Implementation of Modeling Techniques to Resolve the Economic and Managerial Problems in Irrigation Practices in Dinh Hoa District Schemes in Vietnam

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BACKGROUND

Poverty alleviation is one of the most important components of the economic development process in developing countries. However, this concept is often widely misunderstood. In the developed countries, economic efficiency is a desired goal as it helps the entire economy gain a higher aggregate income, which the government can redistribute among the people by various measures such as taxation and transfer. This argument is based on the concept that the rich usually use their incomes to consume or to invest, and through these activities, they can stimulate the economy of the whole country.

However, in developing countries the situation is quite different. The rich in these countries usually buy luxury goods from developed countries or send their money to foreign countries; consequently, their activities do not encourage economic development in their own countries. For this reason, poverty alleviation can increase incomes for the poor people, who usually use their income to consume domestic goods. Therefore, the poor’s consumption activities can encourage the domestic economy. Thus, the poverty alleviation is not only a fair action, but also helps to promote economic efficiency.

Most poor people live in rural areas, so we can help them with measures that promote agricultural production. Many development economists show that in order to meet this goal we must implement unimodal technology to agriculture. Irrigation is one type, in addition to fertilizer and seed, in the “green revolution.”

However, irrigation services are often considered as commodities that have many characteristics of “market failure”; thus, the supply of these goods usually falls upon the public sector. In order to have effective control, we must estimate the price of these services, but this task is not simple. In our case study, available data collected through an investigation project is used to estimate a demand curve and the marginal cost of irrigation supply, from which the price of these services can be established.

In general, estimating the price of water is quite difficult because of the transaction costs, and data limitations prevent efficient management of the irrigation supply. Therefore, we must develop water price estimation techniques together with institutional arrangements. There are many studies trying to estimate the influence of the performance of water

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institutions on water sector performance. However, this case study contributes to solving a small portion of the larger problem.

The problem consists of conflicts between different farmers who have lived in the same area irrigated by a reservoir. After the failure of the cooperative mechanism in 1990, cultivated land was divided among various individuals, some of whom have inherited areas in the reservoir bed. Due to the poor performance of the local managers, the farmers have encroached upon the reservoir and now consider it as their own property. This situation has persisted for more than ten years from 1990 until the present. In this study, in order to model and solve the problem, a Games Theory approach is introduced with suggestions of various alternatives to help the policymakers make better formulate their decisions.

DEMAND-SUPPLY MODEL FOR IRRIGATION SCHEMES IN DINH HOA DISTRICT

Production function of agricultural production in the district

The primary agricultural output in the district is rice. For this study, a seasonal model considering only the winter-spring paddy crop was chosen, because paddy productivity of the summer-autumn crop is not clearly influenced by irrigation. It can be illustrated by the relative paddy productivities of various irrigation systems in the district of winter-spring and summer-autumn crops (figures 1 and 2).

Figure 1. Relative productivity of winter-spring paddy crop in the Dinh Hoa District.
Figure 2. Relative productivity of summer-autumn paddy crop in the Dinh Hoa District.

The production function for agricultural production is:

\[ Y = f(K, L, R, W, PH, ...) \]

where, 
- \( Y \) is paddy productivity,
- \( K \) is capital,
- \( L \) is labor,
- \( R \) is land, and
- \( PH \) is fertilizer.

Because most inputs, except irrigation, are supplied in relatively competitive markets, they are in balance and their integrated impacts can be expressed by the constant term in our model. Then the relation between the crop output and production inputs can be specified as follows:

\[ Y = AW^2 + BW + C \]

where, \( W \) is irrigation service and this form of production function satisfies the following constraints:

\[ \frac{\partial Y(W)}{\partial W} > 0 \quad \text{and} \quad \frac{\partial^2 Y(W)}{\partial W^2} < 0 \]

**Profit maximization problem of individual farmer**

Profit maximization problem of individual farmer is given by the following equation:

\[ \max \pi = \max_w (P_Y Y(W) - F - P_W W) \]
where, $P$ is price of crop output per hectare,  
$Y(W)$ is agricultural production function,  
$F$ is production costs (except irrigation costs) per hectare,  
$P$ is price of irrigation service per hectare, and,  
$W$ is irrigation service.

The first condition for profit maximization problem is:

$$P_y \frac{\partial Y(W)}{\partial W} = P_w$$

or:

This equation is the demand curve for the irrigation service.

### Marginal and average costs curves of irrigation suppliers

The total cost of irrigation supply consists of three components: capital, upgrading costs, and operations and maintenance (O&M) costs. However, capital is a sunk cost and O&M costs are estimated approximately as 8 percent of the value of paddy production in an area unit. Therefore, the marginal upgrading cost component is the relationship between the percent of irrigated area and the increased cost for upgrading at this percent, i.e., $W - \Delta K/DW$, where $\Delta K$ is the increased cost for upgrading and $\Delta W$ is increased percentages of irrigated area. The marginal cost function for irrigation supply is specified as follows:

$$MC = \alpha W^2 + \alpha W + \gamma + MC_{O&M}$$

From the marginal cost function, the average cost equation is derived as follows:

$$AC = \frac{\alpha W^2}{3} + \alpha \frac{W}{2} + \gamma + MC_{O&M} + \frac{C_{O&M}}{W}$$
ESTIMATIONS

For the estimation of the regression, data collected for the “Investigation on Current Situation of Irrigation Schemes in Dinh Hoa” Project was used. The project was funded by the Thai Nguyen Agricultural and Rural Development Department (December, 2000).

Regression results are:

\[ \begin{align*}
  A &= -2.45857 \\
  B &= 5.402239 \\
  C &= 0.778226
\end{align*} \]

The estimated regression equation for the production function is:

\[ Y = -2.45857.W^2 + 5.402239.W + 0.778226 \]

This production curve is shown in figure 3.

The demand equation is:

\[ \frac{P}{W}Y = 2AW + B \]

or,

\[ \begin{align*}
  \frac{P}{W}Y &= -2.45858.2W + 5.402239 \\
  &= -4.91714.W + 5.402239
\end{align*} \]

The graph of this function is depicted in figure 4.

Figure 3. Paddy production function.
For the marginal cost curve, the estimated parameters from the regression analysis are:

The estimated regression function for marginal cost is:

\[ MC = 9641026 W^2 + 219784 W + 2537221 \]

From the marginal cost function, the average cost function can be derived and is given by:

where, \( C_{\text{O&M}} \) is considered at 5.10^6 VND, for example. The plot is presented in figure 5. The combination of the demand and marginal cost curves is depicted in figure 6.
Figure 5. Marginal cost curve for water supply in the Dinh Hoa District.

Figure 6. Demand - supply balance for irrigation in the Dinh Hoa District.
ANALYSIS

In equilibrium, $W = 76$ percent, $P_w = 8.7 \times 10^6$ VND ($\approx$ $621$) per ha. Currently, it is not realizable because paddy productivity in the district averages about 3.8 t/ha, which is about $(3.8 \text{ tons per hectare} \times 1550.10^6 \text{ VND}) \approx 5,890,000 \text{ VND} (\approx $421) per hectare in which other production costs make up approximately $4 \times 10^6 \text{ VND} (\approx $286 per hectare). However, if local farmers apply new high-yield variety seed, they can produce about 10 tons per hectare under similar production conditions, which is about $10t \times 1550.10^6 \text{ VND} \approx 15,500,000 \text{ VND} (\approx $1100 and the individual farmer can almost afford to pay all production costs, even irrigation costs.

Alternatively, if the government only requires payment of O&M costs (8% of income in area unit), the local individual farmer is able to pay all production costs, although the farmer is still very poor. We must notice that under these conditions, the individual farmer is not encouraged to use irrigation water economically. If achieving economic efficiency for water use is a desired goal, then water fees must be increased considerably.

If a bidding mechanism is implemented, then upgrading costs would decline and the marginal cost curve will shift rightwards and the price of irrigation will decrease while the desired level of water use will increase. In our example, marginal costs were assumed to decrease by 30 percent, so that the equilibrium price will be $7.10^6 \text{ VND} (\approx $500) per hectare (a decrease of 22%) and the equilibrium level of water use will be about 83 percent, (an increase of 7%). The current situation is improved markedly because the gap between the ability to pay and willingness to pay decline considerably.

A practical solution that can be implemented is “tiered” pricing. It can improve the cost recovery situation for irrigation suppliers and efficiency in water use for individual farmers. However, there is an increase in the costs required for data collection and analysis. Finally, because of the scarcity of water resources, the price of irrigation services is raised considerably. Therefore, the rational farmers usually do alter cultivated cropping patterns. Additionally, several crops can be successfully grown that do not require as much water as the paddy.

MODELING THE “RESERVOIR” CONFLICT IN DINH HOA DISTRICT

There are many typical problems in irrigation management in Dinh Hoa, such as poor operation and maintenance, lack of clear accountability, and weak functional capacity. However, of particular note in Dinh Hoa district is the “reservoir encroachment” described before. Many farmers have encroached upon the areas in the reservoir bed for two purposes. First, they use these areas to plant rice. Second, the farmers try to take full advantage of the property rights and expect the government to buy these areas with compensation.
Moreover, this situation is spreading throughout the whole district and this process has existed for more than 10 years. In other words, “reservoir encroachment” is not a specific problem of Dinh Hoa district; it is only a symbol of the underlying dilemma, the non-cooperative dilemma, which is one of the most complicated problems in various regions and sectors such as law, economics, management in general and water sector in particular.

**MODELING**

In order to analyze the problem and to suggest different alternatives for resolutions, a Games Theory modeling approach was chosen. The first step in the modeling process is to decompose the entire conflict into component “games.” For simplicity, only one of these games will be introduced. The other games were constructed in a similar manner. The game introduced here is described as a conflict between the government and the farmers cultivating in the reservoir bed (i.e., the “reservoir encroachment” farmers). Each of these “players” has two decisions: the government (player I) can bargain (decision 11) or abandon (decision 12); the “reservoir encroachment” farmers (player II) can bargain (decision 21) or make a nuisance (decision II). The game is described with a “payment matrix” as in figure 7.

*Figure 7. Reservoir encroachment game.*

As can be seen from this model, the game has two equilibriums: one of them is a mixed equilibrium and the other is a weak one (East-South outcome). The East-South outcome is undesirable because in this case both players do not cooperate with each other. On the other hand, if it is desirable to achieve any other equilibrium, then an investment in some resources is required to reverse the directions of certain arrows described in figure 7. Concretely, West-
North outcome is the most desired outcome and in order to achieve it, the arrow directed from West-South to West-North needs to be strengthened, as well as, the arrow directed from East-North to West-North outcome. It means that we have to strengthen working capacity of the local government staff to help the “reservoir encroachment” farmers to understand that their profit maximization behavior in these conditions can damage all the benefits. In a similar way, we can explore all possible situations described in our game according to social preferences and then costs can be estimated for various resolution-alternatives.

RECOMMENDATIONS

a. Establish training courses to promote knowledge and skills of individual farmers in the district.
b. Establish training courses for local authorities to promote managerial capacity.
c. Select appropriate organization, which can internalize all the possible externalities in order to negotiate with the “reservoir encroachment” farmers to exchange land use rights with water rights.