Chapter 7
Analyses using Stochastic Models

7-1. Introduction

A stable water supply for wet season and upland rice cultivation is necessary for food security and lowering risk to farm management. The evaluation of water supply changes on rice yields and the resulting market responses from fluctuations in production are an essential theme of agricultural development in lower Mekong river countries. This chapter analyzes the supply and demand of rice in Laos and Cambodia, focusing on the impacts of fluctuations of water supply on rice production and producer risk.

7-2. Analytical method

7-2-1. Stochastic model

The ET variable is exogenous to the supply and demand model, entering into yield and area functions. To evaluate the impacts of changes in the water supply on rice markets, the ET value must be endogenized in a model which then recursively feeds into the greater supply and demand model. The following basic seasonal ET models with a lagged dependent value using monthly data are estimated as follows:

$$ET^i_t = f\,(ET^i_{t-1}, D_{FEB}, \ldots, D_{DEC}) \qquad (7\text{-}1)$$

where D_{FEB} through D_{DEC} are the dummy variables for February through December.

The equations are specified as linear function of seasonal treatment dummies and equation errors retained when comparing the estimates to the actual data. The empirical distributions and correlations across regions of the resulting errors are maintained and employed to obtaining a set of random ET variables consistent with history. With the use of the joint distribution, consistent with the historical error correlation matrix for provinces and random draws on a normal distribution, correlated uniform deviates for each province are created through the standard normal cumulative distribution. These random numbers are transformed into draws on the empirical error distributions which maintain their historical correlated relationship and distributions. This process creates 500 sets of error draws which are then inserted back into the ET model and used to create 500 simulated future ET paths. The procedure for creating correlated random ET variables is based on the program of Richardson, Klose and Gray (2000) and the system is shown in Figure 7-1 and Figure 7-2. The distributions of the error terms can be expanded to simulate increased variation in future ET distributions.

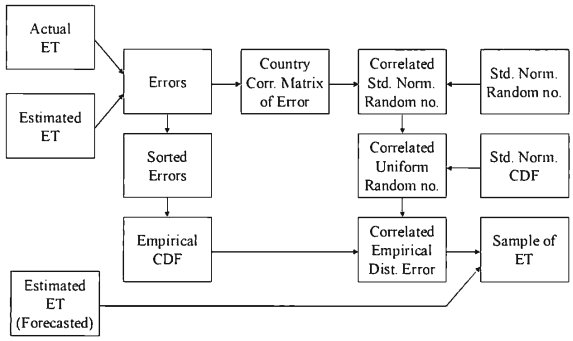

Fig.7-1. Creating correlated random ET variables

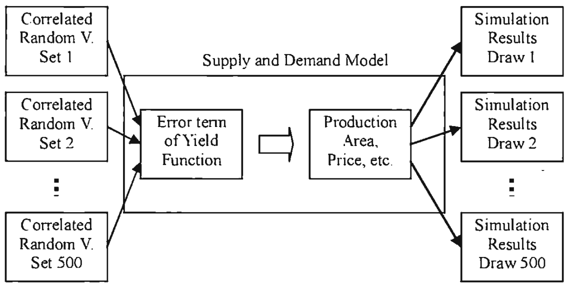

Fig. 7-2. Simulation of stochastic model

7-2-2. Risk neutral farm model

To evaluate the changes in water supply and the resulting price change risk, a risk neutral model for a simulated producer is used. Sadoulet and de Janvry (1995) constructed a risk neutral farm model based on the model of Newbery and Stiglitz (1981) and that is modified for the standard deviation of price in this paper.

$$\max.\; E[\pi] = E[pq] - wx$$
$$= E[p]E[q] + \mathrm{cov}(p,q) - wx \qquad (7\text{-}2)$$
$$\text{s.t.}\; q = \theta f(x) \qquad (7\text{-}3)$$

where π is the profit, p is the producer price which is a random variable, q is production, w is the input price, x is one of the input quantities, χ is the random variable; which has the following expected value and variance,

$$E[\theta] = 1, \quad \mathrm{var}[\theta] = \sigma_\theta^{\,2},$$

and $\mathrm{cov}(p,q)$ is the covariance of price p and production q. If there is a negative correlation between price and production, the expected profit in equation (7-2) will be lower than the case without price fluctuation. The correlation coefficient between price p and random variable θ under the assumption of a linear relationship is as follows:

$$corr(p,\theta)=\frac{\text{cov}(p,\theta)}{\sqrt{\text{var}(p)\,\text{var}(\theta)}} \qquad (7\text{-}4)$$

Multiplying non-random variable $f(x)$ by the definition of the correlation coefficient (7-4), the following equation is obtained:

$$corr(p,\theta)=\frac{E[p\theta f(x)]-E[p]E[\theta f(x)]}{f(x)\sqrt{\text{var}(p)}\sqrt{\text{var}(\theta)}}$$

$$=\frac{\text{cov}(p,\theta f(x))}{f(x)\sqrt{\text{var}(p)}\sqrt{\text{var}(\theta)}}=\frac{\text{cov}(p,q)}{f(x)\sigma_p\sigma_\theta} \qquad (7\text{-}5)$$

where the variance of price is σ_p^2 The covariance between price and production is written as follows:

$$\text{cov}(p,q)=corr(p,\theta)\sigma_p\sigma_\theta f(x) \qquad (7\text{-}6)$$

The first order condition of the expected profit maximization problem, i.e., (7-2) and (7-3), for input x is as follows:

$$\frac{\partial E[\pi]}{\partial x}=\frac{\partial(E[p]E[q]+\text{cov}(p,q))}{\partial f(x)}\frac{\partial f(x)}{\partial x}-w$$

$$=\left(E[p]+\frac{\partial\,\text{cov}(p,q)}{\partial f(x)}\right)\frac{\partial f(x)}{\partial x}-w=0 \qquad (7\text{-}7)$$

Substituting equation (7-6) into equation (7-7), the following equation is obtained:

$$[E[p]+corr(p,\theta)\sigma_p\sigma_\theta]f'(x)=w \qquad (7\text{-}8)$$

The price of equation (7-8), i.e., ($E[p]$ + $corr(p,\theta)$ $\sigma_p\sigma_\theta$)is the action certainty equivalent price and the difference between it and market price, i.e., mark-up; $corr(p,\theta)\ \sigma_p\sigma_\theta$, is used for the evaluation of price risk.

7-3. Simulation results of stochastic model

7-3-1. Results of Laotian model

7-3-1-1. Results of stochastic supply and demand model

The 500 sets of results of the simulation for correlated random ET values are distributed consistent with the historical fluctuations in the variable. To evaluate the expansion in fluctuations of water supply, the case of a 20% increase in the error distribution of ET is examined by expanding the original 500 sets of error terms.

Table 7-1 and Table 7-2 shows the coefficient of variation (C.V.) of production of wet season, dry season, and upland rice for the nation as a whole and wet season rice for each province. These numbers are the average values of the simulation results between 2005 and 2015. These results show that the variation in production for upland rice is quite high and that for wet season rice in the southern region, such as Champasack province, is higher than that in other regions. Figure 7-3 shows a map of the variation by province. The third column in these tables shows the coefficient of variation of production in the case of the expansion of the random errors of ET. The results show that if the fluctuation of ET expands, the rate of increase of the variation of production of wet season rice will be higher than that of upland rice, and provinces in the central region will have a higher level of variation in production than other regions. Figure 7-4 shows a map of the rate of increase of the coefficient of variation of wet season rice production.

Table 7-1. C.V. of production for type of rice

Type of rice Cultivation	Baseline	ET error 20% up	Rate of Increase
Wet season	0.0507	0.0609	20.1
Dry season	0.0727	0.0870	19.7
Upland	0.3226	0.3848	19.3

Table 7-2. C.V. of production of wet season rice

Province	Baseline	ET error 20% up	Rate of increase
Phongsaly	0.0624	0.0746	19.6
Luangnamtha	0.1006	0.1192	18.5
Oudomxay	0.0860	0.1027	19.4
Bokea	0.0641	0.0770	20.1
Luangprabang	0.0562	0.0689	22.6
Huaphanh	0.0675	0.0812	20.3
Xayabury	0.1555	0.1877	20.7
Vientiane Mun.	0.0525	0.0641	22.1
Xiengkhuang	0.0662	0.0801	21.0
Vientiane	0.1099	0.1327	20.7
Borikhamxay	0.0906	0.1102	21.6
Khammuane	0.1464	0.1774	21.2
Savannakhet	0.1155	0.1377	19.2
Saravane	0.1049	0.1253	19.4
Sekong	0.1485	0.1765	18.9
Champasack	0.1994	0.2389	19.8
Attapeu	0.1733	0.2082	20.1

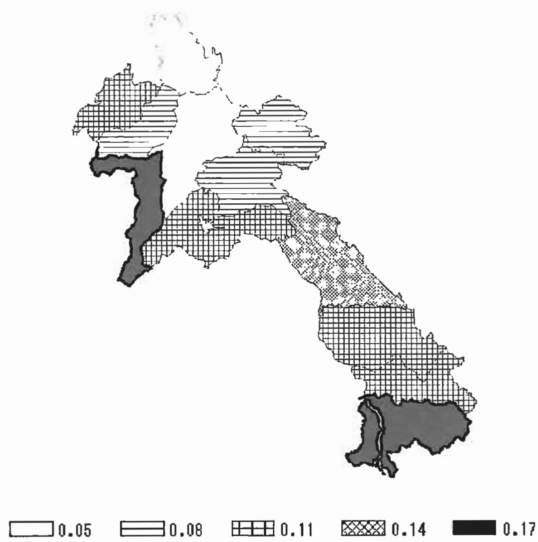

Fig. 7-3. Coefficient of variation of production

Fig. 7-4. Rate of increase of the coefficient

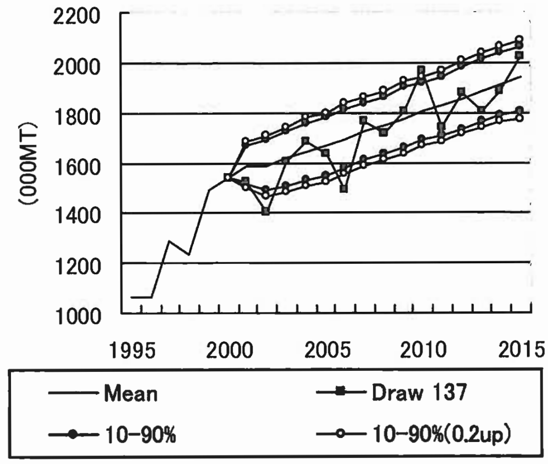

Fig. 7-5. Fluctuation of wet season rice production

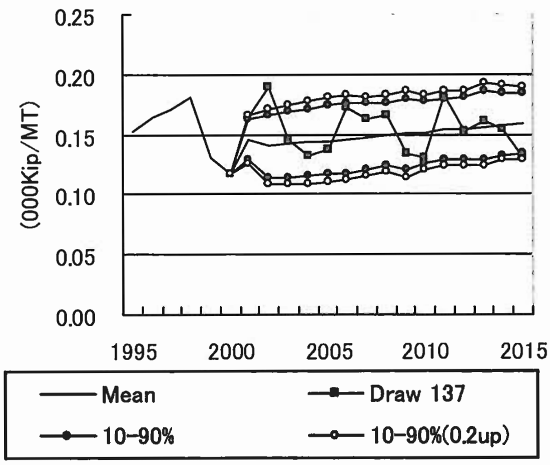

Fig. 7-6. Fluctuation of realized price

Figure 7-5 and Figure 7-6 show the fluctuation of wet season rice production and realized price. If the random error of ET expands by 20%, the average width between the 10th and 90th percentile of simulated outcomes for wet season rice production will increase from 238,000 MT to 285,000 MT, and the range for the real farm price will increase from 54.5 kip to 65.3 kip. The distribution of price is slightly negatively skewed; the width between 90% and mean is 27.8 kip and that between 10% and mean is 26.7 kip for the baseline.

7-3-1-2. Price risk evaluation

Table 7-3 and Table 7-4 show the difference between market and certainty equivalent prices (kip), i.e., the mark-up price. The greater the difference between the two prices, the greater the price risk to producers. The price gap for upland rice is the highest and it indicates that upland rice cultivation is riskier than wet and dry season rice cultivation. On the other hand, if the fluctuation of ET values is expanded, wet season rice cultivation is riskier than others. The third column of Table 7-3 and Table 7-4 shows the price gap for increase in the random ET error. The results indicate that wet season rice cultivation is quite risky under the volatile water supply scenario at the aggregate level. The price gaps for wet season rice are quite different among the provinces. The results show that wet season rice cultivation in Champasack and Attapeu is riskier than in other provinces. Figure 7-7 shows a provincial map of the difference between market and certainty equivalent price, i.e. price risk level. Figure 7-8 shows a map of the rate of increase in the difference between market and certainty equivalent prices due to the fluctuation of ET expanding 20% more than that in the baseline. The map indicates that the central region is sensitive to the risk associated with changes in ET, however, the risk level is lower than that in the southern region.

Table 7-3. Market-certainty eq. price for type of rice

Type of rice Cultivation	Baseline	ET error 20% up	Rate of Increase
Wet season	48.5	150.8	210.9
Dry season	14.3	20.5	43.3
Upland	66.4	94.9	42.9

Table 7-4. Market-certainty eq. price of wet season rice

Province	Baseline	ET error 20% up	Rate of increase
Phongsaly	1.0	1.3	30.0
Luangnamtha	2.8	4.0	42.9
Oudomxay	1.5	2.2	46.7
Bokea	2.7	3.8	40.7
Luangprabang	6.7	9.6	43.3
Huaphanh	1.1	1.7	54.5
Xayabury	9.8	14.7	50.0
Vientiane Mun.	3.6	5.4	50.0
Xiengkhuang	7.6	11.2	47.4
Vientiane	12.5	18.3	46.4
Borikhamxay	2.8	4.2	50.0
Khammuane	4.5	7.1	57.8
Savannakhet	14.6	20.7	41.8
Saravane	6.8	9.6	41.2
Sekong	4.5	6.3	40.0
Champasack	56.3	80.7	43.3
Attapeu	33.9	48.5	43.1

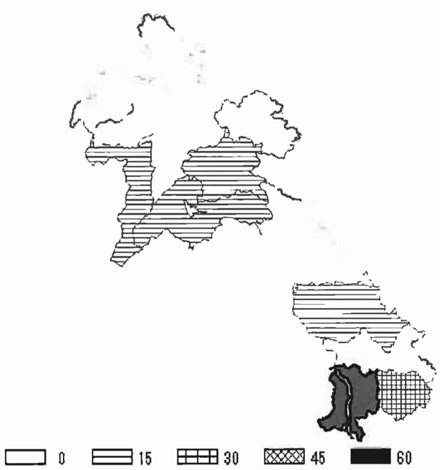

Fig. 7-7. Mark-up price for province

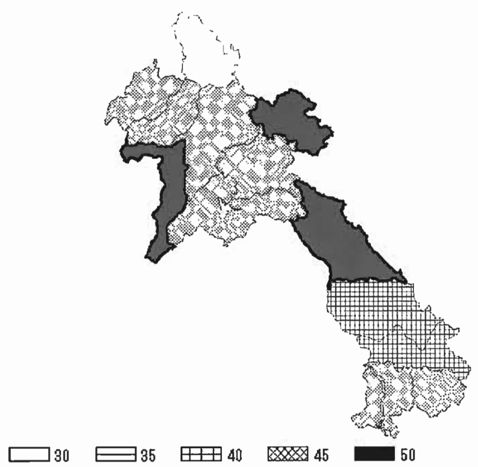

Fig. 7-8. Increase rate of mark-up price

7-3-2. Results of Cambodian model

7-3-2-1. Results of stochastic supply and demand model

The 500 sets of results of the simulation for correlated random ET values are distributed consistent with the historical fluctuations in the variable. Figure 7-9 shows the fluctuation of production in wet season and Figure 7-10 shows that in dry season. 90th and 10th percentiles indicating production band are shown in both figures. Furthermore, randomly selected 137th results of the simulation are shown in these figures. The difference between 90th and 10th percentiles for wet season rice production is about 400 thousand metric tons, which is about 10% of the average production. On the other hand, that for dry season rice production is about 180 thousand metric tons, which is about 17% of the average production; then, the variation of production in dry season is relatively greater than that in wet season.

Investigating increasing the water supply variability, a simulation where the random variation of the ET equation error is increased 20% is conducted. This simulation means that the random variation of the water supply will be 20% greater than the average variation from 1980 to 2000. The difference between 90th and 10th percentiles for wet season rice expands into 500 thousand metric tons and that for dry season rice expands into 220 thousand metric tons. The percentages increase of these changes, relative to the productions in the base year are 2.5% and 3.8% respectively, indicating rice production during the dry season is more affected by water supply changes than during the wet season. It seems that the dry season cultivation is the more stable of the two seasons due to the water control of irrigation facilities; however, planted area in the dry season depends on river discharges and reservoir capacity. Furthermore, if transplanting in the wet season is delayed by a dry spell, transplanting in dry season will also be delayed from the optimal planting season. Thus, the variation of production in the dry season is probably larger than that in the wet season.

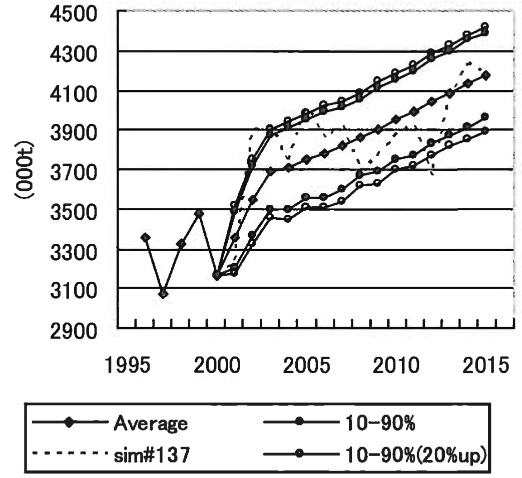

Fig. 7-9. Fluctuation of production of wet season rice for whole country

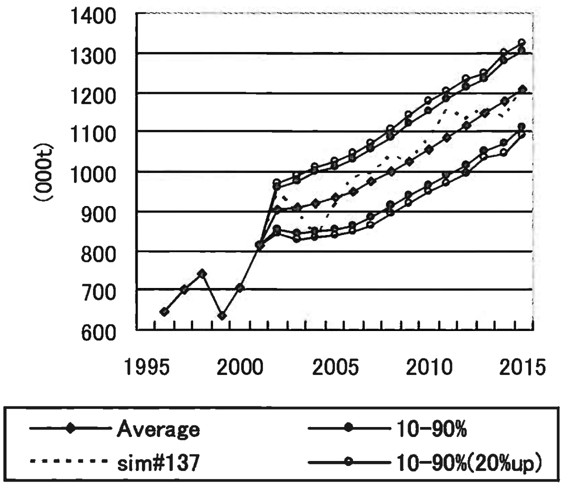

Fig. 7-10. Fluctuation of production of dry season rice for whole country

Next, impacts of water supply changes on the planted area during the wet season are investigated. Figure 7-11 shows a map in which indicates differences in coefficients of variations between the case of 20% increase in water supply fluctuations and baselines. Planted area in regions where elevations are high, such as Rottana Kiri, Mondol Kiri, and Koh Kong, and the land vulnerable to flooding, such as Phnom Penh and Prey Veng, are sensitive to increased fluctuations in water supplies. The average yields of these provinces are low, i.e., 1.5t/ha from 1995 to 2003.

Finally, the variation of the farm price is investigated. Figure 7-12 shows the fluctuation of the farm price similar to figures which show fluctuations of productions. The distribution of price is slightly negatively skewed; the width between 90th percentile and the mean is 75,400 Riel and that of between 10th percentile and the mean is 73,200 Riel for the baseline. The asymmetry of the distribution is based on the logarithmic ET variables of yield and planted area functions, and it corresponds to diminishing planted area in the case of water supply scarcity.

If the random error of ET expands 20%, the average width between the 10th and 90th percentile of simulated outcomes for farm price will increase from 149,000 Riel to 178,000 Riel. Therefore, an increase in the variation of water supplies leads to a higher price of rice.

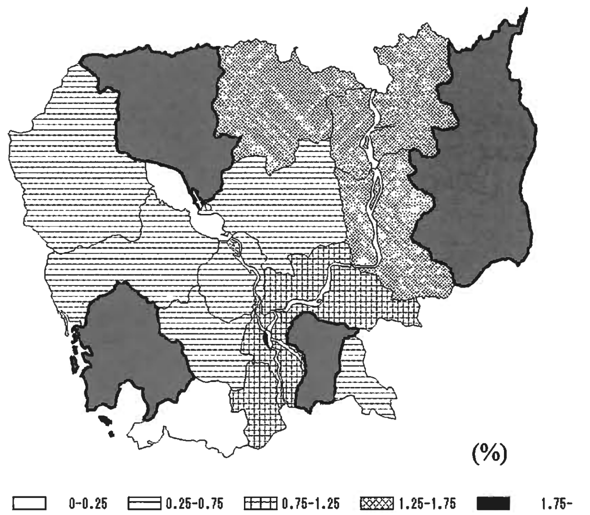

Fig. 7-11. Magnitude of fluctuations of planted area in wet season

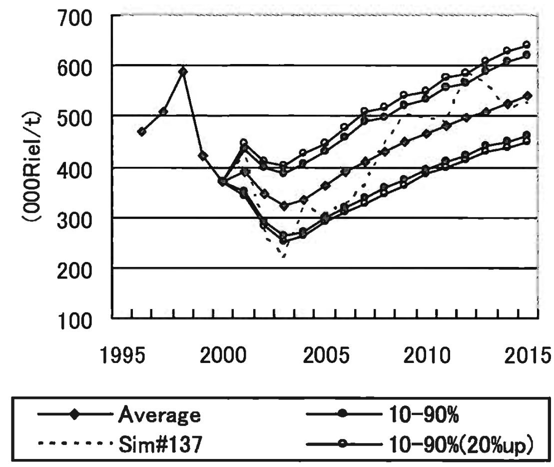

Fig. 7-12. Fluctuations of farm price

7-3-2-2. Price risk evaluation

The second column of Table 7-5 shows the difference between market and action certainty equivalent prices. The greater the difference between the two prices, the greater the price risk to producers. The price gap for wet season rice is higher than that for dry season rice and it indicates that wet season rice cultivation has higher price risk than dry season rice cultivation.

The third column of Table 7-5 shows the price gap, i.e., mark-up, for increase 20% in the random ET error. The results indicate that wet season rice cultivation is riskier than dry season rice cultivation under the volatile water supply scenario at the aggregate level due to an increase in the variation in gross returns. Such variation in production and returns has additional implication for developing country farmers through lack of storage and access to adequate credit.

Figure 7-13 shows a provincial map of the rate of increase in the mark-up price, which reflects the price risk level, due to expanding the fluctuation of ET 20% more than that in the baseline. The map indicates that higher yield and production provinces, such as Kandal or Takeo face higher price risk for water supply changes.

Table 7-5 Mark-up price for type of rice

Type of rice cultivation	Market-Action certainty eq. price		
	Baseline (Riel/t)	ET error up 20% (Riel/t)	Rate of Increase (%)
Wet season	2314	2741	18.46
Dry season	1709	1987	16.30

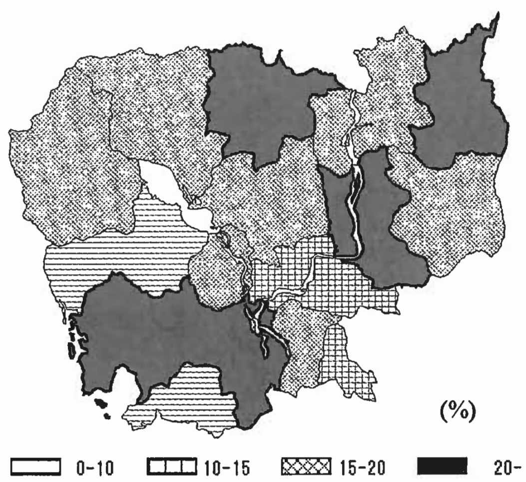

Fig. 7-13. Increase rate of mark-up price

7-4. Conclusions

Results of stochastic analyses of the Laotian rice model show that the production of upland rice is highly influenced by changes in the water supply, and thus adequate water management is required for upland cultivation to reduce the risk faced by producers. However, when considering price risk, the wet season rice cultivation is most vulnerable to water supply changes. Rice farmers producing wet season rice in the southern region, such as Champasack and Attapeu provinces, will likely incur serious damage under a scenario where the variation in the water supply expands.

Results of an analyses of Cambodian rice markets, utilizing a stochastic model, with increased variation in the ET variable, show that the production of dry season rice is more influenced by climatic change than that of wet season rice, and thus adequate water management is required for dry season rice to reduce production risk faced by producers. However, when considering price risk alone, the wet season rice cultivation is more vulnerable to water supply changes. Rice farmers producing wet season rice in high yielding regions with sizeable production, such as Kandal or Takeo province, will incur financial damages under a scenario where the variation in the water supply expands.

The distributions of the farm price of both countries are negatively skewed and the probabilities of higher prices are greater than those of lower prices. These indicates that if the fluctuation of water supply expands, consumers, such as rural poor are most vulnerable as they may face a higher price for rice which is a staple of their diet. The regions or provinces which suffer from highly variable production and higher price risk may need to consider water management and alternative cultivation methods to minimize the impacts on both producers and consumers from increased variation in the water supply.