

Predicting diffusion and feasibility of irrigation schemes: a case study in Kurdistan, Iraq

Fabio Zagonari

Dipartimento di Scienze Economiche, Facoltà di Economia (Rimini), Università di Bologna
via Angherà 22, 47900 Rimini (Italy)

Phone: 0039 0541 434135 Fax: 0039 0541 434120 Email: fabio.zagonari@unibo.it

June 2011

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Abstract

This paper applies *ex ante* econometric, cost–benefit, and financial methodologies to *predict* diffusion and feasibility of the irrigation project in Shahrazoor, Kurdistan, Iraq. To do so, I investigated the socio-economic, psycho-cultural, and financial factors that determine participation. The socio-economic part of the *econometric* analysis showed that the project was appreciated more by poorer and economically weaker farmers who rely on agriculture than those who rely on livestock activities. The psycho-cultural part of the *econometric* analysis emphasized that the project was appreciated more by literate farmers who adopt a maximization (rather than a status quo) approach. The *cost–benefit* analysis applied to the irrigation project tailored to poorer and weaker farmers determined an acceptable internal rate of return, but the *financial* analysis highlighted that values for water prices, a feasible internal rate of return and loan interest rates that simultaneously meet the government and farmer budgets might not exist.

Keywords

Irrigation project, econometric analysis, cost–benefit analysis, financial analysis, development, Middle-East, Kurdistan, Iraq

1. Introduction

Agricultural policy programs, in general, and technological interventions in agriculture, in particular, should be congruent with farmer priorities (i.e. problems to be solved) and expectations, and should also be appropriate for the socioeconomic, cultural, and agronomic circumstances of the farmers. Such policies and technologies would have a greater chance of being accepted and practiced sustainably than programs based on temporary incentives or coercive pressures.

Technological interventions, in general, and irrigation projects, in particular, often result in a low level of awareness among the target group and in a low level of successful diffusion (i.e., dissemination of knowledge leading to participation) because farmers are rarely consulted *a priori* about their specific circumstances, priority problems, and expectations.

Econometric studies on adoption behaviors and cost–benefit and financial studies of the impacts of an intervention should come before the project's costs are incurred. In contrast, approaches based solely on expert knowledge are likely to be biased due to a lack of information on the socio-economic and psycho-cultural attributes of the farmers, and on how these attributes will affect their decisions.

Among the few *ex ante* econometric analyses of policy or technology adoption by farmers, Kondoh and Jussaume (2006) applied logistic regression analysis to estimate the relative impacts of social networks and life experiences on the willingness of farmers' in Washington State (USA) to adopt genetically modified organisms. However, they did not consider the psycho-cultural characteristics of the farmers or the technological features of the proposed interventions. Batz et al. (2003) used linear regression analysis to predict the speed and future ceiling for dairy technology adoption in Kenya by assuming that data on past adoption behavior would provide information about likely future behavior. However, they did not account for the psycho-cultural characteristics of the farmers. Bekele (2006) applied a multinomial logit model to analyze the impact on the preferences of Ethiopian farmers for various types of intervention and on the problems prioritized by the farmers. However, none of these studies analyzed the feasible distribution of costs among the farmers.

The purpose of the present paper was to apply *ex ante* econometric, cost–benefit, and financial methodologies to predict diffusion and feasibility of the irrigation project in Shahrazoor, Kurdistan, by assessing the socio-economic, psycho-cultural, and financial factors that determine participation in order to identify the target farmers, to adjust the project to meet their needs and desires, and to properly distribute the project costs between this audience and the government.

In other words, the objective was to develop and demonstrate a methodological approach in which the results of the econometric analysis (which identifies the major socio-economic and psycho-cultural factors that influence participation decisions by farmers) affect the cost–benefit analysis (for example, by identifying the target group or the project features). In turn, the financial analysis (which specifies water prices for farmers and the interest rate on loans to farmers) is based on the results of the cost–benefit analysis by assuming that the interest rate on loans to farmers must be smaller than the internal rate of return of the project (otherwise, farmers would pay for the inefficiency of the irrigation project) or than the social discount rate applied to the project (otherwise, current generations of farmers would pay more than future generations).

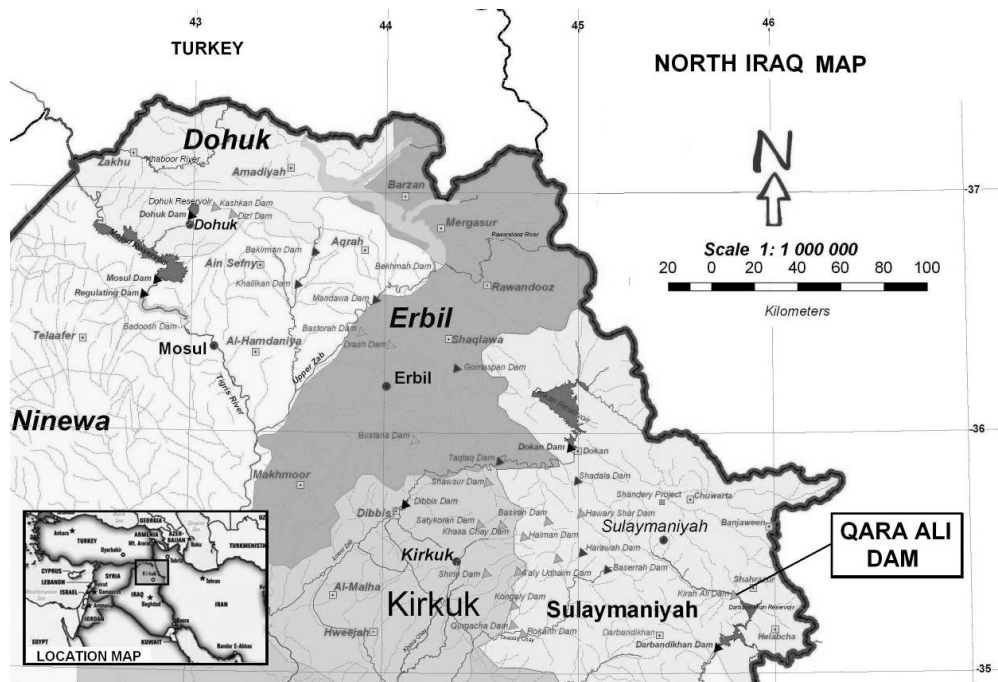
Note that unlike usual contexts, where farmers receive irrigation deliveries in return for some form of payment (in cash or in kind) *once* an irrigation scheme is built, this paper refers to the future decision (at farm-level) to participate to a *hypothetical* program: the conceptual framework is similar to technology adoption, where farmers decide to begin using a new production method or device.

2. The study area and data collection

2.1. The study area

The Iraqi Ministry of Water Resources is planning to implement several irrigation programs, already defined at the end of the 1970s, by revising the original projects in order to achieve an equitable and sustainable use of water resources. The goals were to take into account the development of more competitive markets and a more open society, and to integrate water engineering construction with environmental conservation. In the present study, I focused on the Qara Ali dam and irrigation project that will be implemented in the Shahrazoor basin of Kurdistan (Figure 1).

Figure 1 – The general location map.



The Shahrazoor irrigation area is located in northwestern Iraq, within the highlands of the Kurdistan mountains in Sulaymani Governorate. The project area is located at an altitude of approximately 560 m a.s.l., and the land drains toward the Derbendikhan reservoir. The proposed Qara Ali dam and reservoir are located within the Tanjero River valley, near the point of origin of the Shahrazoor basin. Construction of the dam is planned upstream of the village of Qara Ali. The irrigation project area is located downstream of the dam, along the right bank of the Tanjero River. This is an important project for the future development of the Suleymani Governorate and the Shahrazoor region. The original development study for the area began during the 1970s, and was completed during the 1980s. The overall irrigation scheme was originally designed to be larger than the one that was ultimately selected. The present urban development within the valley, water availability, and socioeconomic reasons were the driving factors for the selection of the present layout for both the dam and the attached irrigation project.

2.2. Data sources

The data used in the present analysis were obtained from face-to-face interviews with the farmers: these are randomly chosen within a list provided by local representative of the Ministry of Water Resources. The irrigation project will directly affect 15 villages: these are quite similar in terms of irrigation opportunities which might be perceived by farmers (e.g., access to input and output markets, access to credit markets). Official statistics report that 315 farmers live in this area, and specify the land area exploited by each owner and the proportions of rain-fed and irrigated

agriculture. Because of time and budget constraints, I only interviewed 46 farmers (15% of the total). I initially stratified the population into three farm-size classes and two tenancy classes (Table 1). I modified the initial sample plan to account for the actual proportions of farm size and type of tenancy that I observed in the field (Table 2). Farm size was overestimated in the official data, probably due to division of land among heirs after the original statistics were collected, and the proportion of tenant farmers also appeared to have been underestimated, probably due to subsequent sales of land by farmers. I accounted for these features of the sample in the subsequent econometric analysis.

Table 1. Details of the survey population, stratified according to type of tenancy and farm size recorded in government statistics.

Type of tenancy	Farm size (ha)			Total
	<5	5-20	>20	
Owner	5	5	7	17
Tenant	10	11	8	29
Total	15	16	15	46

Table 2– The revised survey population, stratified according to the actual types of tenancy and farm sizes determined by the survey.

Type of tenancy	Farm size (ha)			Total
	<5	5-10	>10	
Owner	—	—	9	9
Share-cropper	—	1	—	1
Tenant	16	14	6	36
Total	16	15	15	46

The detailed results of my survey are available from the author on request. Here, I will discuss only the most important results. The average farmer was relatively old (nearly 51 years), with a family structure that included both grandparents and children. Farms averaged around 12 ha in size, and were most often (65%) rain-fed rather than irrigated. All raw data were obtained in *donum*, a local unit of measure that is equivalent to 0.25 ha, and were converted into hectares. Most farmers were poorly educated or illiterate, and government agencies were the primary source of access to information; other farmers were not a significant source. Twelve crops accounted for most of the region's agriculture, and each farmer typically raised both a small number of cows and goats and a larger number of sheep (a mean of 34 per family). Farmers used a mixture of traditional and modern agricultural techniques, and most used their current methods because they had always done so, and had found them to be effective; few used methods because other farmers or the government had advised them to do so. Most felt that increasing prices for agricultural inputs (including labor) were a major concern, despite increasing sales prices for agricultural outputs.

3. Variable selection

3.1. The dependent variable

As the dependent variable in the present analysis, I chose a decision to be taken in the future rather than decisions already taken in the past, so that temporal and spatial aspects of participation cannot be assessed. The resulting dependent variable (i.e., the readiness to adopt irrigated agriculture) will be represented by combining data on willingness to adopt the new approach, access to information, and access to credit.

To determine the key *temporal* factors, I reviewed the literature on such studies. Fuglie and Kascak (2006) applied a duration model in the U.S. to estimate the long-term trends in the adoption and diffusion of technologies designed to reduce environmental externalities from agriculture. Long lags in the adoption of a technology turned out to result from differences in land quality, farm size,

farmer education, and regional factors. In the present study, I did not analyze land quality and regional factors because of the homogeneous and small agricultural area under consideration. Moreover, Batz et al. (2003) showed that the perceived characteristics of technologies such as relative investment, risk, and complexity were significant, but I have not considered the characteristics of alternative technologies because a single irrigation scheme is being proposed in the study area. Finally, Burton et al. (2003) applied a duration model in the U.K. to identify the economic and non-economic determinants of the adoption of organic horticultural technology; they found that gender, attitudes to the environment, and sources of information were important factors. As suggested by pilot surveys, I have not analyzed gender and environmental concerns, because the agricultural society in the study area is heavily male-dominated and sufficiently poor that environmental concerns are not their highest priority.

Similarly, I reviewed the literature to reveal *spatial* factors. Adesina and Chianu (2002) used a logit model to assess the determinants of farmer decisions to adopt and adapt alley farming technology in Nigeria by considering both farmer and village characteristics. They found that farmer origins, previous contacts with agricultural extension agents, number of years of experience with agro-forestry, land pressures, erosion intensity, and the distance from urban centers were all statistically significant factors. I have not included farmer origins in my analysis because all farmers in the study area come from the same Kurdish culture. Similarly, I have excluded previous contacts with extension agents because no survey respondents reported receiving information from such sources, and have not analyzed the years of experience, because the irrigation scheme under consideration is new to the study area. I excluded land pressure and erosion intensity, since these are similar throughout the study area, and excluded the distance from urban centers because all farmers live in homogeneously distributed villages.

Swinton (2002) applied both random-effects regression models and spatial auto-regression models in Peru, using time lags in the choice of keeping some fields fallow as the dependent variable, to depict the impacts of household agricultural management practices on the decisions of neighbors. The spatial structure was evident, and the two models provided nearly identical results; thus, random-effects regression could largely eliminate spatial dependency if the farmers are stratified according to the landscape characteristics. I disregarded the decisions of neighbors, because the irrigation scheme is new in the area. Abdulai and Huffman (2005) employed a duration function to explain the diffusion of crossbred cows in Tanzania; they found that proximity to other users of these cows, the level of schooling, access to credit, and previous contacts with extension agents positively affected adoption of these cows. I did not consider the proximity of farmers to other users of irrigation, because all farmers lived in villages surrounded by farmland, with little use of irrigation in the study area.

Some previous studies have assumed full information on the part of the farmers, so that differences in access to information do not lead to different decisions, and have recommended solutions for when this assumption was violated (e.g., Dimara and Skuras, 2003), but since no farmers knew about the proposed irrigation project before my study, I assumed that all farmers had equal knowledge. I also did not include the economic benefits perceived by farmers (e.g., Udoh and Kormawa, 2009), because irrigated agricultural management is new in the study area and its benefits are therefore not known to farmers. Similarly, no measures were necessary to correct for selection bias (e.g., Adegbola and Gardebroek, 2007), because no farmers were aware of this future irrigation project.

3.2. Explanatory (independent) variables

3.2.1. The socio-economic variables

For the independent socio-economic variables, other studies chose the type of land tenancy, farm size, farmer age, family size, dependency ratio (i.e. the family proportion of children and elderly), and membership in a cooperative, as well as several proxies for income: the farm size (as was done by Soule et al., 2000), the estimated gross income (as was done by Rajasekharan and Veeraputhran,

2002), the estimated consumption per capita (Dillon, 2010) or the stated yields for the main crop (as was done by Fuglie and Kascak, 2006). I used the estimated gross income as a linear function of yields, with prices and yields as weighting factors.

Moreover, I introduced a dummy variable to account for direct access to markets, thereby omitting the alternative reference to local traders (as was done by Adesina and Chianu, 2002), and I introduced four dummy variables for prices, with good or fair (but not unfair) as the options for output prices and for input prices (as was done by De Souza Filho et al., 1999).

Finally, I used dummy variables for direct access to bank loans (as was done by Koundouri et al., 2006), thereby omitting the alternative reference to other sources (i.e. cooperatives and other farmers), and for whether the percentage of income from livestock activities was greater than 50% (as was done by Wale and Yalew, 2007).

Note that the *a priori* nature of the present study made it impossible to highlight the impacts of alternative types of adopters; for example, Zhang et al. (2002) estimated a higher influence by early successful adopters on the decisions of others. The relatively small size of the farmer families involved in the present irrigation project suggested that differences in available labor could be disregarded (unlike Dadi et al., 2004). The *a priori* nature of the present study made it impossible to distinguish non-adopters from alternative types of adopter; for example, Barham et al. (2004) identified the most significant differences between non-adopters and early-adopters, late-adopters, and those who adopted and then abandoned the technology.

De Souza Filho et al. (1999) applied a duration analysis in Brazil to identify the determinants of the probability that a farmer would adopt a certain technology at time t , given that it had not already been adopted by that time. They found that the integration of farmers with farmer organizations, awareness of the negative effects of chemicals on health and the environment, reliance on family labor, location in areas with better soil, and declining output prices were significant positive determinants for adoption, whereas the farm size and increasing input prices were significant negative determinants. Kondoh and Jussaume (2006) showed that, apart from a previous lack of experience with farming or with current organic farming practices, gross incomes, market strategies, and education levels positively affected adoption, whereas whether farmers obtained information about farming practices from other farmers, from cooperative personnel, or from both was not significant.

The small number of owners in my sample made it impossible to highlight the impacts of alternative types of tenancy; for example, Soule et al. (2000) estimated the influence of land tenure on the adoption of conservation practices. The relatively small area involved in the present irrigation project suggested that differences in available technologies could be disregarded, whereas the water shortage perceived by almost all farmers made it impossible to analyze the possibility of a partial participation in the irrigation scheme.

3.2.2. The psycho-cultural variables

For the psycho-cultural independent variables, other studies chose land tenancy, farm size, age, family size, dependency ratio, and membership in a cooperative, as well as the standard parameters of literacy level and farmer rankings of various agricultural problems (as was done by Bekele, 2006). The small sample size suggested I should distinguish literate from illiterate farmers using a dummy variable. For the rankings of agricultural problems, I used dummy variables for access to markets and to additional water, which were ranked as the most urgent problems, and used access to loans as a residual variable (see Table 3). Based on the perception that water shortages mainly occurred during the summer, I created a third dummy variable for summer water availability (always and never), and used water shortages in winter as a residual variable.

Table 3 – Prioritization of issues by the farmers.

	Access to (% of responses in each ranked priority)				
	Alternative agricultural methods	Markets	Additional water	Credit (loans)	Information
Priority					
1	0	39	41	20	0
2	13	28	46	11	2
3	37	15	13	35	0
4	48	15	0	24	13
5	2	2	0	11	85

Moreover, I introduced two variables to account for attitudes towards innovation. To do so, I counted the number of replies that included “I have always done it this way” as the justification (for the current choice of crops, fertilizers, output markets, and irrigation technology) and used this as an indicator of a "habit" (status quo) approach to innovation. I also counted the number that represented a "maximization" approach to innovation, where these respondents justified their current choices as follows: “it offers a better price” for the output market, “they show high profitability” for crops, “they are very effective” for fertilizers, and “it is efficient” for irrigation technology.

Finally, I used two dummy variables for attitudes towards the future: one for positive expectations (i.e., for the future, increasing output prices and either increasing or stable input prices), and one for uncertainty (i.e., not in a position to express any expectation). I also introduced dummy variables for membership in a cooperative and access to information on agricultural technologies from governmental agencies, other farmers or cooperatives, as was done by Moser and Barrett (2006). For the project's potential, I used two dummy variables (changing crops and expanding current crops), since these were ranked as the most significant expectations from the irrigation project (see Table 4).

Table 4 – Ranking of project potentials by the farmers.

	Access to (% of responses for each ranked potential)		
	Changing crop pattern	Expanding current crops	Cultivating additional land
Potential			
1	94	4	2
2	4	76	20
3	2	20	78

Note that Bekele (2006) combined the characteristics of the farm and the farmer with the personal costs and benefits expected by the farmer. Baerenklau and Knapp (2007) developed a dynamic model of technology adoption in California State (USA) by incorporating the age of the technology, whether the investment was reversible, variable inputs and outputs, and stochastic prices, and showed that the optimal decision rule was affected by the age of the technology that was currently adopted, by uncertainty due to variability in input and output prices, and by the irreversibility of the adoption decision. In the present study, I disregarded these factors, because irrigation projects are new in the study area.

3.3. Modeling participation

Binary logistic regression is a standard statistical procedure in which the probability of a dichotomous outcome (in the present case, participation or non-participation) is related to a set of explanatory variables (e.g., He et al., 2007). If the responses of farmers in the study region are assumed to be consistent with utility-maximizing behavior, then the irrigation project will be joined by farmers if the utility obtained from participation exceeds that from non-participation.

The small number of observations suggested that I should perform a combined estimation for the socio-economic and psycho-cultural determinants of participation by considering as many variables as possible from among those suggested by the literature. In particular, the probit models to be estimated were:

$$\text{Prob} (rea = 1) = \Phi(\alpha + \beta_{se} x_{se} + \beta_{pc} x_{pc})$$

where *rea* is the binary outcome variable “readiness to adopt”, x_{se} and x_{pc} are the socio-economic and psycho-cultural determinants of participation (respectively), and Φ is the cumulative distribution function of the standard normal distribution; the parameters α and β are maximum-likelihood estimates.

Note that Moreno and Sunding (2005) estimated a nested logit model and showed that the irrigation technology was selected jointly with land allocation, while Useche et al (2009) applied a mixed-multinomial logit model to estimate the effects of traits and farm and farmer characteristics on adoption outcome. In the present study, I considered a single irrigation scheme with no alternative technological traits, and farmers provided only partial information on potential crop choices.

4. Results of the econometric analysis

The small number of observations suggested I should avoid variables that could split the sample (land tenancy and farm size), disregard variables with a low variance (age and family size), and disregard variables that were strongly correlated with other variables (dependency ratio with gross income, cooperative membership with government information, and farm size with gross income). In particular, I did not consider age, since it turned out to be insignificant: after all 59% of respondents were aged between 40 and 60. Moreover, the small sample size suggested I should include all dummies as independent variables, except for gross income, in order to increase the variability (Burton et al., 2003). Finally, in order to obtain a more robust variance value, I applied the Huber–White sandwich estimator, with type of tenancy as the clustering variable, to allow observations that were not independent within clusters (although they must be independent between clusters).

The following variables turned out to be non-significant and excluded in the estimation:

- “water shortages in summer” is likely to be embodied in “water shortages in all seasons”, since 9% of farmers said to have enough water in winter and 0% in summer
- “the most urgent problem” (39% access to markets, 41% access to additional water, and 20% access to credit) might be irrelevant as implicitly represented by other included variables (see Table 3)
- “the ability to predict trends for output and input in prices” might be considered as a precondition for stating positive expectations
- “the most important project’s potential” is likely to be irrelevant, since 94% of farmers said to aim at changing cropping patterns rather than expanding current crops (4%) or cultivating additional land (2%) (see Table 4)

The main insights can be summarized as follows (see Table 5):

- The irrigation project is more likely to be joined by poorer farmers who rely on agriculture than those who rely on livestock activities
- The irrigation scheme is less likely to be participated by farmers who feel that they obtain fair prices for inputs, they have direct access to product markets, and they have a satisfactory access to the private credit (loans) market
- The irrigation project is more likely to be joined by farmers who have been informed or trained by governmental agencies, and who feel that they can obtain fair prices for outputs
- The irrigation scheme is more likely to be participated by literate farmers
- The irrigation project is more likely to be joined by farmers with positive expectations about the future
- The irrigation scheme is more likely to be participated by farmers who base their decisions on a maximization rather than on an habit approach.

Table 5 – Determinants of the adoption of irrigation technology.

	Ready to adopt			
	Coefficient	Std. error	z-statistic	P
Literacy status *	0.157	0.036	4.28	0.000
Habit approach to innovation	-0.198	0.213	-9.31	0.000
Maximization approach to innovation	0.390	0.263	1.48	0.138
Predict increased output and input prices or increased output and stable input prices *	0.513	0.026	19.46	0.000
Need to cope with water shortages in all seasons *	2.564	0.766	3.35	0.001
Gross income	-0.111	0.034	-3.28	0.001
Income from livestock activity greater than 50% of the total *	-1.964	0.383	-5.12	0.000
Access to fair prices for outputs *	1.701	0.326	5.21	0.000
Access to fair prices for inputs *	-3.943	0.069	-56.84	0.000
Access to suitable information from governmental agencies *	4.871	0.372	13.08	0.000
Satisfactory access to bank loans *	-4.272	0.785	-5.44	0.000
Direct access to output markets *	-1.906	0.447	-4.26	0.000
Constant	0.271	0.049	5.45	0.000

* means dummy variable. Standard errors were adjusted for clustering as a function of the type of tenancy, by assuming independence between clusters only. Log-likelihood = -9.548671, Pseudo R^2 = 0.5133.

Table 6 – Impacts on adoption probability.

	Ready to adopt				
	dΦ/dx	Std. error	z-statistic	P	x-bar
Literacy status *	0.00243	0.001	4.28	0.000	0.565
Habit approach to innovation	-0.00297	0.002	-9.31	0.000	2.5
Maximization approach to innovation	0.00585	0.009	1.48	0.138	0.978
Predict increased output and input prices or increased output and stable input prices *	0.00689	0.005	19.46	0.000	0.369
Need to cope with water shortages in all seasons *	0.09075	0.116	3.35	0.001	0.478
Gross income	-0.00167	0.001	-3.28	0.001	6.234
Income from livestock activity greater than 50% of the total *	-0.05688	0.061	-5.12	0.000	0.5
Access to fair prices for outputs *	0.02881	0.013	5.21	0.000	0.391
Access to fair prices for inputs *	-0.40222	0.117	-56.84	0.000	0.413
Access to suitable information from governmental agencies *	0.94105	0.002	13.08	0.000	0.847
Satisfactory access to bank loans *	-0.89236	0.190	-5.44	0.000	0.108
Direct access to output markets *	-0.21421	0.221	-4.26	0.000	0.065

* dΦ/dx is for discrete change in the dummy variable from 0 to 1. Standard errors were adjusted for clustering as a function of the type of tenancy. Predicted probability at average values (x-bar) of dependent variables = 0.9947983.

Thus, the irrigation project is appreciated most by poorer and economically weaker farmers: this is consistent with a given potential economic benefit per hectare being perceived to be smaller by larger farmers. In contrast, in an *ex post* econometric study of the potential factors that determine adoption, Namara et al. (2007) showed that the largest proportion of micro-irrigation adopters belong to the relatively wealthy group of farmers. In particular, with respect to the average farmer where the probability of acceptance is 0.9947 (Table 6), a poorer and weaker farmer, characterized by an illiterate status, an habit approach to innovation, negative expectations about future prices, half the average income in the sample, no access to fair input and output prices, no access to governmental information, no direct access to product markets, and no access to private credit will show a probability of participation of 0.9931, while a richer and stronger farmer, characterized by the complementary features, will show a probability of participation of 0.4658. Analogously, Harris (2008) suggests that inter-sectional analysis (e.g. men and women, landless and landed) should be carried out in any study of water-related development transformations. In other words, decision-makers in Shahrazoor, Kurdistan, are facing a dilemma: a financially unfeasible irrigation scheme that serves the needs of poor farmers, with 99% farmers joining it; a financially feasible irrigation project that disregards equity issues, with 46% farmers participating in it.

In the cost–benefit analysis in section 5, I will focus on the poor farmers and disregard the rich farmers, in order to double the probability of participation.

The potential impacts on the participation probability relate to access to suitable information from governmental agencies, to access to good prices for outputs, to the farmer's positive expectations about future trends for output and input prices, and to the farmer's literacy status (Table 6). Thus, the existing governmental agencies can play a crucial role in project diffusion *in the short-run* by providing information and training, and by promoting access to fair output prices. Similarly, He et al. (2007) showed that the credit obtained, the technical training received, and the assistance obtained all had significant positive effects on the adoption of rainwater harvesting and supplementary irrigation technologies. The government can play a crucial role in diffusion of the project *in the long run* by improving expectations and by reducing illiteracy, which in turn could promote a maximizing approach to innovation. In contrast, He et al. (2007) showed that the risk preference had no significant influence on the adoption of rainwater harvesting and supplementary irrigation technologies.

5. Results of the cost–benefit analysis

The results in section 4 suggested that my cost–benefit analysis should focus on relatively poor and economically weak farmers. In the survey sample, 4 of the 46 farmers (8.69%) farmed more than 25 ha, and a similar proportion (6.98%) was potentially interested in the irrigation project. On this basis, I assumed that 290 of the 315 farmers reported in official statistics for the study area (92%) would represent the target group. After excluding the four largest farmers, the average farm size in the sample was 7.99 ha. I have rounded this value to 8 ha and used that value as the farm size for the *representative* farmer. Note that in the study area, hydrologists and agronomists will both refer to these assumptions, the former when calculating water network costs and the latter when suggesting alternative cropping patterns and potential increases in crop yields. In my cost–benefit analysis, I will evaluate the project's internal rate of return; Wood et al. (2007) performed a similar analysis.

The increases in net income from both agricultural and livestock activities for the representative farmer as a result of a changed cropping pattern or an increased crop yield that will become possible as a result of the irrigation project can be evaluated by dividing the differences between the potential and current net incomes for the representative farmer by 8 (the size of that farmer's farm) to calculate a value per unit area. (Additional details on the costs estimated by hydrologists and the benefits estimated by agronomists are available from the author on request). Based on these data, the net income increase for the representative farmer is estimated by agronomists to be 5400 USD/ha. The overall irrigation area will be subdivided into 692 representative hydraulic units of 8 ha each, which are directly affected by the irrigation project. The direct benefits can then be estimated at 29.894 million USD (the total irrigated area of 5536 ha multiplied by the income increase of 5400 USD/ha). The indirect benefits that result from improved environmental management are assumed to be 10% of direct benefits for both the farmers directly affected by the project (692) and those who are indirectly affected (1055, i.e. the total affected area of 13976 ha minus the total irrigated area of 5536 ha divided by the hydraulic unit area of 8 ha), for a total of 7.547 million USD (i.e. the total affected farmers 1747 multiplied by the hydraulic units of 8 ha each and by 10% of the income increase of 5400 USD/ha). Combined with costs estimated by hydrologists, the internal rate of return is calculated to be equal to 7.07% with a time period of 50 years.

6. Results of the financial analysis

In section 5, I calculated the internal rate of return of the project, which measures the social expediency of undertaking the irrigation project without considering government or farmer budgetary constraints. However, there are two likely budgetary scenarios: the government might be expected to cover 100% of both the investment and operating costs (case A) or a smaller proportion

(e.g., only 60%) of the investment costs (case B). In both cases, I have assumed (based on the commonly applied values in project appraisals) a 30-year foreign loan at an interest rate of 1%, a 10-year grace period, a 0.5% commitment fee (i.e., the local government pays 0.5% of the cost to prove their commitment to the project), and a 1% interest rate during construction. I have also assumed that 100% of the operating costs for the dam, the power station, and the hydraulic network required to reach each farmer will be repaid by charging farmers for the water they use, which I have assumed (based on local data provided by the Ministry of Agriculture) to equal 7176 m³ per ha per year. These two scenarios make it possible to assess the dependence of the project's value on foreign financial support.

The minimum water prices consistent with the government's budget can also be calculated. Two main scenarios seem to be relevant for farmers based on the assumption that together with the operating costs, each farmer is expected to pay for the investment costs to establish the hydraulic network for their farm by borrowing money from governmental agencies; here, I have assumed a 6-year (case C) or a 15-year (case D) loan repayment period. These two cases allow us to assess the impact of loan conditions on the project's success. Note that farmers are assumed to be willing to renounce up to 50% of their increase in net income due to the irrigation project; this assumption arises from observations that the estimated annual value of water per hectare that was obtained by applying the contingent-valuation method (i.e., based on stated preferences; Mallios and Latinopoulos, 2001) turned out to be about half of the estimate obtained using the hedonic price method (i.e., based on revealed preferences; Latinopoulos et al., 2004) in a nearby area.

Based on these assumptions, the relationships between water prices and the social discount rate and between water prices and loan interest rates can be obtained by accounting for government and farmer budgets, respectively. However, combinations of these conditions must be met simultaneously, resulting in four scenarios: farmers are assumed to rely on either a 6-year or a 15-year loan, and the government is assumed to finance the project either completely (100%) or partially (60%).

Let me assume that the loan interest rate is lower than the social discount rate (otherwise, current generations of farmers will pay more than future generations), the government is expected to cover only the investment and operating costs of the project, the loan interest rate is lower than the internal rate of return (otherwise, farmers pay for the inefficiency of the irrigation project), foreign countries do not finance the government for replacement costs (i.e., the future expenses to replace or repair the infrastructure when it can no longer fulfil its design goals), and farmers can rely on a second loan for replacement costs under the same conditions.

Table 7 shows the results based on a consideration of government and farmer budgets. (The equations used in these calculations are available from the author on request). The main insights of this analysis can be summarized as follows:

- The project is *not feasible* if the government obtains a foreign loan under the conditions specified above and farmers are only supported by a 6-year loan: there is no combination of the water price and loan interest rate that simultaneously meets the government and farmer budgets (Scenario 3).
- The project is *not sustainable* if the government obtains a foreign loan under the conditions specified above and farmers are supported with a 15-year loan, because the government would obtain a foreign loan at 1% by providing a loan rate of 0.23% to farmers (Scenario 4)
- The project is *sustainable* without a foreign loan and with farmers being supported only by a 6-year loan, although this occurs in the unlikely situation in which there are no alternative government projects with an internal rate of return higher than 0.15% (Scenario 1)
- The project is *more sustainable* without a foreign loan and with farmers being supported by a 15-year loan in the more likely situation in which there are no alternative government projects with an internal rate of return higher than 0.47% (Scenario 2)

Table 7 – The internal rates of return, interest rates on farmer loans, and water prices in the four scenarios.

	Government funds the project completely		Government funds the project partially (60%)	
	Scenario 1 (farmers have a 6-year loan)	Scenario 2 (farmers have a 15-year loan)	Scenario 3 (farmers have a 6-year loan)	Scenario 4 (farmers have a 15-year loan)
Water price (USD/m ³)				
Maximum	0.340	0.360	0.340	0.360
Minimum	0.330	0.330	0.340	0.350
Average	0.335	0.345	0.340	0.355
Interest rate on farmer loans (% per year)				
Maximum	0.150	0.470	0.000	0.230
Minimum	0.000	0.000	0.000	0.000
Average	0.075	0.235	0.000	0.115
Internal rate of return (% per year)				
Maximum	0.150	0.470	0.000	0.230
Minimum	0.000	0.000	0.000	0.000
Average	0.075	0.235	0.000	0.115
Water price at the maximum internal rate of return (USD/m ³)	0.340	0.360	0.340	0.360

Therefore, the main conclusions from this analysis can be summarized as follows:

- It seems to be essential for the government to rely on domestic funds or to obtain a foreign loan under more favorable conditions than those described above.
- It is crucial that farmers be able to rely on a long-term (here, 15 years) loan.
- The water prices charged to farmers under the four scenarios, which range from 0.34 to 0.36 USD/m³ might be inconsistent with farmer perceptions of fair prices.
- The maximum internal rate of return achieved in the four scenarios, which ranges from 0.15% to 0.47%) might be inconsistent with government targets for returns on public funds.

To test the feasibility of the scenarios, I also carried out a sensitivity analysis. The results showed that with vegetable prices at 75% (rather than 80%) of current prices (where 75 and 80% are based on the assumption that the elasticity of demand for vegetables is 5 and 4, respectively) all four scenarios are not feasible; that is, there are no values for water prices, a feasible internal rate of return, and loan interest rates that simultaneously meet the government and farmer budgets.

7. Conclusions

The results of the econometric, cost–benefit, and financial analyses described in this paper support the view that participation in irrigation projects could be significantly enhanced by accounting for the characteristics of those who will be affected by and can potentially benefit from irrigation schemes. In Shahrazoor, the current (i.e. gross income, access to fair input prices, satisfactory access to bank loan, direct access to output markets) and expected (i.e. access to fair output prices) socio-economic factors reduce the probability of acceptance to a greater extent than current (i.e. literacy status) and expected (i.e. habit rather than maximization approach to innovation, positive expectations about prices) psycho-cultural factors, with the former factors which might be correlated with the latter factors.

In particular, as in other *ex-ante econometric* studies of the potential factors that determine diffusion, providing farmers with suitable information in the short run and a suitable education in the long run will also increase diffusion of the project (in the present study, by around 94% and 0.2%, respectively: see Table 6). Unlike other *ex ante econometric* studies, the present study highlighted the fact that the probability of acceptance can be maximized by identifying the target farmers (e.g., poorer and economically weaker farmers devoted to agricultural more than livestock activities) and specifying the maximum water prices and loan interest rates by means of cost–

benefit and financial analysis for these farmers (less than 0.36 USD/m³ and 0.47%, respectively) to the largest extent (by around 99% in the present study: see Table 6). To a smaller extent, psycho-cultural aspects (e.g., whether farmers adopt a habit or maximization approach to innovation) could hamper the project diffusion (by around 0.3% in the present study: see Table 6).

In order to reduce decisions to reject an innovation as a result of dissatisfaction with its performance, in an *ex-ante* study, Karami (2006) suggests the use of Analytical Hierarchy Process by a panel of *experts* to help 4 target homogenous groups of farmers (i.e. small young, small old, medium and large farmers) make a rational decision when adopting 3 new irrigation methods (i.e. border, basin, sprinkler), by applying cluster analysis based on 9 variables (i.e. future plans, contact with information sources, attitude towards water-saving technologies, knowledge of irrigation methods, level of farm technology, education, farm size, land slope, land fragmentation, loan obtained, soil texture). The comparison of farmers' actual decisions regarding the adoption of irrigation method in 4 Iranian provinces with the AHP results, to appraise the appropriateness of farmers' decisions regarding the choice of irrigation method, highlights that 74% of farmers made an appropriate decision (16% by adopting and 58% by not adopting sprinkler irrigation), while 26% of farmers made an inappropriate decision (14% adopters and 12% non-adopters). Farm size is significantly more important than attitude in the selection of irrigation methods. Similarly, in order to improve extension programs, the present *ex-ante* study suggests the use of econometrics, cost-benefit and financial methodologies to tailor 1 irrigation scheme according to 2 alternative target homogenous groups of farmers (i.e. small and large farmers), by using 12 variables (i.e. literacy status, habit/maximization approach to innovation, predict increased output and input prices or increased output and stable input prices, need to cope with water shortages in all seasons, gross income, income from livestock activity greater than 50% of the total, access to fair prices for outputs, access to fair prices for inputs, access to suitable information from governmental agencies, satisfactory access to bank loans, direct access to output markets). The application to a Kurdish irrigation project shows that *policy-makers* face a dilemma: the development of an irrigation system that serves the needs of poor farmers more than those of wealthy farmers, with 99% of farmers joining it, although it is financial unfeasible; alternatively, the implementation of an irrigation scheme that disregards equity issues, with 46% of farmers participating it, although it is financial feasible. Farm income is significantly more important than attitude in the decision to join the irrigation scheme. In short, by diverting from a long history of irrigation projects, where wealthy farmers become richer and poor farmers get fewer financial benefits, the irrigation scheme could be tailored to poor farmers, to increase participation and reduce income inequality, by relying on historical observations all over the world, to improve economic and financial feasibility, where wealthy farmers are likely to join the irrigation projects once built (Namara et al., 2010).

In this paper, I obtained significant results, despite relying on a relatively small sample. The approach described in this paper combines the main contributions of economists and sociologists by using variables that measure limitations on the available information and thought processes as well as the institutional contexts, by applying a maximization approach, and by using variables that measure farmer perceptions of irrigation schemes and communication frameworks. In Shahrazoor, if tailored to poorer and weaker farmers, the irrigation project turns out to be socially and economically sustainable but financially unfeasible.

Although I considered a range of potential economic and social determinants of diffusion in the present study, I disregarded some important aspects that might be relevant in alternative contexts, as Weick and Walchli (2002) have recently discussed. Torkamani and Shajari (2008) showed that farmer-specific relative risk premiums have a positive and significant effect on the decision to adopt new irrigation technologies. Governmental agencies should stress the biological risks of moving away from outdated and inefficient agricultural management practices (see also Carey and Ziberman, 2002). Ersado et al. (2004) also showed that the number of days of illness and the opportunity costs that arise from caring for sick family members are significant factors in the adoption of land enhancing technologies. Governmental agencies should therefore not disregard indicators of well-being when they estimate the potential for successful diffusion of a project. In

addition. I did not consider the complexity of the innovation with respect to the ability of farmers to understand and use the technology, as well as opportunities for farmers to observe the technology and communicate about it to other farmers (Udoh and Kormawa, 2009). Governmental agencies should therefore organize training courses to explain all the technical details so farmers can best exploit the innovation (e.g., Coughenour, 2003). I also disregarded the environmental sustainability of the new cropping patterns, which are clearly important (Barham et al., 2004; Burton et al., 2003; Fuglie and Kascak, 2006). Governmental agencies should therefore evaluate the potential impacts of the alternative cropping patterns by means of agronomic studies.

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