Rice Production Response in Cambodia

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Abstract

This paper analyzes how Cambodian farmers and the government can respond to the rise of rice price. The study estimates rice production response in Cambodia using the Cambodia Socio-Economic Surveys (CSES) conducted in 2004 and 2007. The results indicate that agricultural productivity is far from its potential and can be increased substantially by using modern technology and inputs such as fertilizers and irrigation. Our findings also suggest that the Cambodian government needs to design its investment strategy to relax constraints in rural infrastructure such as transportation and electricity in order to increase its agricultural production and productivity and boost farmers' income.

Key Words:

Production response, government investment, price, rice, Cambodia

JEL Code
C21, O13, Q1

1. Introduction

In 2008, the international price of rice escalated from $376/ton in January 2008 to an unprecedented level of $907/ton in April 2008 (World Bank, 2008a). The price has declined recently, but it is still high compared to the pre-crisis level. In Cambodia, the price of rice increased by approximately 100 percent between May 2007 and May 2008 (Ministry of Commerce of Cambodia, 2008). This sharp increase and elevated volatility in rice price raise serious concerns about food and nutrition security of people in Cambodia as rice is the major crop and national staple food of the country. In order to keep the domestic price low, many exporting countries such as Cambodia imposed various export restrictions. Consequently, world rice price increased further due to reduced availability in the international market.

At the national level, as an exporter, Cambodia can benefit from improved terms of trade in the international market. But the effects on different segments of the society can vary enormously. Net sellers will benefit if the higher international price can transmit to the farm level. But domestic consumers will lose. The poorer consumers will suffer even more as they often spend 60-70 percent of their income on food, and particular on rice in Cambodia. Higher food prices force poor people to limit their food consumption and shift to less-balanced diets, with possible harmful effects on their nutrition and health in the short and long run. This could have potentially irreversible consequences and deter the future ability of poor households to escape poverty (von Braun, 2008; von Braun et al., 2008). Thus the rising food prices will compromise progress toward achieving Millennium Development Goal (MDG) to halve hunger and poverty by 2015.

The question is how should Cambodian farmers and the government respond to these high prices? Cambodia's policy in response to these high prices can have a significant impact not only on domestic food security but also on world food prices. Increased production will help to increase farmers' income and thus reduce poverty as the majority of poor live on farming. Increased food production will also help to reduce domestic food price which in turn will help urban poor (18 percent of urban population in 2004, according to World Bank 2008a) since these poor spend large share of their income on food. As one of the ten top rice exporters, increased rice production in Cambodia will reduce international rice price.

The objective of this paper is to analyze how Cambodian farmers and the government can respond to food price rise and use this as an opportunity to increase farmers' income and wellbeing. Section 2 reviews Cambodian agriculture and rice in a broader economy context. Section 3 analyzes agricultural production potentials and constraints based on household surveys in 2004 and 2007. Section 4 concludes and discusses policy options on increasing farmers' production response.

2. Rice and Cambodia Economy

Cambodia has undergone dramatic political, economic and social changes since 1993, the year of the first post-conflict national election leading to the first coalition government. In 1993, agriculture accounted for 45 percent, manufacture for 9 percent and service for 42 percent of GDP. The GDP per capita was $727 (2005 constant international dollars, World Bank 2008a). The share of agriculture has dropped to 30 percent in 2006 and the share of manufacture has increased to 19 percent. In contrast, the share of services in GDP remained about 40 percent over the entire 1993-2006 period. The GDP per capita has increased to $1,569, more than doubled in 14 years.

On average, agriculture growth in Cambodia has lagged behind industry and service growth. The sector has experienced large year-to-year fluctuations due to low investment, overexploitation of forestry and poor infrastructure. As a small open economy with ample unused arable land and a large unskilled labor force, Cambodia's comparative advantage in agriculture is widely recognized. Promoting agriculture is the best strategy to secure a key source of growth that could help absorb a part of the expected increase in the labor force, reduce poverty effectively, and provide a rapid expansion of domestic market for manufactured products. A more dynamic agricultural sector may also encourage foreign investment, which has been lacking, partly because the population of 14 million in 2006 does not provide a sufficiently large domestic market (World Bank, 2008a).

Rice-based farming system is the backbone of Cambodia's agricultural sector. Rice is the main agricultural produce and the country's staple food. It contributed a quarter of agricultural GDP in 2006 and 40.7 percent of agriculture growth between 2003 and 2006. Agricultural land use is also dominated by rice cultivation. In 2004, 84.4 percent of cultivated land was devoted to rice, 9.3 percent to other food crops (including maize, vegetables, mungbeans, cassava, and sweet potatoes), and 6.3 percent to industrial crops (including oil crops like soybean, sesame and groundnuts, tobacco, sugar cane and jute). Rice is cultivated primarily through traditional farming practice by over 80 percent of Cambodian farmers, of which 60 percent produce for subsistence needs. As the staple of the traditional Cambodian diet, it provides 65-75 percent of the population's energy needs.

Rice in Cambodia is mainly produced in the wet season, which accounts for more than 75 percent of total paddy output. But dry season paddy remains an important component, particularly for consumers with a clear variety preference. Over the period of 1994-2008, wet season rice production grew at 7.1 percent per year, faster than dry season rice at 5.8 percent per year. Production growth is the result of continuing yield increase and cultivated area expansion (Figure 1).

On average, rice yield has increased at 5.4 percent per year, from 1.6 ton/ha in 1994-1997 to 2.3 ton/ha in 2003-2008. The yields of wet season increased from 1.0 ton/ha in 1994 to over 2.3 ton/hectare in 2008. This yield increase has been mostly attributed to better access to fertilizer and other inputs, rather than improved varieties of seeds (AIC and CamConsult, 2006). In contrast, productivity figures of the dry season crop are much higher than the wet season crop mainly due to the use of higher yield seeds and better water management. It is also easier to apply fertilizer and treat the land for better production in the dry season.

The rice-based farming system is usually characterized by relatively low income and poverty is pervasive with little diversification into other crops and agricultural activities.

However, there are great potentials in yield improvement for Cambodian rice production. The current low yield and potential increase in planted areas from further land mine clearing suggest that significant scope exists for growth in rice production. Land access is limited in Cambodia, and most households have a landholding of less than one hectare. The World Bank Sharing Growth Report (2007) estimated that 46 percent of the rural households are landless or own less than half a hectare per household. Therefore, improvement in rice yield is the only long-term solution to respond to high rice price and reduce poverty.

Table 1 reports average yield of major rice producing countries in Asia. The yield of rice in Cambodia is the lowest in comparison with other major rice producing countries, even below Laos and war-inflicted Myanmar. The low rice yield in Cambodia in part reflects low land productivity in the country, which calls for substantial improvement in production technology. For example, if Cambodian rice yield were raised to the level of Vietnam at 4.6 ton/ha, rice production would double, an equivalent to 7 percent average annual growth in rice output over a ten year period. AIC and CamConsult (2006) estimated that a surge in rice productivity can add $35 million to Cambodian farmers' income. This increase in productivity of dry season rice could increase agricultural income by 1.85 percent per year and total income by 0.89 percent per year. An increase in productivity of wet season rice could raise agricultural income by another 1.62 percent. Such growth rates would generate additional income, lift large number of farm households above the poverty line, improve food security, and allow for regular rice exports.

3. Farm Household Supply Response: Econometric Analysis from Household Surveys

In this section, we estimate a production function and derive the supply response of Cambodian farmers with respect to rising rice price. More specifically, we examine whether higher market prices can result in an increased supply response or increased output through intensified input use and improved public provision.

3.1 Model Specification

Farmers increase their output in response to both price and non-price factors. The common non-price factors in empirical analysis include irrigation, investment in research and development, extension services, access to capital and credit, agro-climatic conditions, and rural infrastructure. Both price and non-price elasticity estimates are important in understanding the relative importance of these factors in agricultural supply behavior.

Various theories have been developed, adapted and applied to explain the dynamics of supply in agriculture. The approaches to estimate output response also vary considerably. Coleman (1983), Just (1993) and Sadoulet and de Janvry (2003) provide excellent reviews of these methods and empirical studies.

Ideally, supply functions should be estimated directly, assuming that the basic determinants of market supply for a specific commodity are input and output prices and the state of technology. One typical approach estimates the supply response as a function of output and input prices, together with quasi-fixed inputs and supply shifters like technical change and policy interventions. This approach was applied by many researchers, for example, cross country study of developing economies by Subervie (2008), sub-Saharan Africa by Thiele (2003), Mozambique by Heltberg and Tarp (2002), Fiji by Hone et al. (2008). Another approach is to estimate a Nerlovian model to capture farmers' output reaction based on price expectations and partial area adjustment formation. The past several decades witnessed modification and development of the basic Nerlovian model on the theoretical and estimation front, including application to dynamic panel, initiated by Nerlove (1971, 1979). The Nerlovian dynamic model has seen wide applications, and recent applications include estimation of supply response of agricultural sector in Pakistan by Hye, Shahbaz and Butt (2008); rice and wheat in India by Mythili (2008); Zimbabwe by Muchapondwa (2008); India by Deb (2005); wheat in Pakistan by Mushtaq and Dawson (2003), Turkey by Albayrak (1998).

However, quantity and price data of inputs are not readily available at the household level from CSES surveys used for this study. Neither are time series data of output prices. In this case we cannot obtain output response relationships by direct econometric estimation. Instead, they are derived from estimated production functions by assuming profit maximization of farmers. According to the principles of duality in neoclassical theory, there is a direct equivalence between the production and cost, and production and profit functions. Any one of these three functions could be econometrically estimated and used to derive supply response parameters. This indirect structural approach relies on a maintained hypothesis of profit maximization to derive market level supply response and input demand functions from the profit or production functions estimated forehead, assuming the agricultural input and output markets function in a competitive environment. With respect to functional forms, while there is an exact dual relationship for the Cobb-Douglas and Constant Elasticity of Substitution (CES) forms, this is not the case for the more general and flexible forms like translog (Sadoulet and de Janvry, 2003). Many researchers chose to start from a profit function and derive input demand and supply response functions from the profit function based on Hotelling's Lemma (Wall and Fisher, 1988; Grethe and Weber, 2005; Ball et al., 2003; wheat, sorghum, maize, teff, barley Abrar, in Ethiopia by Morrissey and Rayner, 2004; Hattink, cocoa in Ghana by Heerink and Thijssen, 1998).

In our case, the production function is estimated using a typical Cobb-Douglas functional form. Inputs include both conventional inputs (land and labor) and fertilizer, and irrigation. Output is expressed as crop production in quantity and market value. The advantages of using the Cobb-Douglas function are many. First, it allows computation of returns to scale – constant, increasing or decreasing. Second, the estimated coefficient of an input from a linearized Cobb-Douglas function is the direct elasticity of the input. It is widely used in empirical work.

More specifically, the following Cobb-Douglas production function is chosen to represent the production technology of Cambodian farmers:

$$\mathrm{Y} = \mathrm{A} \cdot \prod_{\mathrm{i}} \mathrm{X}_{\mathrm{i}}^{\alpha_{\mathrm{i}}} \cdot \prod_{\mathrm{j}} \mathrm{Z}_{\mathrm{i}}^{\beta_{\mathrm{j}}}\ , \tag{1}$$

where Y is the total output of a certain crop, measured at plot level; X_i are inputs used for crop production, including land, labor, fertilizer and irrigation; Z_j includes other fixed and semifixed inputs that are exogenous such as household head characteristics, as well as infrastructure and government policies; α_i and β_j are coefficients to be estimated; and A is a constant.

The sum of α_i gives the degree of homogeneity or returns to scale. The production exhibit decreasing return to scale if $\sum_i \alpha_i < 1$, constant return to scale if $\sum_i \alpha_i = 1$, and increasing return to scale if $\sum_i \alpha_i > 1$. The Cobb-Douglas form of the production process limits the generality of the results. The elasticities of coefficients are constant, implying constant shares regardless of input level, and the elasticity of substitution among inputs is unity.

Taking natural logarithm of Equation (1) yields a linear functional form:

$$\log(Y) = \log(A) + \sum_i \alpha_i \log(X_i) + \sum_j \beta_j \log(Z_j). \quad (2)$$

Next we derive supply response based on the dual relationship between a production and a profit function. Given production technology as represented by a Cobb-Douglas functional form as defined in Equation (1), the producer is assumed to choose the combination of variable inputs and outputs that will maximize profit subject to the technology constraint:

$$\max \pi = PY - \sum_i w_i X_i \quad (3)$$

$$\text{subject to } A \cdot \prod_i X_i^{\alpha_i} \cdot Z_j^{\beta_j} \geq Y$$

$$X_i > 0,$$

where π is the profit of producing a certain crop; P is the unit price of the crop; and w_i are input prices, including land, labor, fertilizer and irrigation.

The solution to this maximization problem is a set of input demand functions:

$$\frac{\partial \pi}{\partial X_i} = P \cdot \alpha_i \cdot X_i^{\alpha_i - 1} \cdot A \cdot \prod_{j \neq i} x_j^{\alpha_j} \cdot \prod_j Z_i^{\beta_j} - w_i = 0 \text{ for each input } x_i.$$

Hence the demand for input x_i is

$$X_i = \frac{P}{w_i} \cdot \alpha_i \cdot A \cdot \prod_i X_i^{\alpha_i} \cdot \prod_j Z_j^{\beta_j} = \alpha_i \cdot \frac{P}{w_i} \cdot Y \text{ for each input } x_i.$$

(4)

Substitute input demands (4) into production function and rearrange terms, we obtain the supply function as:

$$Y = A^{\frac{1}{1-\sum_i \alpha_i}} \cdot \prod_i \left(\frac{\alpha_i}{w_i}\right)^{\frac{\sum_i \alpha_i}{1-\sum_i \alpha_i}} \cdot \prod_j Z_j^{\frac{\beta_j}{1-\sum_i \alpha_i}} \cdot P^{\frac{\sum_i \alpha_i}{1-\sum_i \alpha_i}}.$$

(5)

The short-run supply elasticity of output with respect to output price is:

$$\varepsilon = \frac{\partial \log Y}{\partial \log P} = \frac{\sum_i \alpha_i}{1-\sum_i \alpha_i}. \quad (6)$$

In the long run, price incentives and increased profitability of a crop will induce adjustment of some of the fixed or quasi-fixed factors over a longer period of time. Taking proper account of these long-term effects, the long-run production response is

$$\varepsilon = \frac{\partial \log Y}{\partial \log P} = \frac{\sum_i \alpha_i + \sum_j \beta_j}{1 - \sum_i \alpha_i - \sum_j \beta_j}. \quad (7)$$

In order to evaluate the impact of different inputs and investments, marginal return and benefit-cost ratio per hectare are calculated. Since farmers' cost of fertilizer per hectare is readily available and is included directly in the estimation in production Equation (2), we can derive the marginal return of production with respect to fertilizer usage per hectare as the ratio of marginal revenue from fertilizer use to marginal cost of fertilizer (fertilizer price):

$$MR = \frac{P * \bar{Y} * \alpha_f}{X_f}. \quad (8)$$

The nominator is the marginal revenue from fertilizer use per hectare, which is the product of output price at farmgate P, average yield $\bar{Y}$ and output elasticity with respect to fertilizer α_f; and marginal cost X_f is the average cost of fertilizer per hectare.

In the case of irrigation, we compute the benefit-cost ratio (BCR) of government spending as total additional revenue from irrigated area to total government expenditure in water resources per hectare:

$$BCR = \frac{P * \bar{Y} * \alpha_{irr}}{Unit\ irrigation\ \ expenditure}. \quad (9)$$

where *BCR* is the benefit-cost ratio of irrigation; unit irrigation expenditure is calculated as government expenditure on irrigation in one hectare of irrigated land; P is output price at farmgate; $\bar{Y}$ is average yield; α_{irr} is output elasticity with respect to irrigation. Since there is a lag between investment and impact on production, we use an average lag of 3 years, i.e., 2007's production is affected by irrigation investment made in 2004.

3.2 Data description

The data used in our analysis is from the national representative CSES conducted in 2004 and 2007. The 2004 CSES includes a total of 14,984 households surveyed in 900 villages during a 15-month period. The 2007 CSES is a considerably smaller survey with 3,593 households in 360 villages. Both surveys collected information on household crop production, food and nonfood expenditures, village information on prices of food and nonfood items. More importantly, they include access to community and social services like roads, electricity, water, markets, schools, and health facilities. We extracted household production information from Household Economic Activities section of the questionnaire, including area, crop production quantity and value, and various input costs by plot. Household head characteristics are from Household Members section. Credit and loan information is from Household Liabilities section. Village Questionnaire provides indicators of access to infrastructure and community services.

Table 2 lists variable used in the estimation, including outputs, inputs, household head characteristics, and infrastructural variables. Outputs include paddy yield from dry and wet seasons. Inputs include conventional inputs (cultivated land and labor), fertilizer and irrigation, as well as land tenure and household loan status. Household head characteristics include gender, age, and literacy. Infrastructure variables include access to market, electrification rate, telecommunication, and access to social services such as hospital and schools. It also includes government extension service of technical support for crops.

Descriptive statistics of the variables are summarized in Table 3. Wet season paddy cultivation remained the predominant crop, accounting for more than 70 percent of total harvest area and engaging more than three quarters of households in the sample. An average Cambodian household owned or operated multiple plots and the number of plots increased over time, for example, 1.53 plots for wet season paddy versus 1.68 plots in 2007. However, average size of harvest area remained small, generally less than one hectare per household. Our results are consistent with Knowles (2008) that the majority of the poor in rice-based farming system of Cambodia are smallholders, who typically own or operate on less than one hectare of land. This suggests that focusing on increase in farm productivity offers the single most important pathway out of poverty.

There is an observable increase in average rice yield between 2004 and 2007. For wet season paddy, average yield increased from 1.75 to 2.02 tons per hectare, growing by 15 percent. Average dry season paddy yield expanded from 3 tons per hectare to 3.6 tons, by more than 20 percent. This is consistent with national average as reported by Ministry of Agriculture, Forestry and Fishery and is aligned with the upward trend and there is no significant deviation from the trend.

Average household size was about 5 persons and barely changed between the two survey years. In terms of modern inputs, average cost of fertilizer for wet season paddy went down but increased sharply for dry season paddy. The percentage of household using fertilizer increased for paddy productions in both seasons. On average, about 78 percent of wet season paddy plots use fertilizers, and the percentage increased to 88 percent in 2007. Share of household paying for irrigation dropped slightly for wet season paddy to 12 percent in 2007, while 4 percent more households incurred cost during dry season paddy cultivation. Among sample households, nearly 20 percent wet season paddy producers reported having irrigation facilities in the village. In contrast, more than 60 percent dry season paddy producers had access to irrigation facilities in the village. More than 90 percent of households own their land plots, regardless of crop type. About 8.4 percent of wet season paddy growing households had taken loans for agricultural production and implementation, whereas about 30 percent took loans for nonagricultural related reasons, including education and health expenses. Of dry season paddy growing households, 15.9 percent borrowed for agricultural purpose and more than one third for nonagricultural purpose.

About 80 percent of households are male-headed, 45-47 years old, with three-quarters being literate. Overall, access to infrastructure and public services has improved considerably. Average distance to market dropped by more than 2 kilometers for all villages in the sample. More households in the village have public or private electricity, but electrification rate remained below 10 percent in rural Cambodia. Access to lower secondary school in village also improved, and about 15 percent of villages in the sample had at least one school. Telephone coverage had spread to almost all over the country, as about 96 percent of the villages in the sample had at least one telephone. Farmers also noticed a step up of technical support from government agencies, with more than one third of wet season paddy, and about one quarter of dry season paddy growers are recipients of such support. Medical care is non-existing in most villages, and less than 2 percent of villages have access to some form of medical care. There was one hospital for every 20 or more villages.

3.3 Estimation

The Cobb-Douglas production function in Equation (2) is estimated for wet season paddy and dry season paddy, respectively, and the results are reported in Tables 4-5. Output is the gross production quantity of each type of unmilled paddy. Inputs are labor, land expressed in cultivated area, fertilizer and irrigation. We also include access to extension, markets, electricity, telephone coverage, availability of schools and hospitals in the village in the production function. There are four agroecological or ecosystem zones in the Cambodian agrarian structure: Plateau/Mountain, Plain, Coastal, and Tonle Sap, which overlap with province borders. Zone dummies are introduced to capture all other regional effects not captured by variables at household and village level.

Since production and inputs are measured in their logarithmic forms, all the estimated parameters are elasticities of these inputs if the inputs are continuous. The function is estimated using OLS at the plot level. The results for wet season paddy are presented in Table 4. The first two columns of the tables report results for wet season paddy production based on 2004 CSES and 2007 CSES using all observations in the sample, respectively. Area expansion provides the greatest impact on wet season paddy production, and production elasticity with respect to cultivated area is 0.68 in 2004 and 0.66 in 2007. Since Cambodia is a relatively land abundant country, increasing cultivated area could be one short-term solution in achieving food security. But in the long-run, enhancement in productivity is the only feasible approach for sustainable growth. Fertilizer application has a sizeable impact on paddy production, with elasticities ranging between 0.1 in 2004 to 0.21 in 2007.

If a wet season paddy field is irrigated, the production could increase significantly by about 0.15 in 2004 (combined effect of household irrigation and community irrigation). An additional 1 percent labor input can elevate production by 0.04 percent. Household head being literate could increase wet season paddy production by 0.06-0.07 percent, while having a lower secondary school in the village could further increase production by an additional 0.05-0.12 percent. Among infrastructure variables, distance to permanent market and electrification rate are both significant and of the expected signs. If the distance to permanent market is shortened by one percent, wet season paddy output could be elevated by 0.008 percent in 2004. A one percent increase in electrification rate would increase output by 0.01 percent in 2004 and 0.02 percent in 2007. The existence of government technical support is also essential to increase wet season paddy production by 0.09 percent in 2004. Land accessibility (in the form of land ownership or rent-in) raises production by 0.7 percent and loan for agricultural production demonstrate marginally significant impact on wet season paddy production in 2004.

The results of estimated wet season paddy production function by year and agroecological zones (Plain, Tonle Sap, Coastal, and Plateau/Mountain) are also included in Table 4. Land still stands out as the most important factor contributing to output increase, whose elasticity ranges from 0.53 in the Coastal zone and 0.73 in the Tonle Sap zone. Coefficients of fertilizer are also universally significant across all zones and of the expected signs, ranging between 0.07 in the Plain zone and 0.21 in the Coastal zone in the CSES 2004 sample.

In the Plain zone, the presence of irrigation facility in the village could increase output significantly by about 0.2 percent. Access to electricity, schooling and telephones, as well as road, are all important for wet season paddy production. Land ownership contributes to a 0.83 percent production increase, while rent in also boost production by more than 1 percent. Wet season paddy production is higher if a household head is literate, or a household has access to irrigation improved production in the Tonle Sap zone in 2007. Distance to market is one of the key drivers of production progress and a one percent decrease in the distance to market can be translated into 0.01-0.03 percent output increase. Improvement in the availability of government extension services increases production by 0.16 percent in this zone. Electrification and agricultural extension services helped raise output of wet season paddy, too. In the Coastal zone, wet season paddy production is more responsive to fertilizer application than other zones, with an elasticity of 0.21-0.24. Production elasticities of road, electricity, and secondary school are significant and of the expected sign. Compared to other types of land use, plots that are rented in tend to have 0.8 percent higher production while plots that are rented out tend to have 0.67 percent lower production. In the Plateau/Mountain zone, coefficients of irrigation are significant and of the expected signs at 0.17-0.20. Electrification rate could propel wet season paddy output by 0.03-0.07 percent.

In summary, a one percent increase in cultivated area produces the greatest increase in wet paddy production in the Tonle Sap zone. The Coastal zone observes the highest production boost from higher fertilizer application. Improved irrigation facilities significantly increase output in all zones except for the Coastal zone. Educational investment, including indicators like higher literacy rate and more secondary school establishment, positively impacts paddy production in the Plain, Tonle Sap and Coastal zones, but has little effect in the Plateau/Mountain zone. In terms of infrastructure indicators, road construction increases paddy production in the Tonle Sap zone and the Coastal zone, whereas telecommunication only affects the Plain zone positively. It is generally observed that output elevated after rural electricity access improves. The impact of government crop extension services is reflected in higher production in the Tonle Sap and Coastal zone. Allowing rent in land is also proved to increase production in the Plain and Coastal zone. Hence, it is clear that the impact of government investment in infrastructure and technical support varies substantially across zones.

The results of dry season paddy production are summarized in Table 5. The biggest coefficient in production function is land, indicating great potentials of output augmentation from land expansion in addition to yield improvement. Paddy production is more responsive to fertilizer use in dry season. A one percent increase in fertilizer application could raise paddy output by about 0.21-0.25 percent. A household with irrigation facilities in the village observes a production increases in 2004. Coefficient of market access is significant at 0.017 and of the expected sign. Coefficients of telecommunication are also positively significant. In the Plain zone, fertilizer and irrigation substantially improved paddy production in dry season. For instance, a one percent increase in fertilizer application could increase paddy output by 0.20-0.26 percent, while irrigation adds additional yield improvement. In addition, access to market and extension services all had a positively impact on dry season paddy production. Telecommunication availability increases paddy production as well. In the Tonle Sap zone, fertilizer and irrigation are important for paddy cultivation. If distance to market were shortened by one percent, yield of dry season paddy could increase by 0.12 percent. Availability of agricultural extension could boost output by impressively, while school was very important for with a coefficient of 0.87. In the Plateau/Mountain zone, no variable significant contributed to dry season paddy production except for land expansion.

While comparing the production functions of wet and dry season paddy, coefficients of area are significant and the largest contributor to output increase, ranging between 0.69 in wet season to 0.63 in dry season. This is followed by fertilizer, contributing to 0.10 to 0.20 percent more paddy output. Irrigation is also a major determinant in rice production with coefficients ranging between 0.15 and 0.21. However, there are substantial differences in the production relationship across regions, especially among infrastructure service variables. In addition, infrastructure and public services are important for both cropping seasons, though each season has different priorities. This analysis is consistent with a multimarket model analysis for Cambodia by Arulpagasam et al. (2003), which found Green Revolution Package (which included fertilizer and irrigation) increased rice production by 4 percent, agricultural income by 1.5 percent, and rice export by 31 percent. With more investment to improve traditional varieties of seeds, rice production will increase by 15 percent, agricultural income by 7 percent, and rice export increase by 228 percent, with a benefit-cost ratio of 1.7.

As discussed above, a Cobb-Douglas production function allows us to inspect the returns to scales, that is, the percentage change of output if all factors are increased by one percent. Table 4 and 5 show that agricultural production exhibits decreasing return to scale at farm level, which is consistent with many empirical works in other developing countries. The return to scale is 0.82 for wet season paddy and 0.89 for dry season paddy.

3.4 Supply Response

Using coefficients estimated from the Cobb-Douglas production function, we can derive supply response with respect to output price based on Equation (6). In a short period of time, household paddy land, domestic labor, and irrigation facilities are inelastic and very difficult to change without enough access to credit. Hence, we calculate a short-run supply elasticity assuming only fertilizer as the only variable input. Short-run supply elasticity is estimated as 0.26 for wet season paddy and 0.33 for dry season paddy in 2007, respectively. In the long run, all inputs are viewed as variable and thus long-term supply elasticity will be bigger than that of short-run. Long-run supply elasticity ranges from 1.15 for wet season paddy to 1.45 for dry season paddy. It is rather difficult for a Cambodian household to increase labor in a short time frame like within a couple of years, or build irrigation facilities like canal, or acquire more land without external help in credit and technology. Therefore, we choose the derived short-run supply response (elasticity) to simulate the output supply change from higher farmgate prices.

Supply response varies substantially across agroecological zones. In the short run, the Plain zone and Coastal zone are more sensitive to market price of wet season paddy, where own price elasticities are above 0.3. In the Tonle Sap zone and Plateau/Mountain zone, less than half of the value (0.14-0.16) is reported. Long-run supply elasticities with respect to own price are much higher than their short-run counterparts, ranging between 0.9 in the Plateau/Mountain zone to 1.25 in the Plain zone. Dry season paddy production responds faster to price changes than wet season paddy, with higher short- and long-run elasticities. The Plain zone is ahead of other zones with a short- and long-run elasticity of 0.35 and 1.53, respectively. It is followed by the Tonle Sap zone with a smaller short-run elasticity of 0.11, but long-run elasticity is still above unity in the region.

Our short-run supply elasticity is in line with many other studies on the topic of supply response of rice in the region (Table 8). Choeun, Godo and Hayami (2006) compiled previous estimates of the price elasticity of Thai rice supply from studies conducted since 1968. The survey of literature showed that the short-run price elasticity of rice supply ranged from 0.02 to 0.65 with an average value of 0.25. The long-run rice elasticities averaged at 0.59 and ran between 0.21 and 2.67. Sae-Hae's (2000) estimate of 0.34 also falls into this range in one region of Thailand. Khiem and Pingali (1995) suggested a supply response elasticity of 0.22 for Vietnamese rice sector. Using a spatial equilibrium model, IFPRI (1996) suggested price elasticity of rice production ranged 0.29 in southern Vietnam and 0.37 in the north. A recent study by Danh (2007) estimated a Nerlovian supply response in Vietnam and suggested price elasticity with respect to supply should be between 0.10 and 0.34. In Indonesia, paddy production is also quite responsive to price signal, and supply elasticities are bounded between 0.02 and 0.68 in the short-run, 0.13-2.0 in the long-run (Rosegrant, Kasryno and Perez, 1998; Irawan, 2001; Siregar, 2002; Warr, 2005). Studies over the last two decades provide a wide range of 0.31-0.95 in the Philippines (Flinn, Kalirajan and Castillo, 1982; Warr, 1992). The aggregate paddy output elasticities with respect to price were relatively low in Sri Lanka in early years, with short-run supply elasticity falling between 0.09 and 0.13 and long-run elasticity 0.11-0.19 (Gunawardana and Oczkowski, 1992; Bogahawatte, 1983; Samaratunga, 1984). Recent researches suggest a higher level of 0.25-0.61 (Rafeek and Samaratunga, 2000; Weerahewa, 2004). A recent article by Imai, Gaiha, and Thapa (2008) directly estimated a rice supply response function and reported a range of 0.23-0.28 in 10 Asian countries.

3.5 Marginal Returns of Inputs and Investment

Based Equation (8) and (9), we calculate the marginal return to fertilizer and benefit-cost ratio of irrigation. Marginal returns, or productivity impacts, are measured in Riels of additional output for an additional Riel of input cost or additional infrastructure improvement. Benefit-cost ratio of irrigation is calculated based on total investment in water resources and total additional revenue from irrigated area. These measures provide useful information for comparing the relative benefits of additional investments in different items in different agro-ecological regions. Such information can be helpful for informing future priorities for stakeholders to further increase production and income, and thus reduce rural poverty.

Table 6 describes the marginal returns of fertilizer application for paddy production under different price scenarios, which is the additional revenue from one additional Riel of fertilizer cost per hectare. The value of marginal return depends on output price and input price (cost of fertilizer). We design 5 scenarios to capture the combination of output and input price changes. The first column (scenario 1) estimates the returns at survey year output and input prices (2004 and 2007, respectively). The second column calculates the returns at the levels of 2007 farmgate price and survey year input prices. The 2007 farmgate price was about 40 percent higher than 2004 price for wet season paddy and 33 percent higher for dry season paddy (CDRI, 2008). Scenario 3 calculates the returns valued at the 2008 farmgate price and survey year input prices in the third column, which climbed another 40 percent from 2007 price. Since input prices are also rising largely due to higher fuel prices, we also simulated the impact of higher input prices on marginal returns while keeping output price at 2008 level in scenario 4 and 5. Scenario 4 (the fourth column) presents marginal return from a 50 percent increase in input costs while keeping the output price at 2008 level, which reflects an increase in total production costs (CDRI, 2008). Scenario 5 stimulates a 100 percent increase in input costs.

Under scenario 1, marginal returns of wet season paddy to fertilizer ranged from 1.2 in the Coastal zone to 3.3 in the Plateau/Mountain zone in 2004, whereas ranged from 1.7 in the Coastal to 4.7 in the Plateau/Mountain zone in 2007. The rates of return to fertilizer have increased in almost each zone between the two survey years. If farmgate wet season paddy price increased to 924 Riels per kg in 2007, marginal returns increase significantly. If price is further increased to 1,300 Riels per kg of 2008 price, the same trend continues. At this high price level, fertilizer price is reported to rise by 50 percent, thus the marginal return will fall but remains greater than one, indicating profitability. Even if fertilizer prices double, it is still profitable for most farmers to produce paddy at this high level of rice price. When dry season paddy price rises from survey year price to 739 and 1016 Riels in 2007 and 2008 respectively, farmers' profit margin surged. When input prices were simulated with a 50 and 100 percent increase, producers still have incentive to engage in paddy production.

According to Ministry of Economy and Finance (2003), the government spent 16 billion Riels in water resources in 2004. Assuming the entire government budget in water resources was allocated to agricultural irrigation, which is the equivalent of about 147,000 hectares of cultivated area, we can calculate unit cost of irrigation as 109,184 Riels per hectare in 2004. We assume that there is a three-year lag in the irrigation investment structure, that is, the benefit of increased paddy yield from construction of irrigation facilities won't materialize until three years after the initial investment. Using coefficients estimated from production function regression, we can calculate the benefit-cost ratio of irrigation in 2007 defined in Equation (9), which is the additional revenue per hectare from irrigated area in 2007 divided by unit cost of irrigation in 2004. In Table 7, benefit-cost ratio of irrigation ranged from 2.2 in the Plateau/Mountain zone to 3.4 in the Tonle Sap zone in 2007. Similar to fertilizer, the ratio is consistently above one even when irrigation cost doubled in the simulation. An important feature of the results in these tables is that all the investments considered increase agricultural land productivity. However, there are sizable differences in productivity gains across agroecological zones.

4. Conclusions

Although political and macroeconomic stability have been achieved and key structural reforms have been initiated, Cambodia's economy remains vulnerable and faces daunting challenges to alleviating pervasive poverty. External shocks stemming from lower global growth and the accelerated recurrence of flooding and droughts in recent years also pose major challenges to Cambodia's development.

This study estimated a production function for Cambodia rice sector by using 2004 and 2007 household surveys. The findings indicate that besides land expansion fertilizer and irrigation are major determinants in paddy supply response. A one percent increase in fertilizer use could increase wet season paddy output by 0.1 percent and 0.2 percent in dry season. The existence of irrigation facilities could increase output by 0.15-0.21 percent. Infrastructure (like transportation and telecommunication) and public services (like education and health care) all contribute to rice production in Cambodia. However, there are substantial differences in the production relationship across regions. Simulation results indicate that higher output price increases profitability of rice production even when input price doubles due to high fertilizer responsiveness. Investment in irrigation provides positive return for paddy farmers.

These findings have important implications on how to promote future rice supply in Cambodia. The poor are likely to benefit most from improvement in agricultural productivity and technology. It is clear that Cambodia has to focus on the agriculture sector to achieve pro-poor growth and thus poverty reduction. As the majority of the poor in Cambodia live in rural areas and depend on agriculture, higher agricultural growth will provide food security by increasing supply, reducing prices, and raising incomes of poorer farm households. The impact of higher food prices could be moderated as supply responds to prices over the medium term of 6 months to 2 years (ADB, 2008b). To facilitate this response and achieve food security, much neglected agricultural sector need to be put on top of political agenda. First, there is considerable scope in improving paddy production in Cambodia. It is possible to raise Cambodian rice yield to the levels of its neighboring countries, if proper technology (fertilizer, irrigation) and infrastructure (market, road, electricity, telecommunications, education, and health) is provided. Given the high responsiveness of fertilizer, farmers could considerably increase their yield and revenue from more market sales. CDRI (2008) concluded that if the 2008 high prices stay after the next harvest, farmers would see 50-80 percent higher net margins, despite higher input costs they were incurring at the same time. Thus a clear, coherent strategy for the rice sector needs to be formulated around the dual objective of achieving food security and exporting rice.

Second, promotion of modern technology and crop diversification should be tailored to local conditions. However, poor road and market conditions prevent local producers from benefiting from the comparative advantage of rice production. More investment in infrastructure could enable farmers to collect the latest market information and transport their produces to Phnom Penh and other regional markets. Investment in rural roads yields high returns to poverty reduction in developing countries (Fan, 2008). Improving rural roads will help the rural population gain access to key services.

Third, there is no one-size-fits-all recipe to increase agricultural income in all geographic regions. Each agro-ecological zone has its only unique soil and water conditions, as well as infrastructure and human capital stocks. It is important to target public investment with the highest impact on productivity and poverty, and to set up government support programs accordingly. The effect of public investment could be enhanced significantly if spatial variations are taken into consideration during planning and implementation. For example, improved access to telephones could increase the output of dry season paddy in the Plain zone but has little impact on farmers in the Plateau/Mountain zone. Thus investment in telecommunication will more likely to generate additional income and alleviate food insecurity through increased production and income in the Plain zone, compared to other dry season paddy producing zones.

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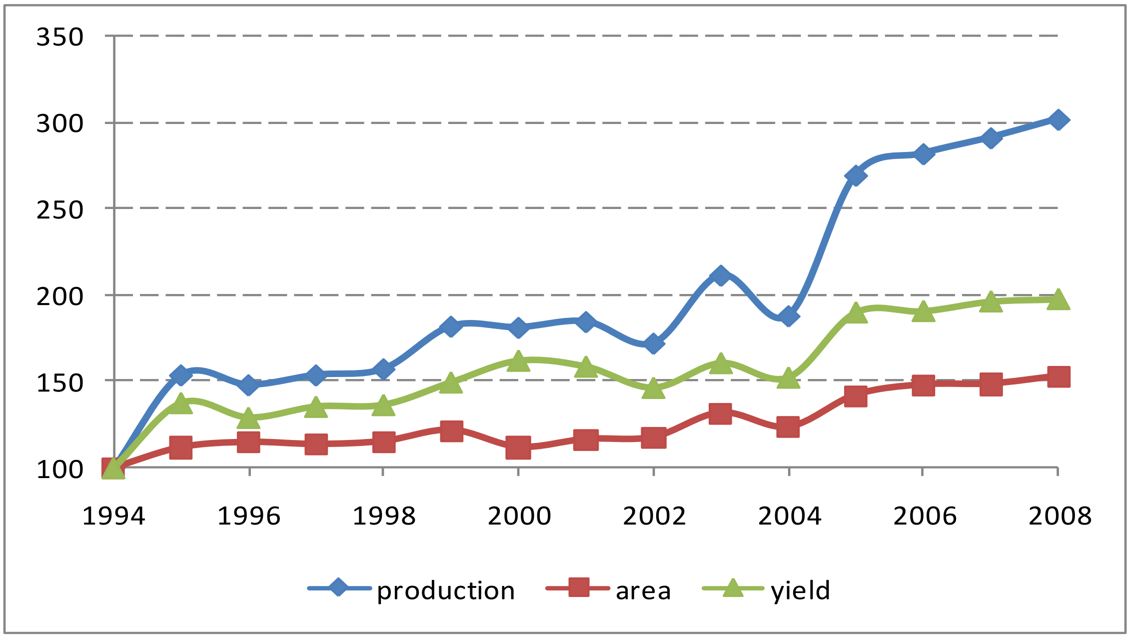
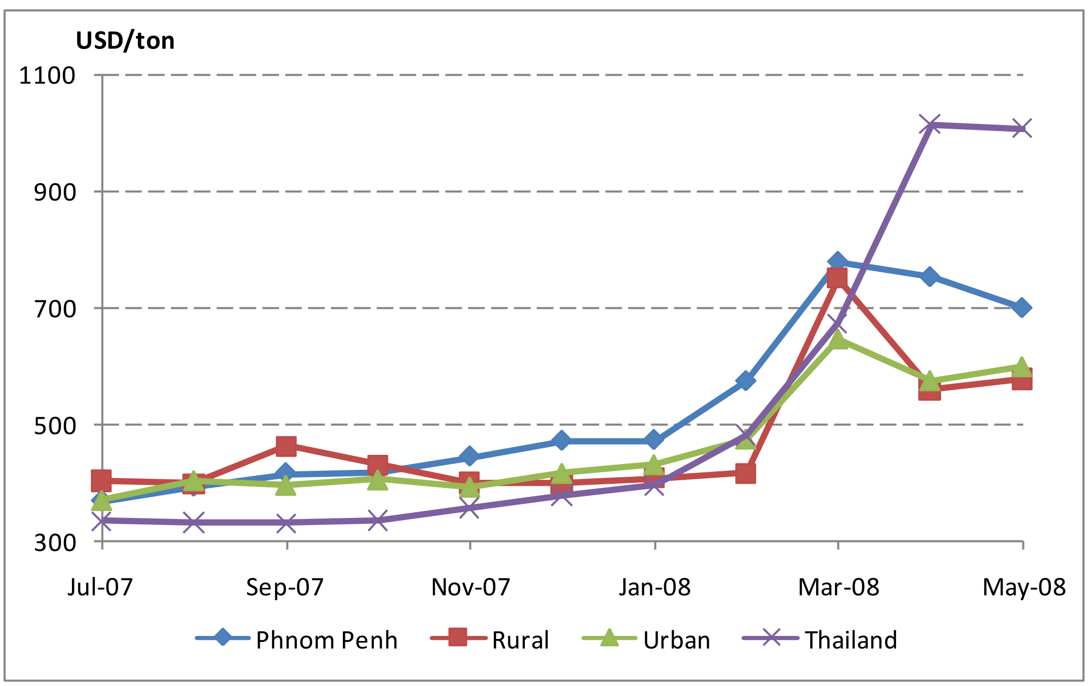
Figure 1. Growth of Cambodia's rice production, area, and yield in 1994-2008, 1994=100



Source: Authors' calculation from USDA, Production, Supply and Distribution Online (2008b).

Figure 2. Rice price in Cambodia, July 2007-March 2008



Source: Authors' calculation from Kaufman (2008) and IMF Primary Commodity Price (2008b).

Table 1. Rice yield in Cambodia and neighboring countries, 2000-2008

Year	Cambodia	China	Indonesia	Laos	Malaysia	Myanmar	Philippines	Thailand	Vietnam
Yield (ton/ha)									
2000	2.12	6.27	4.44	3.06	3.26	3.10	3.11	2.61	4.14
2001	2.07	6.16	4.41	3.13	3.23	2.90	3.19	2.62	4.27
2002	1.91	6.19	4.50	3.28	3.27	3.00	3.17	2.57	4.37
2003	2.10	6.06	4.56	3.14	3.37	2.94	3.46	2.65	4.48
2004	1.99	6.31	4.64	3.29	3.34	2.43	3.54	2.63	4.62
2005	2.48	6.26	4.59	3.49	3.36	2.57	3.63	2.70	4.72
2006	2.49	6.20	4.60	3.50	3.30	2.61	3.70	2.69	4.82
2007	2.56	6.27	4.63	3.49	3.45	2.61	3.76	2.76	4.97
2008	2.58	6.27	4.72	3.53	3.46	2.54	3.77	2.76	4.88
Average	2.26	6.22	4.57	3.32	3.34	2.74	3.48	2.67	4.59
Growth rate %	3.60	0.15	0.74	1.91	0.75	-2.51	2.74	0.82	2.29
Modern technology									
Tractor (per ha) 1999-2003	0.6	6.5	4.4	1.2	23.9	1.0	2.0	14.2	24.9
Fertilizer (kg/ha) 2002-04	5.0	318.5	144.7		805.5	1.2	150.1	132.6	324.4
Irrigation (% of arable land) 1998-2002	7.0	39.0	23.0	19.0	20.0	20.0	27.0	31.0	45.0

Source: Authors' calculation from USDA Production, Supply and Distribution online (2008b) and FAOSTAT (2008).

Table 2. List of variables

Variable	Definition
Outputs	
lnwetyield	Natural log of wet season paddy yield in tons per hectare
lndryyield	Natural log of dry season paddy yield in tons per hectare
Inputs	
lnlabor	Natural log of household size divided by harvest area
lnwetfertilizer	Natural log of fertilizer cost per hectare for wet season paddy
lndryfertilizer	Natural log of fertilizer cost per hectare for dry season paddy
wetirrigation	Cost of irrigation, wetirrigation=1 if cost greater than 0 for wet season paddy
dryirrigation	Cost of irrigation, dryirrigation=1 if cost greater than 0 for dry season paddy
paddyirr	Irrigated paddy fields in village, paddyirr=1 if there are irrigated paddy fields in village
lnarea	Natural log of plot cultivated area
tenuretype	Categorical variable, tenuretype=1 if owning the plot, tenuretype=2 if plot is rented out, tenuretype=3 if plot is rented in, tenuretype= 4 if plot is free use of communal land, tenuretype=5 if other tenure types
agloan	Categorical variable, agloan=0 if a household does not borrow loan for agricultural production and operation or agricultural implementation, loan=1 if borrows
nonagloan	Categorical variable, nonagloan=0 if a household does not borrow loan for nonagricultural purpose, loan=1 if borrows
Household head characteristics	
gender	Gender of household head, gender=1 if household head is male
age	Age of household head
literacy	Literacy of household head, literacy=1 if household head can read or write a simple message
Infrastructure	
lndismarket	Natural log of distance to permanent market in kilometers
lnelectricity	Natural log of percentage of households in the village have public or private electricity
lowsecondsch	Existence of a lower secondary school in the village, lowsecondsch=1 if yes
phone	Existence of a public or private phone, phone=1 if yes
hospital	Number of referral, provincial, national or private hospitals
cropgovtech	Existence of government technical support for crops, cropgovtech=1 if yes

Table 3. Descriptive statistics of outputs and inputs, 2004 and 2007

	Wet season paddy		Dry season paddy	
	2004	2007	2004	2007
Output and input by plot				
Share in harvest area (%)	70.6	70.2	12.6	18.4
Number of households	8151	1576	1602	377
Number of plots per household	1.53	1.68	1.28	1.33
Average household harvest area (ha)	0.94	0.91	1.02	1.26
Yield (tons/ha)	1.75	2.02	3.01	3.64
Household size	5.01	4.84	5.22	5.25
Household cost of fertilizer (Riels/ha)	138760	128719	192412	374457
Household fertilizer usage (%)	73.9	77.8	80.1	87.8
Household irrigation usage (%)	14.4	12.0	41.0	44.3
Share of irrigated area in village (%)	13.9	19.3	68.2	63.4
Household owning plot (%)	95.7	95.6	93.7	91.4
Household have agricultural loans (%)	12.8	8.4	22.9	15.9
Household have nonagricultural loans (%)	30.8	30.1	27.8	35.5
Household head characteristics				
Male head (%)	80.2	79.9	84.6	83.6
Age	44.7	44.7	45.9	46.4
Literacy	66.6	72.5	71.3	76.4
Infrastructure				
Distance to market (km)	11.8	9.7	9.8	7.4
Households with electricity in village (%)	4.1	7.9	4.4	10.0
Lower secondary school (%)	9.5	13.5	12.5	11.4
Phone access (%)	73.1	95.3	86.7	96.7
Hospital	0.05	0.05	0.02	0.01
Existence of government technical support for crops (%)	25.2	37.3	20.9	21.0

Source: Authors' calculation from CSES 2004 and 2007.

Table 4. Wet paddy production functions and returns to scale by agroecological zones

	Cambodia		Plain zone		Tonle Sap zone		Coastal zone		Plateau/Mountain zone	
	2004	2007	2004	2007	2004	2007	2004	2007	2004	2007
lnlabor	0.038	-0.006	0.022	0.002	0.006	-0.071	0.248	0.016	-0.013	0.053
	(2.30)*	(0.18)	(0.99)	(0.04)	(0.19)	(1.31)	(4.84)**	(0.15)	(0.26)	(0.57)
lnarea	0.683	0.656	0.692	0.619	0.731	0.739	0.527	0.559	0.642	0.587
	(97.97)**	(38.12)**	(72.42)**	(22.04)**	(49.99)**	(27.60)**	(25.74)**	(9.74)**	(35.58)**	(12.51)**
lnwetfertilizer	0.100	0.205	0.067	0.238	0.104	0.138	0.211	0.235	0.137	0.128
	(13.68)**	(14.25)**	(6.51)**	(10.48)**	(7.72)**	(5.92)**	(8.17)**	(4.62)**	(6.54)**	(3.23)**
wetirrigation	0.050	0.052	0.051	0.064	-0.010	0.209	-0.025	-0.075	0.166	0.195
	(2.89)**	(1.14)	(2.41)*	(0.98)	(0.22)	(1.75)+	(0.42)	(0.61)	(3.77)**	(2.11)*
gender	0.009	0.074	0.055	0.087	-0.022	0.000	-0.169	0.242	0.008	-0.022
	(0.46)	(1.92)+	(2.24)*	(1.50)	(0.59)	(0.01)	(2.92)**	(2.21)*	(0.14)	(0.21)
age	0.001	0.001	0.002	0.003	0.001	-0.001	-0.000	-0.002	-0.003	0.002
	(1.70)+	(0.94)	(2.77)**	(1.57)	(0.62)	(0.38)	(0.11)	(0.58)	(2.23)*	(1.00)
literacy	0.060	0.071	0.048	-0.018	0.096	0.238	0.094	-0.023	0.062	-0.021
	(3.90)**	(2.09)*	(2.31)*	(0.33)	(3.22)**	(4.67)**	(2.06)*	(0.23)	(1.38)	(0.28)
paddyirr	0.102	-0.022	0.195	-0.085	-0.047	0.005	0.072	-0.101	-0.048	-0.149
	(7.07)**	(0.75)	(10.79)**	(1.63)	(1.45)	(0.10)	(1.36)	(0.70)	(1.07)	(1.87)+
lndismarket	-0.008	-0.001	0.004	0.019	-0.032	-0.014	-0.014	-0.016	0.024	-0.073
	(3.08)**	(0.13)	(1.15)	(1.98)*	(5.61)**	(1.89)+	(1.84)+	(1.31)	(1.20)	(1.25)
lnelectricity	0.009	0.026	0.011	0.021	0.002	0.016	0.008	0.045	0.031	0.066
	(5.30)**	(7.91)**	(4.05)**	(3.67)**	(0.56)	(3.19)**	(1.62)	(3.42)**	(4.07)**	(4.48)**
lowsecondsch	0.052	0.116	0.055	0.317	0.091	-0.020	0.045	0.367	-0.082	-1.503
	(2.15)*	(2.65)**	(1.78)+	(4.08)**	(1.85)+	(0.33)	(0.61)	(1.69)+	(0.79)	(2.44)*
phone	0.027	-0.010	0.054		0.044	0.131	-0.026	-0.140	-0.072	-0.412
	(1.62)	(0.10)	(2.17)*		(1.51)	(1.15)	(0.48)	(0.59)	(1.54)	(2.53)*
hospital	-0.012	-0.053	-0.021	0.019	-0.015		0.026	-0.103	-0.034	0.063
	(2.11)*	(3.49)**	(1.49)	(0.33)	(1.35)		(2.32)*	(3.39)**	(1.54)	(0.98)
cropgovtech	0.086	-0.022	0.029	0.071	0.153	-0.096	0.094	-0.561	-0.128	0.130
	(5.85)**	(0.75)	(1.50)	(1.35)	(5.53)**	(2.14)*	(2.14)*	(3.37)**	(1.19)	(1.51)

tenure type										
own	-0.026	0.729	-0.079	0.829	0.105	0.338	-0.093	0.295	-0.130	0.142
	(0.40)	(3.98)**	(0.91)	(3.45)**	(0.83)	(0.89)	(0.62)	(0.53)	(0.41)	(0.77)
rent out	-0.249	0.127	-0.250	-0.562	-0.234		-0.666	0.614	0.466	
	(1.96)+	(0.27)	(1.46)	(0.78)	(0.97)		(2.00)*	(0.81)	(0.75)	
rent in	0.046	0.707	-0.038	1.028	0.180	-0.001	0.805	0.572	-0.145	
	(0.60)	(3.54)**	(0.36)	(3.75)**	(1.26)	(0.00)	(1.86)+	(0.95)	(0.39)	
free use of commune land	-0.291		-0.651		0.397				-0.545	
	(1.19)		(1.85)+		(0.96)				(0.87)	
loan										
agloan	0.033	0.032	0.027	0.107	0.045	-0.136	-0.121	0.362	0.015	-0.138
	(1.73)+	(0.65)	(1.03)	(1.49)	(1.31)	(1.52)	(1.85)+	(1.82)+	(0.24)	(1.08)
nonagloan	-0.059	0.012	-0.044	0.013	-0.076	0.028	-0.063	-0.136	-0.022	0.092
	(4.13)**	(0.40)	(2.34)*	(0.26)	(2.66)**	(0.56)	(1.37)	(1.53)	(0.54)	(1.22)
Constant	5.714	3.732	5.968	3.761	5.576	5.529	4.677	3.648	5.821	7.113
	(47.70)**	(12.51)**	(30.89)**	(5.76)**	(24.07)**	(11.46)**	(13.87)**	(4.27)**	(13.74)**	(8.44)**
Observations	9576	2000	4840	952	2949	658	905	195	882	195
R-squared	0.58	0.68	0.57	0.56	0.57	0.77	0.55	0.76	0.68	0.73
Return to scale	0.821	0.855	0.781	0.859	0.841	0.806	0.986	0.81	0.766	0.768
Short-run supply response	0.111	0.258	0.072	0.312	0.116	0.160	0.267	0.307	0.159	0.147
Long-run supply response	0.924	1.152	0.841	1.249	0.951	0.960	1.346	1.169	0.911	0.900

Note: Absolute value of t statistics in parentheses, + significant at 10%; * significant at 5%; ** significant at 1%.
Source: Authors' calculation from CSES 2004 and CSES 2007.

Table 5. Dry paddy production functions and returns to scale by agroecological zones

	Cambodia		Plain zone		Tonle Sap zone		Plateau/Mountain zone	
	2004	2007	2004	2007	2004	2007	2004	2007
lnlabor	0.058	0.012	0.083	0.033	0.072	0.066	1.263	-0.448
	(1.35)	(0.16)	(1.85)+	(0.40)	(0.54)	(0.13)	(0.90)	(0.63)
lnarea	0.625	0.703	0.623	0.702	0.610	0.812	0.819	0.819
	(35.17)**	(21.32)**	(33.26)**	(19.74)**	(10.58)**	(4.14)**	(2.47)	(3.81)*
lndryfertilizer	0.203	0.25	0.195	0.259	0.210	0.102	1.991	-0.477
	(12.80)**	(9.57)**	(11.81)**	(9.23)**	(3.71)**	(0.54)	(1.03)	(0.67)
dryirrigation	0.002	0.051	0.003	0.040	-0.180	0.521	-0.039	-0.203
	(0.04)	(0.85)	(0.09)	(0.63)	(1.40)	(1.44)	(0.03)	(0.50)
gender	0.020	0.097	0.030	0.043	-0.227	0.259	-2.359	0.196
	(0.37)	(1.13)	(0.56)	(0.46)	(1.14)	(0.64)	(0.97)	(0.12)
age	0.000	-0.003	-0.000	-0.003	0.005	0.002	-0.143	-0.005
	(0.21)	(1.34)	(0.16)	(1.14)	(1.27)	(0.11)	(0.75)	(0.10)
literacy	0.063	0.043	0.061	0.063	0.190	0.210	0.588	-1.189
	(1.59)	(0.59)	(1.48)	(0.82)	(1.34)	(0.47)	(0.49)	(1.65)
paddyirr	0.214	0.027	0.253	0.087	-0.509	-0.394		
	(4.33)**	(0.16)	(4.73)**	(0.40)	(3.41)**	(0.98)		
lndismarket	-0.017	0.006	-0.015	0.005	-0.121	0.137	-0.111	0.016
	(2.51)*	(0.57)	(2.11)*	(0.39)	(3.42)**	(2.45)*	(0.15)	(0.05)
lnelectricity	0.005	-0.018	0.002	-0.021	-0.013	0.054	-0.433	0.009
	(0.96)	(2.95)**	(0.37)	(3.10)**	(0.62)	(1.32)	(0.82)	(0.15)
lowsecondsch	0.020	-0.086	-0.110	-0.048	0.855	0.719	-0.470	2.162
	(0.39)	(0.79)	(1.88)+	(0.34)	(5.53)**	(1.38)	(0.13)	(0.86)
phone	0.127		0.113		-0.031		3.714	
	(2.41)*		(2.13)*		(0.10)		(0.87)	
hospital	-0.004	0.043	-0.005	0.044				
	(0.31)	(0.98)	(0.35)	(0.97)				
cropgovtech	0.031	0.023	0.084	-0.011	-0.162	1.347	-5.021	0.561
	(0.71)	(0.33)	(1.80)+	(0.15)	(0.88)	(2.84)*	(0.74)	(0.67)

tenure type								
own	0.010	0.275	0.011	0.249	0.374			
	(0.07)	(0.94)	(0.08)	(0.84)	(0.56)			
rent out	-0.064	0.197	-0.069	0.139				
	(0.24)	(0.31)	(0.26)	(0.21)				
rent in	0.006	0.216	-0.065	0.178	1.061	-0.345		
	(0.04)	(0.69)	(0.40)	(0.56)	(1.54)	(0.76)		
free use of commune land		-0.164		-0.174				
		(0.42)		(0.44)				
loan								
agloan	-0.043	0.109	-0.047	0.119	-0.223	-0.520	-1.669	
	(1.10)	(1.34)	(1.15)	(1.40)	(1.66)+	(0.85)	(0.93)	
nonagloan	-0.011	0.036	-0.013	0.049	0.043	-0.456		-0.155
	(0.27)	(0.56)	(0.32)	(0.71)	(0.36)	(1.45)		(0.21)
Constant	4.880	4.961	4.897	4.800	4.788	5.869	-10.255	14.538
	(18.50)**	(8.16)**	(18.14)**	(7.50)**	(4.80)**	(2.42)*	(0.77)	(1.61)
Observations	1636	421	1476	374	144	31	16	16
R-squared	0.61	0.78	0.61	0.77	0.73	0.91	0.92	0.96
Return to scale	0.886	0.965	0.901	0.994	0.892	0.98	4.073	-0.106
Short-run supply response	0.255	0.333	0.242	0.350	0.266	0.114	-2.009	-0.323
Long-run supply response	1.189	1.448	1.189	1.528	1.215	1.106	1.354	-0.080

Note: Absolute value of t statistics in parentheses, + significant at 10%; * significant at 5%; ** significant at 1%.
Source: Authors' calculation from CSES 2004 and CSES 2007.

Table 6. Summary of estimates of supply elasticities for rice in Thailand, Vietnam, Indonesia, Philippines and Bangladesh

Source	Short-run	Long-run	Period
Thailand			
Arromdee (1968)	0.48		1951-1965
Kogjing (1970)	0.45		1952-1966
Ramangkura (1972)	0.26		1953-1969
Ganjarerndee (1975)	0.17	0.21	1960-1972
Wong (1978)	0.41	0.91	1951-1972
Wattanucthariva (1978)	0.19		1951-1975
Konjing (1979)	0.64	2.67	1956-1976
Lokapadhana (1981)	0.18	0.65	1959-1979
Lokapadhana (1981)	0.02		1966-1979
Trairavotvorakul (1984)	0.37	0.65	1959-1979
Orapin (1985)	0.41	0.64	1957-1982
Puapanichya and Panayotou (1985), irrigated	0.65		1980-1981
Puapanichya and Panayotou (1985), non-irrigated	0.5		1980-1982
Sae-Hae (2000)	0.34		1990s
Vietnam			
Khiem and Pingali (1995)	0.22		1976-1992
IFPRI (1996)	0.29-0.37		1976-1992
Danh (2007)	0.10-0.34		1975-2003
Indonesia			
Sugiyanto (1987), wet land	0.32-0.35		
Sugiyanto (1987), dry land	0.25-0.26		
Rosegrant, Kasryno and Pereza		0.3	1969-1990
Irawan (2001), wet land rice	0.02-0.45	0.13-1.25	
Irawan (2001), dry land rice	0.03-0.68	0.21-2.0	
Siregar (2002)	0.452		
Warr (2005)	0.186-0.434		2000
Philippines			
Ryan (1978)	0.07-0.11		1949-1974
Flinn, Kalirajan and Castillo (1982)	0.95		1978
Warr (1992), irrigated	0.74-0.81		
Warr (1992), rainfed	0.31-0.40		
Sri Lanka			
Bogahawatte (1983)	0.13	0.19	
Samaratunga (1984)	0.13		
Gunawardana and Oczkowski	0.09	0.11	1952-1987
Rafeek and Samaratunga (2000)	0.25-0.27		1990-1998

Weerahewa (2004)	0.609		1979-2000
Asia			
Imai, Gaiha, and Thapa (2008)	0.23-0.28		1966-2005
Imai, Gaiha, and Thapa (2008)	0.275		1966-1999
Imai, Gaiha, and Thapa (2008)	0.17		2000-2005
Cambodia			
This study, wet paddy	0.11-0.26	0.92-1.15	2004 and 2007
This study, dry paddy	0.26-0.33	1.19-1.45	2004 and 2007

Table 7. Marginal returns of fertilizer

Scenario Output price Input price		Scenario 1 survey year survey year	Scenario 2 2007 price survey year	Scenario 3 2008 price survey year	Scenario 4 2008 price increase 50%	Scenario 5 2008 price increase 100%
Wet season paddy						
	Plain	1.4	1.9	2.7	1.8	1.3
	Tonle Sap	2.0	2.8	4.0	2.7	2.0
2004	Coastal	1.2	1.7	2.4	1.6	1.2
	Plateau/Mountain	3.3	4.7	6.6	4.4	3.3
	Cambodia	1.8	2.5	3.5	2.4	1.8
	Plain	3.4	3.4	4.8	3.2	2.4
	Tonle Sap	3.8	3.8	5.4	3.6	2.7
2007	Coastal	1.5	1.5	2.1	1.4	1.0
	Plateau/Mountain	4.5	4.5	6.3	4.2	3.2
	Cambodia	3.6	3.6	5.1	3.4	2.5
Dry season paddy						
	Plain	2.1	2.8	3.9	2.6	1.9
	Tonle Sap	6.3	8.3	11.5	7.6	5.7
2004	Coastal	2.2	2.9	4.0	2.7	2.0
	Plateau/Mountain	8.9	11.8	16.3	10.8	8.1
	Cambodia	2.4	3.3	4.5	3.0	2.2
	Plain	2.3	2.3	3.2	2.1	1.6
	Tonle Sap	3.4	3.4	4.7	3.1	2.3
2007	Coastal	1.4	1.4	1.9	1.2	0.9
	Plateau/Mountain	8.6	8.6	11.9	7.9	5.9
	Cambodia	2.5	2.5	3.5	2.3	1.7

Source: Authors' calculation from CSES 2004 and CSES 2007, and CDRI (2008).

Table 8. Benefit-cost ratio of irrigation

Scenario Output price Input price		Scenario 1 survey year survey year	Scenario 2 2007 price survey year	Scenario 3 2008 price survey year	Scenario 4 2008 price increase 50%	Scenario 5 2008 price increase 100%
Wet season paddy	Plain	2.5	2.5	3.5	2.3	1.7
	Tonle Sap	3.4	3.4	4.7	3.1	2.4
	Coastal	2.6	2.6	3.7	2.5	1.8
	Plateau/Mountain	2.2	2.2	3.1	2.1	1.6
	Cambodia	2.4	2.4	3.4	2.3	1.7
Dry season paddy	Plain	3.3	4.4	6.0	4.0	3.0
	Tonle Sap	3.1	3.1	4.2	2.8	2.1
	Coastal	2.7	2.7	3.7	2.4	1.8
	Plateau/Mountain	4.1	4.1	5.6	3.7	2.8
	Cambodia	3.9	3.9	5.3	3.5	2.6

Source: Authors' calculation from CSES 2004 and CSES 2007, CDRI (2008), and MEF (2003).