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An Econometric Estimation of Irrigation Water Demand for Watermelon in Iran

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Abstract. Iran is located in an arid and semi-arid area with scarcity of water resource for its agricultural activities. About 93 percent of the total annual Iranian water consumption is for agricultural activities. Not with standing high irrigation water demand in the agricultural sector, farmers pay very low price for water and the cost borne by farmers for irrigation water is much lower than the actual value of water. The low irrigation fee has caused not only inefficient allocation of water resources in this sector, but it has also resulted in farmers producing crops which require relatively large amount of water as well as non-essential crops. The main objective of this study is to estimate the demand for irrigation water, and to analyze the current pricing mechanism (policy) for water. The demand elasticity of goods, services and input determines which a change in price, ceteris paribus, affects users' quantity demanded. This study investigated the structure of irrigation water demand by estimating the derived demand for water on a particular crop, watermelon, in Iran. A derived demand function is estimated after performing the relevant statistical tests. The price elasticity of irrigation water demand and other elasticities are also computed. The price elasticity is found significant. Data and information from 2001 to 2006 from 21 provinces in Iran is employed. Parameters for the demand functions were estimated using Ordinary Least Squares (OLS). The parameters of models were estimated using the econometric method on panel data. The estimated water price coefficients are found to be negative which confirm the economic pricing theory.

Keywords: Price elasticity, Panel data, watermelon

1. Introduction

Water has very important role in the formation and continuation of civilizations and it is a necessary factor for economic development. In the past decades, accompanied by increasing from day to day raise of population, urbanism development, industries expansion, and another factor has increased demand for water (potable, agriculture, industry). We know that water resource account as one of the most principle of capital factor for every country.

Iran is an arid and semi-arid country with a mean annual rainfall of about 250 mm. It is about 30% of the mean annual precipitation in the world. The increasing water demand has caused an alarming decrease in annual per capita renewable water resources. In this context, one of the most important tasks of regulatory authorities is to provide the water for Iran's agricultural sector.

Agriculture plays an important role in the Iranian economy, and watermelon is one of the major crops whose production and export contribute to the economy of Iran. Its production averaged at 2866324 (metric tons) in 2006. In the same year, the cultivated areas for watermelons and the average application of water for it were 119096 (ha) and 7542 (m3/ha), respectively. The total irrigated production during the year under consideration was reported to be about 2719320 tons, using 5761113 man days of labour. As reported by

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FAO, the export level of watermelon crop was about 90775 metric tons, with value of $ 14516 million in 2004.

Meanwhile, the yields for watermelon in the Iranian provinces were indicated to range from 21233.5 to 44386 (kg / ha). In particular, Khozestan province had the largest irrigated cultivation area (21536 ha) and the highest production level of 680394 metric ton among all the provinces in Iran. Iran's total irrigated area was 95718 ha in 2006. As mentioned in the section devoted for tomato, a comprehensive dataset of studies conducted worldwide revealed that the global values for crop water productivity (CWP) were generally very high for crops like tomatoes and watermelons. With 6.38 and 2.01, Kerman and Fars provinces took the first and last places respectively in terms of water productivity levels. The water productivity, average application of water and yield for this crop in Khozestan province were 3.87, 8147, and 31593 (kg/ha), respectively.

2. Literature Review

Estimates of the demand function for irrigation water and its price elasticities have commonly been based on the use of mathematical programming, especially linear programming. The early studies such as Moore and Hedges (1963) often intended to show that the demand is more price responsive than generally believed, and that even for low prices it is not perfectly inelastic as the U.S. Bureau of Reclamation had claimed in the past. Later studies have constructed sub-regional or regional demand functions from models of representative farms, and commonly calculated responsiveness by either arc-elasticity estimates along the stepped demand curve or by calculating elasticity after fitting continuous regression equations to the parametric data.

The results typically show either an inelastic estimate for the whole price range considered, or an inelastic estimate for the lower prices and a less inelastic or elastic estimate for the higher prices (Shumway et al. 1984). During the 1970s and early 1980s estimates of irrigation water demands and their shape have also been developed with statistical crop-water production functions based on data from field crops experiments conducted at state experiment stations Ayer and Hoyt (1981); and Kelley and Ayer (1982). Demand functions were constructed using an output price and varying the cost of water. Elasticity estimates based on field experiments generally are relatively unresponsive to price changes.

Elasticities have also been estimated with econometric studies that use data of actual farmer behavior via Moore et al.(1994). Estimates calculated with econometric methods relying on secondary data tend to be more inelastic than suggested by mathematical programming models, but in some cases they are also very elastic. Overall, elasticity estimates vary widely not only between studies with different methods of analysis but also among them. A number of variables influencing the shape of the demand function as well as elasticity estimates have been identified in the literature, but there has been little systematic study on how and to what extent these variables influence the estimates and the policy recommendations based on them.

Zare (2006) estimated demand elasticity for groundwater input of Kerman by production function. He found that the marginal production of crops per unit of water was higher than the corresponding cost of pumping, and that excessive pumping of water would decrease in the social welfare rate of farmers. He also concluded that increasing the pumping costs would not lead to any significant impact on the rate of extraction, so that the best way to increase irrigation efficiency is to promote efficient irrigation methods.

Schoengold et al. (2006) estimated a model of agricultural water demand based on the role of water in the farm production function. They then presented estimates of the parameters of the model using a unique panel data set from California's San Joaquin Valley. They also found that agricultural water demand is more elastic than shown in previous work on urban water demand, a result which has important implications for differences in the optimal design of policies directed at agricultural users of water as compared to urban users.

Sahibzada (2002) used an initial Cobb-Douglas production function for estimate the relationship between total aggregated farm output, fertilizer use, labor supply, tractor use, and irrigation water input. He found that irrigation water demand is price inelastic and that predicted water usage exceeds actual use across the sample.

Scheierling et al. (1997) propose that the correct specification of irrigation water use is not to model demand as a continuous variable, but to view the irrigation decision as discrete irrigation events of approximately equal volume. They utilize a crop simulation model, termed the van Genuchten-hanks model to estimate water-crop production functions for corn and dry beans in Northeastern, Colorado.

3. Materials and Methods

In the estimation of input demand and output supply, different approaches have been suggested and adopted. Chembezi (1990) identifies two approaches direct and indirect estimation. Indirect approaches include deriving demand functions from agronomic response functions and research. Direct methods include estimating demand functions directly from observed market data on input consumption and prices, and the prices or amounts of farm output. For the purpose of this study, the direct method approach will be used to estimate the water demand function associated with watermelon product.

Conditional factor demand is a function that gives the optimal demand for each of several inputs as a function of the output expected, and the prices of inputs. Conditional demand functions are obtained using the Shepard's Lemma where the cost minimization problem is the production of a specified level of output with the least expenditure on inputs (Arrigada, 2004). Sadeghi et al. (2010) illustrated a detailed derivation of the input demand function for irrigation water in Iran.

In this research the demand functions of irrigation water will be estimated using Cobb-Douglas functional form and Panel Data econometric methods. It is assumed that, under cost minimization, the water demand function is a function in terms of crop quantity and the prices of the seven inputs namely, water price, land rent, fertilizer price, machinery rent and cost, seed price, wage and pesticide price. The water demand function can be written as

$$ln\ Dw_{i,t} = \beta_0 - \beta_1 ln\ Pw_{i,t} + \beta_2\ ln\ Pp_{i,t} + \beta_3\ ln\ Rl_{i,t} + \beta_4\ ln\ Ps_{i,t?} + \beta\ ln\ W_{i,t} + \beta_6\ lnQ_{i,t?} + \beta\ \ ln\ Pm_{i,t} + \beta_8\ ln\ Cl_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where,

$Dw_{i,t}$ = amount of water demanded (consumed) in i th region in year t (Cubic Meter), Pw = the vector of water prices (Toman/m^3), Pm = the vector of machinery rent cost (Toman/m^2), Pp = the vector of pesticide prices (Toman/kg), Cl = the vector of prepare cost of land (Toman/kg), Ps = the vector of seed prices (Toman/kg), W = wages paid for production (Toman/Man day), Q_i = Irrigated Production (Kg), Rl = Land rent (Toman/ m^2), $\varepsilon_{i,t}$ denotes the effects of the omitted variables that are peculiar to both the individual units, and time periods. In this study i denotes the provinces of Iran and t indicates year (i= 1,2, … , 21 ; t = 2001, 2002, …, 2006).

Respect to elasticity estimation, the data is collected from secondary sources such as Ministry of Energy, Ministry of Agriculture, Iran Meteorological Organization, Central of Iran statistic and relevant institutions. We used a panel data of 21 provinces in Iran of period 2001 - 2006 corresponding to a total number of 126 observations. The variables required for estimation of water demand function were input prices which are seed, water, wage, pesticide, cost of land, machinery rent cost, land rent, and fertilizer and for dependent variables, watermelon quantity, and quantities of water required of watermelon

4. Results and Discussion

The most prevalently used form of the derived demand functions are the Cobb-Douglas functions, in that the resulting coefficients have made it possible to interpret the elasticity of demand, with respect to price of inputs, and amount of output.

The equation of water demand, as a function of the current price of water, fertilizer and seed prices, wage, land rent, and the output amount, was then estimated using the panel data method comprising of 126 observations from 21 producer provinces for the period between 2001 and 2006. The Breush and Pagan Lagrangian Multiplier Test was used to juxtapose the Pool and Panel Data approaches seeking for a suitable function. Finally, the Panel model was proven to be more appropriate than the Pool model. Meanwhile, the fixed effect and random effect were compared in the Hausman's specification test which was run on STATA 10. The results revealed that the irrigation water demand function of watermelon could be best derived using the fixed effect approach. The estimation for the best model was employed to carry out the pretest and diagnostic checks. The regression results are as follows:

$$\begin{array}{l} \ln Dw_{i,t} = \underset{\substack{(0.66)\\(1.66)}}{1.10} - \underset{\substack{(0.02)\\(-5.39)}}{0.09} \ln Pw_{i,t} - \underset{\substack{(0.02)\\(-2.07)}}{0.05} \ln Rl_{i,t} + \underset{\substack{(0.04)\\(2.84)}}{0.04} \ln Ps_{i,t?} - \underset{\substack{(0.05)\\(-4.56)}}{0.21} \ln W_{i\,t} + \underset{\substack{(0.02)\\(37.2)}}{0.81} \ln Q_{i,t?} + \underset{\substack{(0.02)\\(2.96)}}{0.05} \ln Pp_{i\,t} + \underset{\substack{(0.06)\\(4.19)}}{0.26} \ln Cl_{i,t} - \underset{\substack{(0.06)\\(-2.78)}}{0.02} \ln Pm_{i,t} \\ t = \\ R^2 = 0.99 \end{array} \quad (2)$$

Based on the results, the estimated coefficient for the price of water is negative at 1% level. The coefficient was found to be approximately -0.09. This indicates that the demand for water is infinitely inelasticity, and that the farmers are insensitive to the changes in the price of water. Thus, the estimated coefficients vindicate the first and second hypotheses of the research; the price of water and the amount demanded for it are negatively related, and that the price of water is not efficient.

Likewise, the coefficients for wage, machinery rental and land rental are negative, and they are significant at 1%, 1% and 5% levels, respectively. These suggest that water, labour force, land, and machinery services are complementary inputs, which explains that a one percent increase in the wage, machinery rental, and land rental will decrease the demand for water by 0.21, 0.02 and 0.05 percent, respectively.

The coefficients for the price of seeds, price of pesticide, and cost incurred in land preparation are all positive and significant at 1%. Hence, it could be deduced that water and all the inputs given above are substitute inputs, and this means that a one percent increase in price of seed, pesticide, and cost in land preparation will be caused that water demand 0.04, 0.05, and 0.26 percent increase, respectively. Among the reasons for the existence of a substitution relationship between land preparation and water usage is that quality of soil and its ability by absorption and retention of water was considered as a whole.

The estimated coefficient for quantity of output is positive and significant at 1% level. The estimated parameter coefficient suggests the elasticity of water use, with respect to the quantity of output, is 0.81. This also means that a one percent increase in the output (watermelon) will result in a 0.81 percent increase in the use of water. The yielded coefficients also confirm the fifth hypothesis of the research, i.e. the amount of crops has a strong effect on the usage of water. When we select Cross section weights, EViews will estimate a feasible GLS specification assuming the presence of cross-section heteroskedasticity.

5. Conclusion

Water is a blessing from the Almighty God, and it is easily accessible at a minimal cost. It has been known as a public good that needs finance to cover the cost of servicing worldwide. This study has been directed towards evaluation and modification of the current price of water in order to save and optimally use this rare resource. For the purpose of the analysis conducted in this study, the derived demand functions of irrigated water were estimated, and the price elasticity were extracted from these irrigated water functions. As discussed in the above mentioned, this particular model is different from the prior models and methods which have mostly been applied in the agricultural sector. In the panel data econometric method, the intercept coefficients for every province are considered. These coefficients can show regional variations such as climatic or soil characteristics, and prices of output.

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