Hybrid Rice as a Pro-Poor Technology? Evidence from Bangladesh

William McFall, Graduate Student
Department of Agricultural and Applied Economics, University of Georgia
309 Conner Hall, Athens GA, 30602
Email: wmcfall@uga.edu

Nicholas Magnan, Assistant Professor
Department of Agricultural and Applied Economics, University of Georgia
315C Conner Hall, Athens GA, 30602
Email: nmagnan@uga.edu

David J. Spielman
International Food Policy Research Institute
2033 K St NW, Washington DC, 20006
Email: d.spielman@cgiar.org

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August 4-6, 2013.

Hybrid Rice as a Pro-Poor Technology? Evidence from Bangladesh

William McFall, Nicholas Magnan, David J. Spielman

ABSTRACT

We examine the use of hybrid rice as a pro-poor technology for subsistence rice farmers in South Asia. Hybrids, for which seed cannot be saved, is often thought to be ill-suited for poor farmers. However, poor subsistence farmers may find it advantageous to produce "sticky" hybrid rice instead of generally preferred slender open pollinated varieties, even though there is little market demand for it. We use two separately estimated double hurdle models to model the decision making process of subsistence rice-producing households as they allocate their land and consumption bundle between hybrid and open pollinated rice varieties. We find that relatively rich households are more likely to adopt hybrid rice. However, contingent on adoption, poor households allocate a higher percentage of their land to hybrids. Moreover, we find that own-produced hybrid rice consumption constitutes a higher percentage of total rice consumption for poor households than for rich households.

Key Words: hybrid rice, technological adoption, market access

JEL Codes: 013, O14, O33

Culturally and physically rice is one of the world's most important cereals, sustaining over half the world's population. Although produced across the globe, rice production occurs mainly in developing countries with over 50% of the world's 840 million chronically hungry people living in areas dependent on rice production (Redoña, 2004, United Nations, 2005). However, nowhere is rice more important than in Asia with 92% of the world's rice consumption coming from the region. In addition to consumption, the continent dominates world rice production with nine out of ten of the world's largest rice producing countries coming from Asia; China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, the Philippines, and Japan (United Nations, 2005). Recently, declines in rice yield growth rates as well as land pressures from urbanization and population growth have left Asian countries searching for ways of improving rice yields. For many countries in the region, hybrid rice seems to be a viable option with a wide range of studies noting the benefits of the technology including yield increases over conventional open pollinated varieties (OPV), increases in farm incomes, and stabilized grain prices for both urban and rural consumers (Spielman, et al., 2012).

Hybrid rice in China, which has had rapid and widespread adoption since its initial commercialization in 1976, has been estimated to have helped China feed an additional 60 million people per year while opening 5 million hectares of land for alternative uses (Li, et al., 2010). China's success largely reflects long-term investment in research and development of hybrid varieties that began in 1964 (Li, et al., 2010,

Spielman, et al., 2012). Beyond China, development of the technology has been much slower due to limited institutional support and research capacity.

For countries unable to domestically produce hybrid varieties, importation of seed can allow for immediate adoption. Adoption of imported hybrids is hindered by the fact that they are generally not as well adapted to the local environment and could potentially have decreased yields, lower grain quality, and taste. Organizations and individuals in opposition to the technology have expressed concerns over the possibility that imported hybrid rice varieties ill-adapted to the local soil and photoperiodic climate could cause increases in the use of pesticide, herbicide, and irrigation (GRAIN, 2009). They cite the potential for soil toxicity and nutrient depletion as well as water contamination and the potential for long-term dependence of small farmers on multi-national seed companies (GRAIN, 2009).

Despite the risks, hybrid rice plantings in South Asia have come largely from imported seed from China and domestic seed production from germplasms of Chinese parent lines (Spielman, et al., 2012).[1] For both India and Bangladesh, initial introduction of hybrid varieties not appropriate for South Asian tastes has caused significant problems for producers and likely contributed to the slow adoption of the technology in those countries. In South Asia, consumers generally prefer longer grain slender rice

[1] As of the date of publication, Bangladesh and India have recently introduced locally developed varieties that seem to offer some improved characteristics over imports, including grains better suited to South Asian tastes. In 2001, a Basmati rice hybrid (Pusa RH-10) was developed at the Indian Agricultural Research Institute. Further study of varietal impact on hybrid adoption could be an additional area of interest.

with a high amylose content while in Southeast Asia and China, consumers generally prefer coarser grain "sticky" rice with a lower amylose content (Muazzam Husain, et al., 2001, Rashid, 2011, Spielman, et al., 2012).[2] In fact, producers in Bangladesh and India who grow "sticky" hybrid rice from imported Chinese seed have to decide between consuming rice that they do not prefer or selling the grain to a market that offers a discounted premium due to limited demand. Initially in Bangladesh a price penalty of 4% - 5% existed for hybrid rice over conventional inbred varieties, however more recently adopted hybrid varieties seem to have diminished this premium (Spielman, et al., 2012). In India, price penalties vary more widely across the country however certain areas have seen penalties of 11% for hybrid rice over conventional inbred varieties (Janaiah and Xie, 2010).[3]

Price penalties for hybrid rice are especially interesting as India and Bangladesh both have large populations of calorie-insufficient households. Economic theory tells us that calorie-insufficient households will choose the cheapest calories available when given a choice, however recent research suggests that even poor households prefer food quality over quantity (Deaton and Drèze, 2009, Jensen and Miller, 2008, Minten, et al., 2013).[4] For subsistence households, this choice is a production choice rather than a consumption choice. In Bangladesh, higher quality rice, medium and long grain rice, are

[2] Consumers in South Asia seem to prefer rice with an amylose content of 25% or greater as anything below that threshold gives a "sticky" texture.
[3] In Haryana and Uttar Pradesh, price penalties were close to zero however in Chattisgarh price penalties were almost 11%.
[4] Suggestions for the changing behavior include declines in calorie requirements due to recent changes in transportation systems, labor requirements, and rice milling practices

garnering a larger percentage of the rice market with the price premium for higher quality rice doubling over the last thirty years (Minten, et al., 2013). The relationship between wealth and hybrid rice adoption is therefore complicated and multifaceted.

This study specifically looks at adoption processes in Bangladesh by analyzing the role of the hybrid rice as a "cheap" calorie source for poor subsistence households. In the study we model the production and consumption decision processes of hybrid rice producers using double hurdle models. The models help us better understand who is producing and consuming hybrid rice and to what extent. We begin by providing some background information on cereal grain hybridization and hybrid rice in Asia. We then introduce our study area, Bangladesh and present the data used for the study. Next, we outline the methodology used and present relevant findings. Finally we present concluding remarks, potential implications of the study, and areas for further research.

Background

Hybridization of cereal crops, including rice, is the process of crossing differing parent lines with superior traits to form offspring with characteristics desirable to agricultural production. Crop scientists cross parent lines that lead to offspring that produce higher yields than traditional inbred lines, a phenomenon called hybrid vigor or heterosis (International Rice Research Institute, 2003, Spielman, et al., 2012). The offspring of the hybrid cross have increased yields for only one growing season and are therefore not commonly saved for planting the following year. For this reason, hybrids must be

crossed every year, unlike traditional varieties and high yielding varieties (HYV), which are self-pollinated and can be saved for following growing seasons without yield loss. Farmers' inability to save hybrid seed, although potentially creating reliance on commercial seed companies, creates economic incentives for seed companies to improve their product through seed research and development. This potentially leads to significant advancements in seed technology as seen in maize and other hybrid crops (Spielman, et al., 2012).

Hybrid Rice in Asia

Although the potential for rice hybridization was first documented in India in 1954, China has been the major developer of the technology, initiating research in 1964 and identifying critical germplasm by 1970 (Li, et al., 2010). Continuous research and development of the technology has allowed China to increased yields from 3.5 ton/ha in 1975 to almost 7 ton/ha today (Li, et al., 2010). Research advancements as well as governmental policies promoting the technology have given China the greatest degree of adoption with hybrid rice accounting for 63% of the rice area under cultivation (Li, et al., 2010). In addition to yield improvements, hybrid adoption in China has allowed the country to open up more than 2 million hectares of land for other uses (Julfiquar, 2002, Spielman, et al., 2012). However, China is certainly not the only country conducting research and development on technology. The government of India began systematic research in 1989, Bangladesh in 1993, Vietnam in 1992, and the Philippines in 1993

(Spielman, et al., 2012). Private and non-governmental organizations in the region have begun research as well. Initial research on the technology suggests significant benefits to production, however farmers in South Asia and Southeast Asia have been slow to adopt. Currently, hybrid rice accounts for less than 10% of area under cultivation in Bangladesh, India, Indonesia, and the Philippines and just 10% in Vietnam (Spielman, et al., 2012).

Hybrid rice in Bangladesh

Bangladesh is one of the most densely populated countries on the planet with an estimated 139.25 million people in an area roughly the size of Iowa (Bangladesh Bureau of Statistics, 2011a). Although densely populated, the country is largely rural with 81% of the population living in rural areas and 47% of the population working in the agricultural sector (Bangladesh Bureau of Statistics, 2011a, Bangladesh Bureau of Statistics, 2011b). Sitting at the base of the Himalayan Mountains, Bangladesh is one of the world's wettest countries with average annual rainfall levels of 90 inches. Although beneficial for agriculture, the heavy annual rains leave the country prone to natural disasters with over 80% of the land area within a floodplain (Brammer, 1990). Floods and cyclones continually destroy assets and productive resources, leaving many individuals in poverty. The country is one of the poorest in Asia with an estimated 40% of the population living below the national upper poverty line. Poverty levels have led to widespread malnutrition in the country with an estimated 48% of children under five

underweight. The major crops produced in Bangladesh are rice, jute, wheat, and potato although in 2010-2011, 77% of the area under cultivation was used for rice cultivation (Bangladesh Bureau of Statistics, 2011b).

Rice cultivation is conducted during three seasons: *aus*, *aman*, and *boro*. *Aus* is generally directly planted in March-April and harvested in July-August, *aman* is generally transplanted in June-July and harvests in November-December, and *boro* is generally transplanted in December-January and harvested in May-June. This study will focus largely on the *boro* season as the vast majority of hybrid production occurs in this season. The annual harvest area and yield for the 2007/08 season to the 2010/11 season are shown below in Table 1.

Table 1. Annual Harvest Area and Yield by Season and Variety, 2007/08 – 2010/11

Crop	Variety	2007/08		2008/09		2009/10		2010/11	
		Area[1]	Yield[2]	Area	Yield	Area	Yield	Area	Yield
Aman	Broadcast	761.1	377	996.2	463	1175.1	482	1052.8	483
	Local	3308.3	502	3443.5	603	3494.6	640	3251.0	658
	HYV	8404.4	918	9145.0	992	9323.2	1009	9647.1	1051
	Aman Total	12473.8	775	13584.6	855	13992.9	872	13950.9	917
Boro	Local	311.5	724	301.9	721	265.2	809	195.3	829
	HYV	9118.9	1534	9341.6	1484	9671.3	1512	9967.9	1538
	Hybrid	1955.5	1816	2010.9	1853	1694.7	1901	1624.8	1924
	Boro Total	11385.9	1560	11654.3	1528	11631.2	1553	11788.0	1579
Aus	Local	884.5	461	929.0	481	832.2	473	780.4	504
	HYV	1385.5	793	1704.0	850	1599.5	823	1969.6	883
	Aus Total	2270.0	664	2633.0	720	2431.7	703	2750.0	776

Source: (Bangladesh Bureau of Statistics, 2011b)
[1]Area in thousands of acres harvested
[2]Yield in kilograms per acre

Beyond the importance of rice to producers and agricultural laborers, rice is the most important food stuff in Bangladesh, providing 76% of the daily caloric intake for consumers (Salam, et al., 2009). In addition, rice expenditures make up a significant portion of total food expenditures, comprising 40% (Minten, et al., 2011). Because rice is essential for producers and consumers alike, the government of Bangladesh is working to promote rice research and development. They are especially focused on improving rice yields that will allow the country to remain self-sufficient despite the nation's annual population growth rate of 1.5% per annum (Julfiquar, 2002).

Hybrid rice research and development began in the 1993 at the Bangladesh Rice Research Institute (BRRI), although concerted efforts were not undertaken until 1996 with additional technical support from the International Rice Research Institute (IRRI) and financial support from Bangladesh Agricultural Research Council (BARC) (Julfiquar, 2002, Rashid, 2011). In 1998-99 widespread floods led to shortfalls in domestic seed supply, leading the National Seed Board (NSB) to allow imports of two hybrid varieties: Alok, a variety from China and Sonar Bangla, a variety from India.[5] In 2001, the government of Bangladesh released their first governmentally developed national hybrid, a variety called BRRI hybrid dhan-1 (Julfiquar, 2002). From 1998-2010, a total of 85 hybrid varieties were released in Bangladesh by the NSB. Of the 85 varieties, 83 were intended for transplant in the *Boro* season with only 2 intended for *Aman* season

[5] The NSB is a statutory body comprised of 21 members from governmental institutions and private seed companies. The board helps advise the government of Bangladesh on the creation of rules and regulations related to the seed industry. All new rice varieties must undergo registration, testing, and certification before gaining approval from the NSB.

(Rashid, 2011). In addition, private firms or non-governmental organizations released 80 of the 85 with only 5 coming from the public sector. Only eight of these varieties were developed within Bangladesh: four from BRRI, two from BARC, and two from private firms. As of now, hybrid rice cultivation occurs mostly within the *boro* season in northern districts, particularly within Rajshahi and Rangpur districts (Spielman, et al., 2012). This area is generally drier than other rice producing regions of the country and is heavily irrigated. As mentioned previously, the vast majority of currently available hybrids are "sticky" imported coarse grain varieties. A great remaining challenge is the development of hybrid rice suitable to South Asian tastes.

Before delving into an empirical analysis of our data, we first present a conceptual framework to serve as a guide. Current research on rice marketing in South Asia shows that market availability of hybrid rice is limited and varies widely across the country. The market for hybrid rice is therefore characterized by asymmetry in which producers are able to sell hybrid rice but are unable to buy hybrid rice. Producers can sell OPV varieties and can sell hybrid varieties, although hybrid varieties are sold at a price penalty to millers who are often polish hybrid grain and mixed it with OPVs for sale. Consumers can purchase OPV rice but limited market availability leaves producers unable to purchase hybrid rice.

Given these limitations, it becomes apparent why poor subsistence farmers may grow relatively more hybrid rice than OPVs; poor farmers may choose to grow hybrid rice for the relatively cheap calories that can't be obtained in the market. We would

therefore expect that poorer households would allocate a larger percentage of their land to hybrid rice in order to obtain the relatively cheap grain not available in the market. We would also expect that poorer households would consume a larger percentage of hybrid rice as compared to wealthier households. However, we recognize that a number of well-documented barriers might prevent poorer farmers from adopting hybrid seed at all. Given the barriers to hybrid adoption for poor farmers and the incentives to produce and consume a greater amount of cheap calories using hybrid rice, we model the adoption process in two steps using double hurdle models for the production and consumption decision process facing rice producers.

Data

The data for this study comes from the Bangladesh Integrated Household Survey Questionnaire (BIHS) 2011-2012. The BIHS is a household-level survey administered to 5,503 households between October 2011 and March 2012, 2,573 of which are rice farmers. For our analysis, rice producers from Barisal division have been removed as no hybrid households were found in this division. The nationally representative survey was designed and supervised by International Food Policy Research Institute (IFPRI) and administered by Data Analysis and Technical Assistance Limited (DATA). The survey covers a wide range of household-level economic and social variables as well as plot-level variables on agricultural plot utilization and management.

For analysis, we divide rice producing households into hybrid and OPV households and calculate basic statistics of central tendency for a range of household characteristics. To get an initial look at household wealth characteristics we include total land holdings, estimated resale value of land holdings, *qurbani* expenditures, television ownership, housing condition, and flooring material.[6] Households are classified as hybrid households if at least one of their plots was cultivated with hybrid rice, regardless of extent of adoption. Hybrid households may also produce OPV varieties. Results of the calculation of descriptive statistics are shown below in Table 2.

[6] Housing condition was based on survey enumerator observation of housing condition. Enumerator responses of 'somewhat damaged', 'very damaged,' and 'in a very poor state' were considered indicators of poor housing conditions and were classified as the affirmative response for the factor analysis. Enumerator responses of 'no sign of damage' or 'slightly damaged' were classified as the negative response for the factor analysis. Flooring material was based on survey enumerator observation of floor material. Houses with concrete flooring were classified as the affirmative response for the factor analysis and all other materials were classified as the negative response. Qurbani expenditures includes cash expenditures on the sacrifice of animals for religious ceremonies.

Table 2. Descriptive Statistics for Hybrid and OPV Households

Variable	Hybrid Rice Households[1] N = 206 Mean Value	OPV Rice Households N = 2346 Mean Value	P-value of Difference
Wealth Variables:			
Television ownership (= 1)	0.354	0.266	0.0109**
Land holdings (acres)	1.20	.89	0.0072***
Land holdings estimated market value (taka)	1415172	1194517	0.1286
Housing damage (= 1)	0.583	0.666	0.0208**
Concrete floor (=1)	0.107	0.097	0.6686
Qurbani expenditures (taka)	2347	1972	0.2715
Geographic Variables:			
Dhaka (=1)	0.214	0.345	0.0000***
Rajshahi (=1)	0.189	0.128	0.0316**
Chittagong (=1)	0.126	0.105	0.3850
Khulna (=1)	0.150	0.123	0.2926
Rangpur (=1)	0.209	0.108	0.0007***
Syhet (=1)	0.112	0.119	0.7519
Barisal (=1)	N/A	0.071	N/A
Consumption Variables:			
Household consumption of own rice (kg)	915	672	0.0000***
Production Variables:			
Literacy[2] (=1)	0.529	0.461	0.0613*
Rice cultivation area (acres)	1.80	1.37	0.0006***

Note: *, **, *** indicate that means are statistically different at the 10%, 5%, and 1% levels.
[1] Hybrid households may also produce OPV varieties
[2]A household is considered literate if the primary respondent self-reported the ability to both read and write. Individuals that could only write or only read are considered illiterate.

As the descriptive statistics show, certain individual wealth variables, including television ownership, land holdings, and housing damage, seem to indicate that hybrid households are wealthier than OPV households however additional wealth variables are not statistically significant at the 10% level. We also find that hybrid households have

higher literacy rates and cultivate larger rice plots than OPV households. While these results indicate that hybrid rice is adopted more by relatively wealthier farmers it is only part of the picture. Next we look at the amount of hybrid rice produced and consumed (relative to the total amount of rice produced and consumed), conditional on having adopted hybrid.

Hurdle Model Estimation

To further investigate the role of hybrid rice as a pro-poor technology we use two double hurdle models run separately for the production decision process and the consumption decision process. A double hurdle model is a two-tiered model which estimates a probit model for the first tier or hurdle and a truncated normal linear model for second tier or hurdle (Cragg, 1971). The model helps account for the high frequency of OPV households and allows for the explanatory variables to differ by tier. We first estimate a double hurdle model focused on the production decision, which we call the production model. This production model is specified with a first hurdle that estimates a household's decision whether or not to adopt the technology and a second hurdle that, contingent on adoption, estimates the extent of adoption (Ricker-Gilbert, et al., 2011). We then estimate the second double hurdle model, the consumption model. This model focuses on the consumption decision process. The consumption model is specified with a first hurdle that estimates a household's decision whether or not to consume hybrid rice and a second hurdle that, contingent on consumption, estimates

the extent of consumption of their own hybrid rice consumption. The following sections will contribute a more in-depth explanation of the models used.

Hybrid Production

Based on our conceptual model we expect that in the first tier we will find that wealthier households will be more likely to adopt hybrid rice as they generally have greater access to extension and complimentary inputs. However in the second tier we would find that conditional on adoption, poorer households dedicate a higher percentage of their land to hybrid rice as they attempt to maximize the number of cheap calories available to them. Empirically, the dependent variable in the first tier is a dichotomous variable indicating household adoption. The adoption variable takes a value of one if a household allocates hybrid rice to one or more plots and takes a value of zero otherwise. Although rudimentary, household cumulative land holdings are included in the model as a proxy for overall household wealth. Cumulative landholdings are measured in acres and include only land area owned by the household. This variable does not include rented or leased land. Division dummies are included for the seven divisions with dummies for Sylhet division removed to account for perfect multicollinearity and dummies for Barisal removed due to a lack of adoption observations within the region. Division dummy variables are included to account for geographical fixed effects.

In the second hurdle, the dependent variable is a continuous variable of the ratio of the area under hybrid rice cultivation over the total area under rice cultivation. In other words, this variable represents the percentage of the total area under rice cultivation that is used for hybrid rice production, thus a higher percentage would indicate that the household adopts the technology to a greater degree. Although it is possible to use different independent variables for the second stage of the double hurdle model, we have chosen to keep the variables the same as we hypothesize that the household characteristics that affect initial adoption also affect the extent of adoption. The results of the double hurdle model for household production are shown below in Table 3.

Table 3. Double-Hurdle Model of Factors Influencing Adoption and Extent of Adoption of Hybrid Rice – Production Model

	Hurdle 1 Probability of Adopting Hybrid Rice	Hurdle 2 Ratio of Hybrid Rice Cultivated Area to Total Rice Cultivated Area
	Probit Estimator	Truncated Normal Estimator
Independent Variables: The coefficients displayed are the conditional average partial effects (APEs)	Coefficient (p-Value)	Coefficient (p-Value)
Cumulative land holdings (acres)	.07005***	-.05023***
	(0.002)	(0.004)
Division dummy - Dhaka	.0459732	-.1614679**
	(0.707)	(0.044)
Division dummy - Rajshahi	.4693302***	-.5355196***
	(0.000)	(0.000)
Division dummy - Chittagong	.3714564**	-.1972311**
	(0.011)	(0.031)
Division dummy - Khulna	.3658525***	-.2431321***
	(0.009)	(0.005)
Division dummy - Rangpur	.5979445***	-.3727114***
	(.000)	(0.000)
Literacy dummy	.0842771	.0305229
	(0.269)	(0.522)
Age of primary respondent (years)	-.0035341	.0000781
	(0.224)	(0.968)
Average distance to point of sale (km)	-.0495477*	.0015297
	(0.098)	(0.944)
Intercept[1]	-1.592646***	.8525784***
	(0.000)	(0.000)

Note: *, **, *** indicates that the corresponding coefficients are statistically significant at the 10%, 5%, and 1% levels.

[1] Intercept includes Sylhet division which was removed to prevent perfect multicollinearity. The seventh division, Barisal, is not shown due to lack of adoption observations in the area.

The results of the double hurdle model for production indicate that households with larger land holdings, wealthier households, are more likely to adopt hybrid rice at the

1% level of significance. This supports previous studies that indicate that wealthier households, likely due to better access to seeds, fertilizer, and information, are more likely to adopt the technology (Muazzam Husain, et al., 2001). In addition, the model shows that division dummies are statistically significant for all division except the Dhaka division. This may be an indication that an indication that fixed effects may be more heterogeneous in the Dhaka division than in the other divisions. In addition, we find that average distance to point of sale has a negative influence on adoption of hybrid rice at a 10% level of significance. Although this could be due to numerous factors, it is hypothesized that as distance to markets increases, household are less likely to adopt the technology due to lack of access to seeds, extension services, and complementary inputs such as fertilizer, pesticides, and irrigation equipment. A lack of significance in the age and literacy variables is contrary to the findings of previous research however the sign of the point estimates matches our initial hypothesis.

The results of the second hurdle indicate that contingent on adoption, household with smaller land holdings, poorer households, utilize a higher percentage of their land for hybrid rice production at the 1% significance level. The findings suggest that hybrid rice offers additional utility to resource poor households willing to sacrifice taste preferences for the relatively cheap calories offered by hybrid rice. However, we need further information on the consumption decision process in order to fully investigate the role of the technology as a non-marketed consumptive good. The

following section highlights the specification and findings of the double hurdle model for household consumption.

Hybrid Consumption

The second model that we will use for the study is the consumption model. It is important to note that consumption in this analysis refers only to the consumption of rice grown by the household. Additional purchase of rice is not included in this model. The rationale for using a hurdle model for consumption is similar to the rationale for using one for production. Based on our conceptual model we expected that the first tier of the consumption model will be very similar to the first tier of the production model as a producer's decision to consume their own hybrid rice requires that they first grow hybrid rice. But the decision of how much of its own hybrid rice production a household will consume could be different, both from the decision to consume any hybrid rice and different from the decision of how much of their land to produce hybrid on, given that they adopt hybrid at all. In the second tier we expect that poorer households will consume a higher percentage of hybrid rice as they directly consume the cheap calories offered by hybrid rice. The results of the double hurdle model for household consumption are shown below in Table 4.

Table 4. Double-Hurdle Model of Factors Influencing Consumption and Extent of Consumption of Hybrid Rice – Consumption Model

	Hurdle 1 Probability of Consuming Hybrid Rice Probit Estimator	Hurdle 2 Ratio of Hybrid Rice Consumption to Total Rice Consumption Truncated Normal Estimator
Independent Variables: The coefficients displayed are the conditional average partial effects (APEs)	Coefficient (p-Value)	Coefficient (p-Value)
Cumulative land holdings (acres)	.04134* (0.083)	-.04396*** (0.003)
Division dummy - Dhaka	.0686454 (0.589)	-.0593661 (0.430)
Division dummy - Rajshahi	.3381512** (0.018)	-.2568648*** (0.002)
Division dummy - Chittagong	.4166416*** (0.005)	-.1440041* (0.083)
Division dummy - Khulna	.3266192** (0.024)	.0032933 (0.968)
Division dummy - Rangpur	.5696874*** (0.000)	-.0834167 (0.280)
Intercept[1]	-1.771791*** (0.000)	.9004815*** (0.000)

Note: *, **, *** indicates that the corresponding coefficients are statistically significant at the 10%, 5%, and 1% levels.

[1] Intercept includes Sylhet division which was removed to prevent perfect multicollinearity. The seventh division, Barisal, is not shown due to lack of adoption observations in the area.

The results of the first hurdle of the double hurdle model for consumption indicate that households with larger land holdings, wealthier households, are more likely to consume hybrid rice at the 10% level of significance. This is not surprising as the households that

choose to adopt the hybrid rice are also likely to consume that rice as the majority of farmers in Bangladesh directly consume a large portion of their rice production. In addition, we see that the signs of significant independent variables for the division dummies and intercept are the same for both models.

The results of the second hurdle of the double hurdle model, indicate that as cumulative land holdings increase, as wealth increases, the percentage of the total household rice consumption that comes from hybrid rice decreases at the one percent level of significance. This fact, in combination with the findings of the second hurdle of the production model, strongly supports our hypothesis that poor households prefer the relatively cheap calories provided by hybrid rice despite the lack of market demand for the crop.

Conclusions

In South Asia, hybrid rice adoption has been slow with less than 10% of rice area allocated to hybrid rice. In addition, lack of domestic research and development has left the countries dependent on imported hybrid seed poorly suited to South Asian tastes. Low consumer demand and limited production has created an asymmetric market for hybrid rice in which producers can sell hybrid rice but cannot easily buy hybrid rice. In this study we presented evidence that despite price penalties for hybrid rice and taste preferences for OPV varieties, producers in the region choose to adopt hybrid rice as a means of obtaining cheap calories offered the technology. In effect, for subsistence

households hybrid rice can serve as a pro-poor technology. Using two double hurdle models, we model the decision making process of rice-producing households as they allocate their land and consumption between hybrid and open pollinated rice varieties. We find, as expected, that rich households are more likely to adopt hybrid rice.

However, contingent on adoption poor households allocate a higher percentage of their land for the technology. Moreover, we find that hybrid rice consumption constitutes a higher percentage of own-produced rice consumption for poor households than for rich households. These findings support our hypothesis that rice producers in the region adopt hybrid rice as a means of obtaining cheap calories offered the technology. Further adoption of the technology could help promote food security in South Asia. In addition to more direct findings of the study, this paper also highlights the importance of consumer demand in hybrid adoption, particularly in a setting dominated by subsistence farming. Studies of technological adoption often focus solely on the advantages of a technology to the producer while mentioning only briefly the effect that the technology may have on consumer demand. In addition, this study may provide a justification for increased institutional support for research and development of hybrid varieties well adapted to domestic challenges.

References

Bangladesh Bureau of Statistics. 2011a. *Bangladesh Population & Housing Census.* Dhaka, Bangladesh: Bangladesh Bureau of Statistics.

---. 2011b. *Yearbook of Agricultural Statistics of Bangladesh.* Dhaka, Bangladesh: Bangladesh Bureau of Statistics.

Brammer, H. 1990. "Floods in Bangladesh: Geographical Background to the 1987 and 1988 Floods." *The Geographical Journal* (1):12.

Cragg, J.G. 1971. "Some statistical models for limited dependent variables with application to the demand for durable goods." *Econometrica: Journal of the Econometric Society*:829-844.

Deaton, A., and J. Drèze. 2009. "Food and Nutrition in India: Facts and Interpretations." *Economic and Political Weekly* (7):42.

GRAIN (2009) Bangladesh: Spread of Hybrid Rice Degrading Land, Increasing Pesticide Use Say Experts, GRAIN.

International Rice Research Institute. 2003. *Hybrid rice for food security, poverty alleviation, and environmental protection*. Metro Manila, Philippines: IRRI.

Janaiah, A., and F. Xie. 2010. *Hybrid Rice Adoption in India: Farm Level Impacts and Challenges*: IRRI.

Jensen, R.T., and N.H. Miller. 2008. "Giffen Behavior and Subsistence Consumption." *The American Economic Review* (4):1553.

Julfiquar, A.W. (2002) Hybrid Rice Research and Development in Bangladesh: Hybrid Rice for Food Security, Poverty Alleviation and Environmental Protection. Hanoi, Vietnam, pp. 235-245.

Li, J., Y. Xin, and L. Yuan (2010) Hybrid rice technology development: ensuring China's food security, ed. D.J. Spielman, and R. Pandya-Lorch. Washington; USA, International Food Policy Research Institute.

Minten, B., K.A.S. Murshid, and T. Reardon. 2013. "Food Quality Changes and Implications: Evidence from the Rice Value Chain of Bangladesh." *World Development* 42(0):100-113.

Minten, B., K.A.S. Murshid, and T. Reardon (2011) The quiet revolution in agrifood value chains in Asia: the case of increasing quality in rice markets in Bangladesh. Washington; USA, International Food Policy Research Institute.

Muazzam Husain, A.M., M. Hossain, and A. Janaiah. 2001. *Hybrid rice adoption in Bangladesh : a socioeconomic assessment of farmers' experiences*. Dhaka: Research and Evaluation Division, BRAC.

Rashid, H.-A. "Farmers' Participatory Yield Maximization Trial of Potential Rice Hybrids: Boro 2010-2011." Agricultural Advisory Society (AAS), July 2011.

Redoña, E.D. (2004) Rice Biotechnology for Developing Countries in Asia, ed. A. Eaglesham,A. Wildeman, and R.W.F. Hardy. Ithaca; USA, National Agricultural Biotechnology Council.

Ricker-Gilbert, J., T.S. Jayne, and E. Chirwa. 2011. "Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi." *American Journal of Agricultural Economics* 93(1):26.

Salam, M.A., M.S. Alam, and M.S. Islam. 2009. "Changing land use pattern and hybrid rice production: a way to improve food security in Bangladesh." *Bangladesh Journal of Political Economy* 25(i-ii):191-204.

Spielman, D.J., D. Kolady, P. Ward, R. Harun ar, and K. Gulati (2012) Public expenditures, private incentives, and technology adoption: the economics of hybrid rice in South Asia. Washington; USA, International Food Policy Research Institute.

United Nations, ed. 2005. *Rice is life : International Year of Rice 2004*: Rome, Italy : International Rice Commission : FAO, 2005.