2.4%	1.6%	10.3%	0.8%	1.7%	2.5%
Benchmark Scenario Year 2020	85.9%	85.5%	138.0%	122.1%	32.9%	94.6%
Tech 1 Scenario Year 2020	84.1%	82.6%	133.8%	120.0%	30.9%	89.9%

1. Expressed in paddy basis.
2. Percentage increase in consumer prices from the 2008 baseline.

Furthermore, the real price of rice is forecasted to increase significantly over the next decade, and doubling the adoption of hybrid rice will contribute to reduce prices only slightly. Consumer prices are estimated to more than double the prices observed in 2008 in China and India, and almost double in Bangladesh and Vietnam. In other words, consumers in these Asian countries will need to spend twice as much as what was needed in 2008 to afford the same level of consumption. Putting these results in perspective and assuming that the forecasted 2008-2020 real gross domestic product rates of growth for Bangladesh (87%), China (140%), India (130%), U.S. (35%), and Vietnam (108%) are achieved, then rice will become more affordable in all regions but more significantly in Vietnam and India. However, the high income inequalities estimated for the Asian countries under consideration means that the poorest segments of the population that rely the most on rice for caloric intake will perceive lower income gains, most likely lower than the expected increases in rice prices, thus making rice less affordable.

These results are troublesome because they mean that, if per capita consumption remains the same as in 2008, given the current endowment and productivity of resources devoted to rice production, the availability of rice will shrink and its price increase significantly, which will likely worsen food security situation primarily in Asia.

So if hybrid rice is the key to improve productivity and output, then the empirical inquiry is by how much adoption should increase to maintain the levels of availability observed in 2008. As the findings reported in the following table show, the adoption rate of hybrid rice must increase dramatically over the next decade for countries to afford the 2008 per-capita availability. But even if countries afford to boost hybrid rice adoption to the estimated rates, consumer prices are nevertheless likely to experience significant increases, although lower than the estimated benchmark prices (see Table 7 above) and forecasted 2008-2020 growth in gross domestic product estimated for these countries. But as discussed above, income inequality in these regions lead us to infer that food security among the poorest segments of the population will be undermined.

Table 9. Estimated rate of adoption required to maintain per-capita availability of rice and change in equilibrium prices relative to the 2008 price level

	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Hybrid Adoption Rate	**90%**	**84%**	**50%**	**70%**	**55%**
Per-capita Production	-0.1%	1.5%	-0.7%	-4.2%	0.8%
Per-capita Consumption	-0.5%	2.0%	1.6%	-3.5%	6.8%
Real Producer Prices	60.9%	151.8%	108.3%	16.7%	87.1%
Real Consumer Prices	55.3%	123.8%	94.8%	25.4%	72.8%

The rise in producer prices is likely to improve the income of landowners and thus compensate for the higher consumption cost[8]. However, such a rise in producer prices will not improve the purchasing power of the landless rural and urban population.

CONCLUSIONS

The challenge remains for many countries to bring food insecurity down to the levels committed under the World Food Summit and the Millennium Development Goals. The results of this study

[8] By zero profit condition in production, the cost of production will exhaust total revenue. Since land is assumed to be in inelastic supply, the increase in revenue will translate primarily into higher land rental prices, thus benefiting owners of land.

are troublesome in the sense that per-capita availability of rice is forecasted to decrease significantly while at the same time real consumer prices are forecasted to increase from the level observed in 2008. What happens to rice dramatically affects what happen to food security, for rice happens to be a staple in those regions most affected by undernourishment.

Even more troublesome is the fact that our counterfactual does not represent a world with acceptable levels of undernourishment, but rather 2008, a year in which food insecurity was at its peak. Hence, the sharp increase in the adoption of hybrid rice needed to maintain a per-capita availability of rice similar to that observed in 2008 is undoubtedly insufficient to bring food insecurity down.

Hybrid rice is a promising technology to help countries cope with the rising demand for rice and the constraints on supply, but it can be only a part of the solution to food insecurity. Scientists must come up with other alternatives to improve the productivity of the constraining resources in a sustainable manner.

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APPENDIX

Appendix Table 1. Baseline volume and market value of production for selected countries

VARIABLES	WORLD	BANGLADESH	CHINA	INDIA	U.S.	VIETNAM
Production (mmt paddy)	**659.4**	**46.9**	**193.4**	**148.3**	**9.2**	**38.7**
Long Grain Paddy	*543.2*	*46.9*	*116.0*	*145.3*	*7.4*	*38.7*
Medium Grain Paddy	*105.3*	*0.0*	*77.4*	*0.0*	*1.8*	*0.0*
Fragrant Paddy	*10.9*	*0.0*	*0.0*	*3.0*	*0.0*	*0.0*
Production (USD million)	**236,549**	**20,638**	**44,858**	**57,211**	**3,465**	**9,952**
Long Grain Paddy	*175,620*	*20,638*	*26,219*	*56,084*	*2,447*	*9,952*
Medium Grain Paddy	*56,385*	*0*	*18,639*	*0*	*1,018*	*0*
Fragrant Paddy	*4,544*	*0*	*0*	*1,127*	*0*	*0*
Consumption (mmt paddy)	**652.3**	**48.7**	**191.0**	**138.5**	**5.9**	**31.7**
Long Grain	*536.4*	*48.7*	*114.4*	*137.6*	*4.2*	*31.7*
Medium Grain	*105.0*	*0.0*	*76.6*	*0.0*	*1.1*	*0.0*
Fragrant	*10.9*	*0.0*	*0.2*	*0.9*	*0.6*	*0.0*
Consumption (USD million)	**292,310**	**23,490**	**54,483**	**60,494**	**2,855**	**11,477**
Long Grain	*208,820*	*23,490*	*31,439*	*60,121*	*1,710*	*11,477*
Medium Grain	*76,316*	*0.0*	*22,833*	*0.0*	*666*	*0.0*
Fragrant	*7,174*	*0.0*	*211*	*373*	*479*	*0.0*