An analytical supply response model of irrigable area project: A case study of the Chao Phraya river basin*

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Abstract: *Competition for water in the dry season has become more intense between upstream and downstream farmers, between agriculture and non-agricultural sector and even between government agencies. Objective of water resource management is to allocate the water resource in the efficient and equity manners. Approximately, 90% of the total water use in Thailand is used by the agricultural sector. The study's objective is to estimate the marginal value of irrigated water in the agricultural sector in the Chao Phraya River Basin. Methods used in the study are i) the estimation of a share equation (supply of crop) with the dependent variable being the area share of each subgroup (3 subgroups – rice, field crops and others) in the total area and ii) the estimation of a rice yield response function. Data used in the analysis was collected from the 16 irrigation projects in the basin. Results of the study showed that marginal value of irrigated water ranges from 0.19 to 1.42 bath per cubic meter. Wide range of these values may be explained by characteristics of the variables in the model. However, the model will be improved by treating more independent variables in order to obtain more precise outcome. Water resource management is usually more concerned with agricultural development. Technological change in agricultural production, e.g. machinery and early mature rice variety, have been considered as major factors that have led to increase cropping intensity. In addition, higher price of paddy induces some incentive to the Thai farmers to produce more paddy rice. Therefore, policies on agricultural production, trade and water allocation are necessary for increasing welfare of society.*

Water is an important input factor in agricultural production which need more water quantity than other economic sectors. The Chao Phraya Basin, including sub-basin in Northern; those are Ping, Wang, Yom, and Nan, is covering Northern and Central regions and being area that many conflict had occurred in dry season for long time, especially from Nakhon Sawan, where is mainly agricultural land, along through Bangkok, where is urban area. Therefore, the conflicts of both sectors have been occurred, especially in crisis of the dry season and

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stocking of water quantity in Bhumiphol Dam and Sirikit Dam totally under 6 billion cubic meter on January, 1st. For instance, during 1992 to1994 it was extremely dried period and only 2-3 billion cubic meter of water was available.

The mentioned conflict leads to the question how to allocate water resources for both economic sector and also for upstream and downstream area with equally and equity. According to efficiency managerial principle, things should be allocated to sectors that bring more economic added value first so that opportunity cost will not occur on them.

The main objective of the study is to estimate the marginal value of irrigated water in Chao Phraya basin by using production function regarding water resources as a input factor. And the out come would reflect policy in 2 points those are; (1) How many limited water resources should be allocated to Agricultural sector while compared with its economic value. And (2) How to add economic value of cultivated water. However the objective of this paper is to provide the estimation measurement conceptual framework of marginal value of irrigated water in agriculture sector for further study advantage.

This paper is divided into 3 sections, (1) theoretical framework, (2) the economic of marginal value of irrigated water (MVPw), and (3) conclusion.

1 Theoretical framework

1.1 Conceptual framework

The model used in this study is model for analysis of supply responding in irrigation area in the dry season that is the result of combination of output price, irrigated water factors, and other input factors together with fixed factor, those are land and capital which are constant in short-run period, and variable factor and receive output. This is under restriction that its price factor, substitute crop price factor, and non-agriculture commodities price factor determine production quantity and resources allocation. Furthermore, irrigated water quantity variable is an important factor for supply increasing in the dry season.

An important behavioral assumption on farmer’s decision-making is based on farmer’s aims to have maximize profit. And equation for maximize profit from agricultural output is shown as below.

$$\Pi = PQ - WV \qquad (1)$$

when Q and V are varies on production function, see equation (2);

$$Q = f(V, Z) \qquad (2)$$

Where Q is the vector of all the crop output
V is the vector of all the variable inputs
Z is the vector of other undefined variables
P is the vector of output prices
W is the vector of variables input prices

In maximize profit of firm there show of supply system equation thus as follow with equation (3),

$$Q = g(P, W, Z) \qquad (3)$$

The above structure of production is assumed that agricultural area is divided into 4 groups, consist of paddy field, field crop, fruit and tree, and vegetable. Supply equation of each group is nested to the others. Therefore the analysis of supply equation of each group have to be joint estimation with another crop supply in the structure. In addition, we assumed that production supply of each group is result from area and yield responding together.

Yield response function is as following equation (4);

$$Yi = Qi/Ai = h(Pi, W, Z) \qquad (4)$$

Where Yi is output i per area and Ai is cultivated area i

Equation (4), the correlation between yield and price variable, and irrigated water variable are positive. It means price variable and irrigated water variable increasing affected yield increasing. But other variables are negatively correlated with yield.

1.2 Econometric estimation

An important objective of production supply analysis of each crop is to estimate the elasticity of economic variable and irrigated water variable. In supply equation, we assumed that planned output is different from actual output. Because some input factors are not controlled by the farmers. This different output is used to construct farmer decision-making equation of 2 steps. At first step, farmer will make area using planning. The second step is to plan how to produce, which is upon planning of adding output per area unit (Behman, 1968; Evan and Bell, 1978; Isvilanonda and Poapongsakorn, 1995).

In farmer decision-making of area using, we assume that the planning for area using will upon price of output and input factors such as paddy and other crops price and labour cost is upon physical factors such as rainfall, irrigated water. All factors affect to change on supply curve as below.

$$sjt^* = aj + \Sigma_i aij.\ln Pit\text{-}1 + \Sigma_k akj.\ \ln Wkt + \Sigma_m amj.\ \ln Zmt + u1jt \qquad (5)$$

where sjt* is share of planned crop area by total area at time t
aij, akj, amj are coefficient of independent variable; u1jt is error term

By assuming that behavior of crop area follow as method in equation (6) (see Gudjarati, 1978 for more information).

$$sjt - sjt\text{-}1 = \Phi(sjt^* - sjt\text{-}1) \text{ and, } 0 < \Phi < 1 \qquad (6)$$

where j is crop area share we assumed 4 types, and t is year.

sjt and sjt-1 are actual area share of each crop by total cultivated area in year t and t-1 respectively. Equation (6) explains that the different of actual agricultural area (sjt) in year t and t-1 (sjt-1), is from adjustment of the difference between planned agriculture area in time t and actual agriculture area in time t-1. When we solved equation (5) and (6), it can be appeared in equation (7) that will be used in the estimation.

$$s_{jt} = \alpha_j + \sum_i \beta_{ij} \ln P_{t-1} + \sum_k \gamma_{kj} \ln W_{kt} + \sum_m \omega_{mj} \ln Z_{mt} + \chi_j s_{jt-1} + \eta_{2jt} \quad (7)$$

where j is 1,2,3,4 and t is time year.

In coefficient estimation of supply response equation, we estimate from system equation using pooling cross-section and time series data. Data used in the model was collected from the irrigation projects. Seemingly unrelated technique is used for coefficient estimation to reduce bias (Maddala, 1977) with following restrictions.

$$\sum \alpha_j = 1 \quad (7.1)$$

$$\sum \beta_{ij} + \sum \gamma_{kj} = 0 \quad \text{, all i and k} \quad (7.2)$$

$$\sum \omega_{mj} = 0 \quad \text{, all m} \quad (7.3)$$

$$\beta_{ij} = \beta_{ji} \quad \text{, all i and j} \quad (7.4)$$

From equation (7.1) to (7.3), summation of Sij equals to 1 for all cases, equation (7.4) is represented for symmetry requirement. In addition, by considering equation (7.2) and (7.4) share supply response equation is homogeneous degree zero to price variable (Siamwalla et al, 1990; Rosgrant and Kasryno, 1992).

For yield response equation and price factor and area physical, we assign equation as log-linear form which can be shown as equation (8).

$$Y_{jt} = \delta_j + \sum_h \Theta_{jh}.P_{ht-1} + \sum_k \xi_{jk}.W_t + \sum_m \rho_{jm}.Z_{mt} + v_{jt} \quad (8)$$

In estimation of supply elasticity by price factor and related factor, we used to link area share (of crops those are paddy, field crop, vegetable, and fruit and tree) and yield together. The result is the total crop supply as following equation (9).

$$Q_{jt} = s_{jt}.A_j.Y_{jt}, \quad (9)$$

Where Qjt is crop j output at time t. There calculated from j times crop j area.

From equation (7), (8), and (9), the coefficient received from estimation will be used to estimate elasticity of supply by economic factor and irrigated water variable. The elasticity of irrigated water (**ej**Q_{IR}) is derived from equation (10) as followings:

$$\mathbf{ej}Q_{IR} = \mathbf{ej}Y_{IR} + \mathbf{ej}A_{IR} \quad (10)$$

Where **ej**Y_{IR} represents elasticity of crop j when concerning of irrigated water. **ej**A_{IR} is elasticity of crop j area (in being as area share) concerning of irrigated water quantity.

1.3 Estimation model

From conceptual framework and econometric estimation, we can derive estimation model of price elasticity and marginal value of irrigated water (VMPx). The estimation have 2 steps, the first step is to estimate area response. The second step is to estimate yield response. The both steps will be linked together on irrigated water elasticity.

1.3.1 First Step : area response estimation

Dependent variable is share of crop area in each irrigation project which are divided into 3 type those are paddy area (s1), field crops and sugarcane area (s2), and other crops (s3), where s1 + s2 + s3 is equal to total crops area in the dry season. This study assume that paddy area share is our target, and field crop and sugarcane area share are substitute commodities and other crops area share is residual. There are 6 independent variables consist of paddy price, field crop price, vegetable price, irrigated water, agricultural labor wages, and fertilizer price. The model is ;

$$S1_{it}\ S2_{it} = f\ (PDDP_{t-1}, CRPP_{t-1}, FRTP_{t-1}, WU_{it}, LBP_t, FTZP_t)$$

Where $S1_{it}$ = Share of dry paddy area in irrigated area i at t
$S2_{it}$ = Share of field crops area in irrigated area i at t
$PDDP_{t-1}$ = Paddy Wholesale Price at time t-1 (baht per kg.)
$CRPP_{t-1}$ = Sugarcane Wholesale Price at time t-1 (baht per kg.)
$FRTP_{t-1}$ = Vegetable Wholesale Price at time t-1 (baht per kg.)
WU_{it} = Amount of Irrigated Water in Irrigation project i at time t (m3 in the dry season)
LBP_t = Agricultural Labor Wages at time t (unit : baht per day)
$FTZP_t$ = Fertilizer Wholesale Price on formulation 16-20-0 at time t (baht per ton)

From above equation, our hypothesis is that farmers will make-decision to increase allocated area for paddy by comparing with field crop area when they expected paddy price at time t-1 will be higher than field crop price. Irrigated water variable used for cultivation at time t is enough for demand in whole dry season. The both variables affect decision-making for paddy area allocation in positive direction. Meanwhile field crop price in last year (t-1) had been decreased comparing with paddy price. And input factor price, which are agricultural labor wages and fertilizer price, is not so expensive that farmer expected marginal profit would decline and not reach maximize profit. Field crop price variable and input price will affect in negative direction. The vegetable and fruit price variable in last year (t-1) will be price reference used for decision-making to longer change to fruit and vegetable cultivation or not, is upon the assumption that the area can be changed from paddy field to other crops by land physical is fixed.

The estimation method used for the model is system equations method which concerned with changing of other independent variables those are changed together. Estimation technique is Generalized Least Square (GLS) technique, the coefficient received from estimation of the log-form is elasticity of area response by irrigated water.

1.3.2 Second step : yield response estimation

Paddy yield of each project is a dependent variable. There are 4 independent variables consist of paddy price, irrigated water per area, agricultural labor wages, and fertilizer price. The model is ;

$$Yield_{it} = f\ (PDPI_{I,t-1}, WURAI_{it}, LBP_t, FTZP_t)$$

Where $Yield_{it}$ = Paddy yield in irrigation project i at time t (unit :kg per rai)
$PDDP_{t-1}$ = Paddy Wholesale Price at time t-1
$WURAI_{it}$ = Irrigated Water per area i at time t (unit : m3/ria)

LBP_t = Agricultural Labor Wages at time t
$FTZP_t$ = Fertilizer Wholesale Price on formulation 16-20-0 at time t (baht per ton)

The above model is under hypothesis that, after farmer made decision on allocating area for paddy, they aimed to get output to maximize profit. Thus, the motivation of production is high paddy price, as well as to receive input, water quantity, continuously. Then, the coefficient of both variables is positive direction, but the input, such as agricultural labor wages, fertilizer price which are production cost, is negative direction.

The estimation of this model used ordinary least square method (OLS).The received coefficient from the log-linear equation is elasticity. With this estimation, we will receive elasticity of paddy output per paddy price and per water quantity used in the project.

1.4 Data

Irrigation project area in the Chao Phraya river basin consists of 18 provinces,namely Chai Nat, Sing Buri, Ang Thong, Ayutthaya, Lop Buri, Saraburi, Nonthaburi, Pathum Thani, Nakorn Sawan, Suphan Buri Nakorn Pathom, Samutsakorn, Samutpakarn, Chachoengsao, and Bangkok. There are 26 large projects, 14 medium projects, and 119 small projects. Total project area is 8.855 million rai or 70.4 percent of the Chao Phraya river basin. The large scale project are covered 8.351 million rai or 94.3 of total irrigation area, irrigated area is 6.633 million rai or 74.9 percent of the large scale irrigation project. (Table 1)

The irrigation system for the Chao Phraya river basin is divided in 3 systems as its distribution; (1) Gravity irrigation system, the efficiency of this system is to irrigate around 62-82 percent in the dry season and 48-84 percent in the rainy season. This system is applied for 16 projects, comprise of i Polathep, ii Boromathad, iii Thabote, iv Samchuk, v Don Jedee, vi Pho Phaya, vii Chanasuth, viii Yangmanee, ix Phak Hai, x Manorom, xi Chong Kae, xii Khok Kateim, xiii Roeng Rang, xiv Maharat, xv Pasak Tai, and xvi Nakhonluang. Projects and irrigated area cover 4.545 and 4.082 million rai respectively.

(2) Conservation area irrigation system, is the system using natural canal as water storage and dispense water quantity fix to the shortage quantity. Agricultural land in irrigation system can be cultivated in all seasons. However, almost project's area characteristic are flood plain. Thus it has flooding problem. The efficiency of this system is to irrigate around 57-88 percent in the dry season and 50-84 percent in the rainy season. This system is applied for 8 projects, comprise of i Chao Ched-Bang yeehon, ii Phrayabanlue, iii Phrapimol, iv Pasicharoen, v Rangsit Nua, vi Rangsit Tai, vii Klong Dan,and viii Phra Ong Chai Ya Nuchit. Projects and irrigated area cover 3.807 and 2.551 million rai respectively. And (3) Pumping irrigation system cover 2 projects; i Bangbal and ii Wad Singh. Irrigation water is pumped and distributed by gravity system. Its efficiency is to irrigate around 72-89 percent in the rainy season.

This paper studied on the gravity irrigation system and pumping irrigation system. As we can measure water quantity used in the cultivation. We assumed that the whole cultivated area as if one area unit so the model can explain changing of area using for cultivation with changing of irrigated water quantity.

From above model in part 1.3, the study used pooling data for analysis. That is to join cross-section and time series data together. The data set is total 16 projects of irrigation area for 13 years, covering 1987 to 1999. Output price factor was Bangkok wholesale price during 1986 to 1998. Input factor price were agricultural labor wages in the central region. For fertilizer price formula 16-20-0 price during 1987 to 1999 was selected. The data was collected from Department of Economic Commerce and Office of Agricultural Economic)

2 The economic of marginal value of irrigated water (VMPx)

From the theoretical framework in section 3, the estimation of both model are received area response elasticity of irrigated water factor ($e_{a,w}$) and yield respond elasticity of irrigated water ($e_{y,w}$). Summation of both elasticity, is yield elasticity of irrigated water per area ($e_{q,w}$). By multipling the received elasticity with paddy yield (kilogram) and average paddy price (baht per kilogram) and divided by average irrigated water per area (cubic meter per rai). Equals marginal value of irrigated water (VMPx).

2.1 Model selection

The study estimated the estimation model in 2 forms as follows:

Model I, all output prices are wholesale prices of Bangkok market adjusted form to price index those are paddy price index, field crop price index (Cassava, Cotton, Ground nut, Mangbean, Soybean, Kenaf, Maize, Sugarcane, and Pineapple), vegetable price index (Tobacco, Chili, Shallot, Onion, Garlic, Cabbage), and fruit and tree price index (Rubber tree, Palm oil, Coconut, Longan, and Coffee). All price indexes are calculated by Divisia Price Index (DPI)[2] for 1986 to 1998 and fixed 1988 as base year. Labor wages,is nominal wages of central region deflate by consumer price index (CPI), adjusted by distance from Bangkok to Chai nat or Lop buri. For fertilizer price, we used Bangkok wholesale price deflated by GDP deflator adding by transportation cost from Bangkok to each province.

[2] DPI is price index that concerned rate of total commodities value changing at time t by calculate from sum of average commodity value i and commodity value i at time t multiply with rate of commodity price i changing at time t compared with commodity price i at time t-1 (see below equation). Which in economical thought, this method provide better meaning than Laspeyres Price Index and Paeches Price Index which are concerned comparing of commodities value at time t and commodities value at time t-1, and Fisher Price Index which is concerned changing of exponential price index. Divisia Price Index formulation is as below.

$$\log (D)t = (0.5) \sum_{i=1}^{I} (si + si,t\text{-}1) \log (pit / pi,t\text{-}1)$$

where sit = (pit * qit) / (pt * qt)
Dt is Divisia Price Index
sit is commodity value i at time t compared with commodity value of based year t
pit is commodity price i at time t where i=1,2,…,N and t=1,2,…,T
qit is commodity quantity i at time t, where i=1,2,…,N and t=1,2,…,T
pt is fixed commodity price at time t
qt is fixed commodity quantity at time t

Table 1 Irrigation Projects in the Chao Phaya River Basin (unit : rai)

Project	Provincial Area	Construction Started	Construction Finished	Project Area	Planed Irrigated Area	Actually Irrigated Area
1. Polathep	Chai Nat	2495	2506	103,000	96,300	96,300
2. Boromathad	Chai Nat, Suphan Buri, Sing Buri	2495	2506	405,000	365,000	365,000
3. Thabote	Chai Nat, Suphan Buri	2495	2506	218,356	196,400	196,520
4. Samchuk	Suphan Buri, Ang Thong	2478	2498	370,000	305,000	305,000
5. Don Jedee	Suphan Buri	2504	2507	164,652	146,000	148,129
6. Pho Phaya	Suphan Buri	2464	2476	415,938	370,000	370,000
7. Chanasuth	Sing Buri, Chai Nat, Suphan Buri, Ang Thong, Ayutthaya	2495	2506	527,000	448,200	474,300
8. Yangmanee	Ang Thong, Sing Buri, Ayutthaya	2495	2506	233,689	210,300	210,321
9. Phak Hai	Ayutthaya, Ang Thong, Suphan Buri	2495	2506	219,658	206,000	206,000
10. Bangbal	Ayutthaya, Ang Thong	2513	2526	160,000	137,000	137,000
11 Wad Singh	Chai Nat	Na.	Na.	Na.	Na.	Na.
12. Chao Ched	Ayutthaya, Suphan Buri	2482	2493	437,850	406,000	406,000
13. Phrayabanlue	Nonthaburi, Ayutthaya, Suphan Buri, Nakhon Pathom, Pathum Thani	2482	2493	420,000	358,650	350,000
14. Phrapimol	Nonthaburi, Nakhon Pathom	2482	2493	340,350	266,000	250,950
15. Pasicharoen	Nakhon Phathom, Bangkok, Samut Song Khram	2445	2450	202138	124,800	56,454
16. Manorom	Chai Nat, Nakhon Sawan, Sing Buri	2495	2505	285,104	268,000	262,681
17. Chong Kae	Nakhon Sawan, Sing Buri, Lop Buri	2496	2506	261,624	238,700	238,740
18. Khok Katiem	Lop Buri, Saraburi, Ayutthaya	2496	2506	228,300	205,500	205,470
19. Roeng Rang	Saraburi, Ayutthaya	2495	2506	203,781	179,000	179,000
20. Maharat	Sing Buri, Chai Nat, Lop Buri, Ang Thon, Ayutthaya	2495	2507	523,912	422,000	476,300
21. Pasak Tai	Ayutthaya, Saraburi	2464	2476	272,000	240,600	270,160
22. Nakhonluang	Ayutthaya	2503	2507	301,846	267,000	276,048
23. Rangsit Nua	Ayutthaya, Phatum Thani, Saraburi	2458	2467	445,500	454,000	359,775
24. Rangsit Tai	Phatum Thani, Bangkok	2464	2476	892,000	526,000	441,970
25. Klong Dan	Samut Prakan, Bangkok, Chachoengsao	2464	2476	559,000	525,000	409,757
26. Phra Ong Chai Ya Nuchit	Chachoengsao, Samut Prakan	2464	2476	511,000	510,000	510,000
Total Irrigated Area				8,350,698	7,471,450	6,632,523

Source : Royal Irrigation Department, and Kasetsart University and ORSTOM (1996).

Model II is derived from model I by using Bangkok nominal wholesale price information that formed to be constant price in 1988. We used the average price for whole year. Sugarcane price and cabbage price was selected for the field crops used vegetable price, repretively 16 dummy variable represent irrigation project in the Chao Phraya river basin.

The result of the study showed that overall testing for both model have significant and model II has higher significant and R2 than model I. Considering independent variable in modei I, only irrigated water variable has significant positive effect as expected. On the other hand, other variables have not significant effect. We can say that the result from model II is better than from model I. That is the coefficient of economic variable, irrigated water variable, and input factor variable are expected direction and significant at 0.01 percent. Consequently, we used the result of model II for interpretation.

2.2 The area study statistic

The irrigation project area in the Chao Phraya river basin covers 8.351 million rai there is irrigated area 79.4 percent of total irrigation project area and cultivated area in dry season 63.1 percent of total irrigated area. The studied area covers 54.4 percent of total irrigation project area in the Chao Phraya river basin or 4.544 million rai which is irrigated area 89.8 percent of studied project area and cultivated area in dry season 77.5 percent of studied irrigated area.

More than 70 percent of studied cultivated area in dry season is paddy field and the left area is field crops, vegetable and fruit, and other crops which are 15.6, 5.0, and 1.4 percent respectively. Growth rate of vegetable and fruit are increased more than 88.9 and 144.6 per annum. While paddy field growth rate is nearly constant (see table 2 and 3).

2.3 The result of area response and yield response

The estimation of area response equation by economic variable and irrigated water showed that the last price period (t-1) of paddy and sugarcane affect farmer's decision-making to allocate paddy area in the dry season with significant at 0.01. It means when paddy price rose up, farmers will also increase area for the paddy. When sugarcane price was relatively higher than paddy price, they will reduce paddy field and change to sugarcane. The price sensitivity of paddy and sugarcane are unequal and incomplete substitution.

The elasticity of paddy area response to paddy price factor and irrigated water factor is 0.515 and 0.17 ($e_{a,p}$ = 0.515 and $e_{a,w}$ = 0.170) respectively. It means, when paddy price or irrigated water increase by 1 percent, paddy field area in irrigated area will increase by 0.515 and 0.17 percent respectively. However, paddy price factor affected farmer decision-making more than irrigated water for allocation paddy area. Because in the Chao Phraya river basin, usually there are high risk for water resources scarcity in the dry season. Once paddy price rose up, farmers willingly take risk for paddy cultivation since they expected to get maximize profit even under uncertainty.

For 13 years ago, paddy yield have been increased from 600-700 kg. per rai during 1987-1989 to 700-800 kg. per rai in 1992. From the yield response estimation, the result showed that irrigated water factor affected the changing of paddy yield in the dry season at the significant of 0.01. The elasticity of paddy yield by irrigated water is 0.315 ($e_{y,w}$ = 0.315). It means, once irrigated water change by 1 percent, paddy yield will change by 0.315 percent.

Paddy price variable affected the increasing of paddy yield per area. Once farmers decided to produce paddy, its price will be an incentive for them to expect to maximum yield. However, paddy price factor is insignificantly.

2.4 The marginal value of irrigated water (VMPx)

The result of estimation in part 2.3, showed that the economic marginal value of irrigated water in the Chao Phraya river basin is range 0.192-1.436 baht per cubic meter that means farmers used 1 cubic meter irrigated water to produce on farm it will create economic return at range 0.192-1.436 baht. (table 8) However, how much received economic return more or less depending on the estimation model.

3 Conclusion

The preliminary result is not able to summarize completely about economic value of irrigated water. There is because the estimation on each variable is unexpected and insignificantly. However, we may conclude that economic value of irrigated water a cubic meter ranges between 0.192-1.436 baht.

The preliminary conclusion for policy making may be said that if government will restrict paddy area in the dry season in order to manage the limited water resources to have enough demand response in economic sector, the government has to use the economic value of irrigated water as an instrument to limit paddy area or to set compensation for the farmer's opportunity cost to stop paddy cultivation in the dry season.

TABLE 2 IRRIGATION PROJECT STATISTIC IN THE CHAO PHRAYA RIVER BASIN

Description	Chao Phraya river basin		
	Min.	Max.	Average
Irrigation project			
- Total Project area (million rai)	8.351		
- Total irrigated area million rai)	6.633		
- Total cultivated area (million rai)	5.267		
- Ratio of irrigated area and project area (%)	79.43		
- Ratio of cultivated area and irrigated area (%)	63.07		
Area Studied			
- Total project area (million rai)	4.544		
- Total irrigated area (million rai)	4.082		
- Total cultivated area (million rai)	3.520		
- Ratio irrigated area and project area (%)	89.83		
- Ratio cultivated area and irrigated area (%)	77.47		
Cultivated area share in area studied (%)			
- Paddy field	59.77	90.42	77.96
- Field crop	6.93	31.24	15.58
- Vegetable and fruit	0.91	8.88	5.05
- Other	0.66	2.23	1.42
Growth rate of cultivated area, during 1987 to 1999 (per annum)			
- Paddy field	14.23		
- Field crop	-32.73		
- Sugarcane	63.13		
- Vegetable	80.86		
- Fruit	144.56		
- Tree	26.53		
- Other	2.93		
- Average Growth rate	19.29		
Irrigated water per area (cubic meter / rai)	**1,519.69**		
Paddy Yield (kg. / rai)	**653**		

Source : calculated by the author

TABLE 3 CROP CULTIVATION AREA IN THE CHAO PHRAYA RAVER BASIN (UNIT : RAI)

Year	Paddy	Field crop	Vegetable	sugarcane	fruit	tree	Fish and other	Total
2530	2,472,745	96,219	55,334	55,447	198,621	34,901	199,035	3,112,302
2531	2,498,548	51,240	49,595	51,226	237,587	15,225	216,096	3,119,517
2532	2,769,481	44,635	52,152	61,276	218,586	15,745	234,468	3,396,343
2533	2,937,022	58,181	50,733	58,106	249,712	10,558	250,730	3,615,042
2534	1,775,698	84,752	35,919	157,743	239,240	7,524	139,804	2,440,680
2535	2,066,552	96,828	44,289	167,807	290,169	12,057	79,241	2,756,943
2536	1,870,834	77,373	49,479	183,325	296,017	12,581	159,689	2,649,298
2537	1,662,489	60,899	37,974	136,242	313,265	15,827	153,595	2,380,291
2538	2,460,405	53,016	37,174	191,570	343,197	13,764	123,414	3,222,540
2539	3,560,670	28,235	45,213	214,789	366,654	26,211	167,253	4,409,025
2540	3,444,669	23,619	43,022	192,231	380,351	10,880	76,461	4,171,233
2541	3,196,927	31,395	42,237	164,047	359,099	12,216	137,460	3,943,381
2542	2,701,470	37,744	32,777	165,093	383,065	22,466	198,725	3,541,340
2530-33	2,669,449	62,569	51,954	56,514	226,127	19,107	225,082	3,310,801
2534-37	1,843,893	79,963	41,915	161,279	284,673	11,997	133,082	2,556,803
2538-40	3,155,248	34,957	41,803	199,530	363,401	16,952	122,376	3,934,266
2541-42	2,949,199	34,570	37,507	164,570	371,082	17,341	168,093	3,742,361

Source : Royal Irrigation Department

Table 4 Area response estimation in model I

	OLS		GLS	
	Coeff.	t-test	coeff.	t-test
No. Obs.	204			
Constant	-1.454	-1.100	-2.847	-2.895
LWPDDI	0.072	0.378	-0.085	-0.526
LWCRPI	0.260	1.392	0.183	1.632
LWFRTI	-0.053	-0.508	-0.084	-2.831
LWU	0.043	3.096	0.045	3.252
LFTZP	0.159	1.045	0.319	2.774
adj. R-square	0.112		0.105	
Chi-square	-		2.529	
F-test	6.140		5.750	
DW. Stat.	0.992		1.028	
Paddy Share	0.695		0.695	
e (p,w)	X		x	
e (a,w)	0.062		0.065	

Remark LWPDDI is log of paddy wholesale price index
LWCRPI is log of wholesale price index of field crop group
LWFRTI is log of wholesale price index of fruit and tree group
LWU is log of irrigated water
LFTZP is log of fertilizer wholesale price

Source: estimated by the author

Table 5 Yield response estimation in model II

	OLS	
	coeff.	t-test
No. of Obs.	204	
Constant	-3.264	-0.577
LWPDDI	0.339	0.395
LWURAI	-0.018	-0.201
CHPYW	0.390	1.898
LFTZP	1.092	1.688
adj. R-square	0.054	
F-test	3.920	

Remark LWPDDI is log of paddy wholesale price index
LWU is log of irrigated water
CHPYW is dummy of the West of Chao Phraya river basin bank
LFTZP is log of fertilizer wholesale price

Source : estimated by the author

Table 6 Area response estimation in model 2

	OLS		GLS	
	coeff.	t-test	coeff.	t-test
No. of obs.	221			
PDDP	0.054	4.629	0.052	4.668
SGCP	0.531	2.184	-0.049	-5.349
LVGTP	-0.024	-2.197	0.006	2.188
LWU	0.134	6.620	0.119	6.113
LFTZP1	-0.256	-4.543	-0.216	-4.979
D1	0.422	4.986	0.397	4.701
D2	0.403	4.781	0.373	4.437
D3	-0.004	-0.041	-0.006	-0.066
D4	0.113	1.312	0.010	1.117
D5	0.277	3.169	0.265	3.029
D6	-0.056	-0.558	-0.046	-0.466
D7	-0.178	-1.876	-0.176	-1.860
D8	0.019	0.214	0.003	0.035
D9	0.363	3.970	0.307	3.393
D10	0.434	4.676	0.375	4.096
D11	0.034	0.915	0.081	0.887
D12	0.149	1.770	0.118	1.406
D13	-0.019	-0.214	-0.028	-0.312
D14	-0.212	-2.427	-0.225	-2.580
D15	-0.116	-1.302	-0.125	-1.412
D16	-0.193	-2.175	-0.203	-2.284
Adj. R-square	0.392		0.320	
Chi-square	-		28.340	
F-test	8.090		6.160	
DW. Stat.	1.638		1.479	
Paddy Share	0.696		0.696	
E (p,w)	x		x	
E (a,w)	0.192		0.170	

Remark PDDP is paddy wholesale price deflated by GDP non-agricultural deflator
SGC is sugarcane wholesale price deflated by GDP non-agricultural deflator
LVGC is log of cabbage wholesale price deflated by GDP non-agricultural deflator
LWU is log of irrigated water
LFTZP1 is log of fertilizer wholesale price deflated by GDP agricultural deflator
D1,.,D16 is dummy of 16 irrigation projects

Source : estimated by the author

Table 7 Yield response estimation in model 2

	OLS	
	Coeff.	t-test
No. of obs.	221	
LFPDDP1	0.409	0.948
LWURAI	0.315	4.976
LLBP1	0.433	1.688
D1	1.632	3.741
D2	1.862	4.220
D3	1.447	3.320
D4	1.414	3.244
D5	1.734	3.960
D6	1.189	2.684
D7	1.410	3.232
D8	1.283	2.918
D9	1.848	4.158
D10	-0.415	-0.939
D11	1.117	2.533
D12	0.274	0.629
D13	0.815	1.825
D14	0.130	0.289
D15	1.199	2.738
D16	0.636	1.445
Adj. R-square	0.134	
F-test	2.890	

Remark LPDDP1 is log of paddy wholesale price deflated by GDP non-agricultural deflator
LWURAI is log of irrigated water per area
LLBP1 is log of agricultural labor wages deflated by GDP agricultural deflator
D1,.,D16 is dummy of 16 irrigation projects

Source : estimated the author

Table 8 Marginal value of irrigated water in Chao Phraya river basin

	e (a,w)	e (y,w)	e (q.w)	VMPx
Model 1				
OLS	0.062	-	0.062	0.1835
GLS	0.065	-	0.065	0.1924
Model 2				
OLS	0.192	0.315	0.507	1.501
GLS	0.170	0.315	0.485	1.4356

Remark Assumption for calculation the marginal value of irrigated water in Chao Phraya river basin: paddy yield 653 kg./rai, irrigated water per area 1,520 m3/rai, and paddy wholesale price 6.89 baht/kg.

Source : calculated by the author

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