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Analyzing the Effects of Changes in Price and Amount of Irrigation on Cropping Pattern in Khorasan Razavi, Using PMP Pattern

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ABSTRACT

Water is one of the scarcest factors of production in agriculture. There is a direct relationship between the development of the agriculture sector and the quantity and quality of the water resources and how to manage and use of these resources. Many efforts take place to reduce water use in agriculture and improvement of its allocation. The main purpose of this study is analysing the effect of change in water costs and reduction of available water on the cropping patterns of different products. For this purpose,changes in the cropping pattern of five products - wheat, barley, sugar beet, canola and tomato - in KhorasanRazavi province of Iran were studied using the positive planning in the six scenarios. The data of this study has obtained in the cities of Mashhad, Nishabur and Torbat-e-Heydarieh (in KhorasanRazavi province) for the crop year of 2011. The results show that the usage of water for wheat, barley and tomato in Mashhad and wheat, barley and sugar beet in Torbat-e-Heydarieh doesn't change so much by increasing water price.

JEL classification: Q12, Q15, C60
Key words: PMP, Water Price, Cropping pattern

INTRODUCTION

Over the past two decades, because of changes in population, climate, increasing prosperity and etc. the renewable water amount per capita reduced and water crisis increased. Increasing water scarcity in developing countries caused to policies for wisely usage of the water resources and appropriate irrigation system to encourage water conservation. The results of a research in International Resource Management show that by 2025 many areas will face the water shortage problem (30).

In recent decades, the scarcity of water resources and the inability of humans in producing the water, unlike other products, have increased the gap between supply and demand of the water, especially in regions of the world witch there is a shortage of supply in water. In many regions of Iran there is not enough water in the required time for agricultural activities. In most areas water is the most important and most restrictive factor in production. According to available statistics and studies in Iran, water is one of the most scarce factor in production of agricultural products and development of the agricultural sector is most directly in relationship with the quantity and quality of water resources and how to manage and use these resources (21).

Today, many efforts are made over finding policies to reduce water usage in agriculture and improving its allocation. To improve water allocation, economists offer an increase in price of water, but policy makers due to economic, cultural and political reasons, reject this offer (11).

Briscoe (1996), Perry et al., (2001) and Hellegers (2002) (6, 26 and 12) argue that calling water as an economic good does not means to determine suitable price for it, but the goal is choosing correct allocation.

Programming models (MP)[1]are used widely in analysing the effects of agricultural policy and market status on the cultivation pattern, amount of water consumption and economic variables related to the farm. The main advantage of MP model is its ability to survey more precise the influence of policies at the farm level (25).

There are three categories of mathematical programming models: normative mathematical programming (NMP)[2] or optimization models, positive mathematical programming (PMP)[3] and econometric mathematical programming (EMP)[4] (7).

In normative mathematical programming (NMP) that are used more than half a century in agricultural economics researches, an optimum solution should be selected from many possible answers. In these models, objective function variables and constraints are not calibrated based on historical data. The NMP models can not guarantee that the answers are as in the base year and this is the major problem of these models (16, 9).

Developed PMP is used more than NMP models. Unlike NMP models, in PMP some of the parameters are able to reproduce the data from the base year. This method can reproduce the observed data called positive. The main purpose of this model is to explain the reaction of manufacturer to foreign changes that makes the PMP models interesting for policy makers.

Onate et al., (2007) (24) compared the effects of supportive mechanisms related to CAP on sample farms production in a region in Spain by using PMP method. The results showed a significant decrease in gross profit toward previous policies. Arfini (2001) (1) provided data to improve mathematical programming model to analyze the behavior of farmers under the common agricultural policy of Europe Union. This evolution is supplied with necessity to use of a new group of equilibrium models and PMP are shown.

Mohseni and Zibaee (2008) (23) studied the outcomes of increasing cultivation of canola in the Namdan prairie of Fars province by PMP model. The results indicate a decrease in wheat and beans cultivation, but its impact on the water consumption in the fields is different.

Sabouhi et al., (2007) (29) examined the impact of changes in the water price and reducing the amount of available water on the private and social benefits in Khorasan province using PMP model. The results show that farmers respond to increasing the price of irrigation water through change in cropping patterns, so it does not lead to decrease the consumption of water.

Hey et al. (2006) (11) used PMP model to analyze alternative policies to improve the efficiency of the allocation of irrigation water in Egypt and Morocco. The results showed that tax on product can be a replacement policy for water pricing in both countries. Qarqany et al., (2009) (28) has a study on the effect of reduction in available water for irrigation and increase in water prices on the cultivation pattern using the PMP method in Fars province of Iran. According to the findings of the research, reducing the available water and doubling the price of water has no effect on the amount of its consumption.

Medellin Azuara et al., (2009) (22) made an economic assessment on irrigation water in three regions in California using the PMP model. The results showed that the value of water is at least 6.2 times more than the paid price by farmers.

MATERIALS AND METHODS

Interests toward using programming patterns from the past 15 years is due to make a model of economic behavior and then in analysis of environmental and agricultural policies, flows from a series of factors, among them proof mathematical programming (PMP) plays a privileged role (2). Even before the nominal presentation (16), PMP was used in the agricultural sector in economic modeling (5, 14, 15 and 20). After the article HOWITT, its obvious benefits cleared and desires to its evolution increased (1, 3, 4, 8, 10 and 12). Growing daily needs to model and simulation of the behavior functions under the technical, economic, political and recently, environmental conditions has strengthened using mathematical programming (MP) as a basis for information and the requirements for PMP (19).

1. Mathematical Programming
2. Normative mathematical Programming
1. Positive Mathematical Programming
2. Econometrics Mathematical Programming.

The main reason for using PMP models is to avoid difference between the current basic position and the basic simulation position, also reconstruction the farmers' behavior based on the quantitative data which exist in decision process of the farm.

Recent researches by Paris and Howitt from Davis University of America has inclined many agricultural economists to use positive programming as a tool to analyse potential effects of agricultural policies on the agricultural sector. Using this method in two important projects of Europe Commission[1] shows interests in this method (27).

The proposed method by Howitt(16), positive mathematical programming (PMP), is used widely for calibrating agricultural productions and supply in several scales, for example, farm, region and sector.

In this study, positive mathematical programming (PMP) is used to analyse the effect of an increase in prices of water and reducing available water with GAMS/MINOS software.

PMP method follows three steps:
1st step: the standard form is a simple linear programming (LP) that is designed to maximize profits that can be demonstrated as follows:

Maximize $Z= Px- cX$
Subject to $AX\leq b$
$X\geq 0$ [ρ]

By adding the calibration constraints (which limits the level of activities to the observed levels of base situation) to the constraints of resource in a linear programming model, dual values relating to the mentioned restrictions witch represent the shadow prices of products can be calculated:

$x\leq X_0+\varepsilon$ [λ]

The calibration constraint has added to model to obtain the shadow prices and evaluate production parameters. So it will be omitted in the next step.

The general idea in PMP is using the dual variables of measure constraints which imitate the answer of the linear programming question to the level of current activities.

Z = objective function,
P = vector (n×1) of cost of production,
X= non-negative vector (n×1) of production activities,
c = vector (n×1) of variable costs per unit of input,
A = matrix (m×n) of the coefficients of constraints,
b = vector (m×1) of the existing resources,
X_0 = non-negative vector (n×1) of the observed activities level
P= dual variables related to the limits of measurement,
ε= Vector (n×1) of the positive small numbers of calibration constraints.
We assume that all activities are positive and all constraints can be become limited.

2nd step- PMP method uses these dual values to calibrate the target nonlinear parameters of target function which usually has a Multi-product form. However, the cost of keeping the input price variables permanent in the market is based as follow:

$C^{\nu} = \alpha X + 0.5X\beta X$

$\alpha$is a N×1 vector which is the result of difference between the cost of inputs and the dual inputs of land values. $\beta$is a M×M semi-symmetric positive matrix that shows the results of doubling amount of input values divided by inputs values.

3rd step- PMP is a nonlinear calibrated model which includes the choice of activities of non-linear function of cost or derived function in the previous step and produces activity levels and double values of resource constraints limited. Following PMP model is achieved for simulation.

1. FAIR5-PL97-3403 by Judz and colleagues, and 1849 - 96 FAIR by Hendrich Mir

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Maximize Z=(p-c)X –C^{v}(x)

Subject *to:* $Ax \leq b$
$X \geq 0$

The capability of CES (Constant Elasticity of Substitution) method in forming the substitution of inputs makes it appropriate to analyse the policies related to agricultural inputs, particularly when inputs substitution is an important method for farmers (17).

A production function with constant substitution elasticity, three inputs and one output is shown as follows:

$$y_i = \alpha_i(\beta_1 x_{i1}^{\gamma} + \beta_2 x_{i2}^{\gamma} + \beta_3 x_{i3}^{\gamma})^{\frac{1}{\gamma}}$$

Where $\gamma = \frac{\sigma - 1}{\sigma}$ and $\sum \beta = 1$and σshows the previous value of a substitution elasticity.

It is assumed this production function has constant return to scale for a given quality of land. Although, a Cobb-Douglas or a quadratic bound production function can be used instead of the CES. The values of parameters are calculated by the first order derivative of production function:

$$\beta_2 = \beta_1 \frac{\omega_2}{\omega_1}\left(\frac{x_1}{x_2}\right)^{\frac{-1}{\sigma}}$$
$$\beta_3 = \beta_1 \frac{\omega_3}{\omega_1}\left(\frac{x_1}{x_3}\right)^{\frac{-1}{\sigma}}$$

Assuming constant return to scale:

$$\beta_3 = 1 - \beta_1 - \beta_2$$

The value of α can be calculated due to the obtained values of β_1, β_2 and β_3 through following equation:

$$\alpha = \frac{\overline{y}x_1}{(\beta_1 x_1^{\gamma} + \beta_2 x_2^{\gamma} + \beta_3 x_3^{\gamma})^{\frac{1}{\gamma}}}$$

$$\alpha = \frac{\overline{y}x_1}{(\beta_1 x_1^{y} + \beta_2 x_2^{y} + \beta_3 x_3^{y})^{\frac{1}{y}}}$$

According to the previous studies (19), the substitution elasticity between inputs is 0.7. Production values from production function are used with succession elasticity in the third stage of nonlinear function and results net income objective function. Finally, the model calibration is based on parameters and proper stretching and results of calibrated CES model is exactly similar to the basic information used, in other words relationships and parameters used in the model is correctly modified.

RESULTS AND DISCUSSION

In this study, the effects of increases in price and decreases in amount of the available water on the cultivation pattern have been studied in six scenarios.

The scenarios number 1 and 2 (s1, s2) show increases in price by 50% and reduplication respectively. The scenarios number 3 to 6 (s3, s4, s5, s6) consists decreases in amount of the available water to 10%, 20%, 30% and 50%.

Table 1: The results of decreases in amount of the available water and increasing its price on the amounts of inputs toward available level in different scenarios.

Constraints	**Irrigation**						**Land**					
Area - Crops	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**S_6**
Mashhad Wheat	-0.00029	-0.00029	-0.005	-0.003	-0.002	-0.0085	-0.002	-0.002	-88.701	-76.052	-61.185	-22.421
Mashhad Barley	-0.00040	-0.00040	-0.003	-0.003	-0.002	-0.001	-0.002	-0.002	-89.896	-78.385	-64.464	-60.366
Mashhad Bee	-53.97	-53.97	-57.120	-55.584	-54.868	-54.152	-53.958	-53.958	-92.644	-84.627	-76.353	-25.282
Mashhad Tomato	-0.001	-0.001	0.032	0.017	0.009	0.001	-0.001	-0.001	-76.830	-55.747	-37.169	-8.978
Mashhad Canola	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Torbat-e-Heydarieh Wheat	-0.00038	-0.00038	-0.007	-0.004	-0.003	-0.002	-0.002	-0.002	-91.180	-82.889	-74.106	-54.216
Torbat-e-Heydarieh Barley	-0.001	-0.001	-0.056	-0.036	-0.026	-0.014	-0.003	-0.003	-92.134	-84.652	-76.602	-57.770
Torbat-e-Heydarieh Beet	-0.001	-0.001	0.204	0.128	0.088	0.044	-0.001	-0.001	-86.438	-74.493	-62.822	-40.212
Torbat-e-Heydarieh Tomato	-0.06	-0.06	-0.0476	-0.176	-0.073	-0.016	-0.025	-0.025	-81.794	-66.600	-53.005	-30.267
Torbat-e-Heydarieh Canola	-34.869	-34.869	-100	-75.701	-63.098	-48.973	-34.770	-34.770	-100	-95.067	-88.826	-73.660
Nishabur Wheat	-42.342	-42.342	-42.298	-42.305	-42.319	-42.336	-42.344	-42.344	-94.089	-87.455	-79.796	-59.154
Nishabur Barley	-61.38	-61.38	-61.331	-61.342	-61.358	-61.376	-61.38	-63.996	-96.700	-92.940	-88.492	-75.680
Nishabur beet	-7.25	-7.25	-7.719	-7.493	-7.390	-7.285	-7.249	-7.249	-85.663	-70.729	-55.486	-24.384
Nishabur Tomato	-1.48	-1.48	-1.620	-1.551	-1.521	-1.493	-1.483	-1.483	-79.224	-59.72	-42.283	-13.782
Nishabur Canola	-93.290	-93.290	-100	-100	-97.562	-94.434	-94.501	-94.501	-99.997	-99.992	-99.204	-96.564

Constraints	**Capital**						**Chemical**					
Area - Crops	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
Mashhad Wheat	-0.004	-0.004	1.046	0.528	0.289	-0.014	-0.012	-0.012	-0.024	-0.019	-0.017	-0.014
Mashhad Barley	-0.005	-0.005	1.051	0.529	0.289	-0.018	-0.016	-0.016	-0.022	-0.022	-0.021	-0.018
Mashhad Beet	-53.958	-53.958	-56.652	-55.332	-54.720	-54.141	-53.959	-53.959	-57.108	-55.572	-54.856	-54.141
Mashhad Tomato	-0.0021	-0.0021	1.141	0.583	0.324	0.004	-0.002	-0.002	0.077	0.041	0.023	0.004
Mashhad Canola	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Torbat-e-Heydarieh Wheat	-0.006	-0.006	-0.022	-0.016	-0.014	2.576	-0.013	-0.013	13.647	8.030	5.371	2.576
Torbat-e-Heydarieh Barley	-0.006	-0.006	-0.139	-0.090	-0.066	2.514	--0.047	-0.047	13.481	7.917	5.282	2.514
Torbat-e-Heydarieh Beet	-0.003	-0.003	0.491	0.307	0.212	2.706	0.002	0.002	14.240	8.390	5.620	2.706
Torbat-e-Heydarieh Tomato	-0.040	-0.040	-1.032	-0.314	-0.065	2.678	-0.025	-0.025	12.504	7.721	5.332	2.678
Torbat-e-Heydarieh Canola	-34.772	-34.772	-99.996	-75.609	-63.001	-48.876	-34.772	-34.772	-99.997	-73.641	-61.007	-47.551
Nishabur Wheat	-42.351	-42.351	-42.318	-42.320	-42.332	-42.387	-42.392	-42.392	-42.359	-42.361	-42.373	-42.387
Nishabur Barley	-64	-64	-63.958	-63.966	-63.979	-64.039	-64.044	-64.044	-64.002	-64.010	-64.023	-64.039
Nishabur beet	-7.250	-7.250	-8.133	-7.710	-7.516	-7.315	-7.250	-7.250	-8.133	-7.709	-7.516	-7.315
Nishabur Tomato	-1.483	-1.483	-1.793	-1.635	-1.567	-1.506	-1.487	-1.487	-1.797	-1.639	-1.571	-1.506
Nishabur Canola	-94.504	-94.504	-99.968	-99.967	-98.023	-95.463	-94.507	-94.507	-99.971	-99.970	-98.026	-95.463

As the Table 1 shows in the 1st and 2nd scenarios, by increasing water price, the cultivation of rapeseed in Mashhad is reduced 100% and has been eliminated. Also its cultivation in Nishabur is decreased 93% and reduced from 0.2 ha 0.01, so its water usage shows a 94.5% reduction. But duplicating the price of water doesn't affect the cultivation of wheat and barley in Mashhad and Torbat-e-Heydarieh.

By increasing the water price to 50% and 200%, water usage for wheat, tomato and barley in Mashhad and wheat and barley in Torbat-e-Heydarieh will reduce triviality. Because water is an essential input and it has no substitution. Another reason may be that farmers do not pay much for water and they are landowner. In Nishabur, wheat cultivation decreases 42%, from 28 to 16 hectares and barley cultivation decreases 61%, from 22 to 8.49 hectares. Cultivation of sugar beet in Torbat-e-Heydarieh and tomato in Mashhad does not change much. Water consumption for sugar beet in Mashhad decreases 53.95 % and also the amount of capital and poison will reduce. Increasing water prices has the same effect on the cultivation, water usage, capital and poison.

Reducing the inventory of available water to 10% (S_3), the cultivation of rapeseed in will be zero in all 3 cities that can be due to its high water requirement. After that, the greatest loss of cultivation is for barely in Nishabur, sugar beet in Mashhad and wheat in Nishabur respectively. But the cultivation of wheat and barley in Mashhad and Torbat-e-Heydarieh will not change much by reduction of available water. The cultivation of crops like sugar beet of Torbat-e-Heydarieh and tomatoes in Mashhad increases.

By increasing the cultivation of sugar beet in Torbat-e-Heydarieh, the rate of capital and poison usage increase 0.4% and 14% respectively. Also, by increasing the cultivation of tomatoes in Mashhad, the rate of capital will increase 14.1% and capital consumption rate will increase 0.07%. In the 4th scenario (20% reduction in inventory of available water), cultivation of rapeseed in Mashhad and Nishabur and will be eliminated and in Torbat-e-Heydarieh will decrease 75%, i.e. from 0.23 hr to 0.02 hr.

In this scenario, by reducing inventory of the available water, sugar beet cultivation in Torbat-e-Heydarieh and the rate of capital increase will increases 12% and 0.3% respectively.

By reducing water inventory to 30% and 50% in the 5th and 6th scenarios, rapeseed cultivation, only in Mashhad, will be eliminated. In the 5th scenario with reduction of water inventory to 30%, cultivation of sugar beet in Torbat-e-Heydarieh and tomato in Mashhad increases, in the 6th scenario the cultivation of all crops reduces, but the cultivation of tomato in Mashhad and sugar beet in Torbat-e-Heydarieh increases.

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