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Application of Game Theory to Compare the Effect of Market Sale and Contract Strategies on Agricultural Yield in Iran (A Case Study of Tomato)

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Abstract: This paper has been attempted to compare the effect of market sale and contract strategies on yield, using a 90 survey data from tomato farmers in Khorasan-Razavi province, Iran on 2007 and applying the game theory approach. The results showed that the effect of no-contract strategy with tomato processing factories is more than contracted strategy on tomato yield in farm level. With respect to this finding, producing the support-extension services as distributing the high-yield seeds, organizing the production cooperatives from small farms and drawing up the village-collectively contract framework has been recommended to planners and policymakers.

Key words: Game theory · Sale · Contract · Risk · Tomato · Iran

INTRODUCTION

Tomato as one of the most important vegetable's plays a main role in human health by including the special vitamins, carotene, amino acids, hard sugar and minerals. Tomato has been recommended in thinness regimes because of low calorie [1]. The world production and acreage have been over 90 million ton and 2.4 million hectare in 2003, respectively. USA, China and Turkey are the major tomato producers in world. Khorasan-Razavi province is one of the main regions in Iranian tomato production. Tomato was allotted the first grade in vegetables acreage so that plays an economic role in Khorasan agricultural sector and processing industries [2]. The high dispersion in cultivation as well as changes in acreage and production, price distortion, diversity of production factors and also high dispersion in farmers' education and experience level are of tomato producers' problems [2].

Agricultural productions are risky activities. These risks can be caused by production, market, credit, etc [3]. Some policies have been made to reduce the risk in traditional and based on support programs by farmers and government such as diversification, rotation, short sale, guarantee prices, price stabilization, crop insurance as well as delivery contracts [3-6]. If producers want to maximize their profits, they have to accept the risk of production and marketing process [7]. On the basis of strategically management viewpoint, obtaining the potential benefit is approximately impossible without accepting the risk [8]. Therefore, the producers should be going on the balance between loss risk and obtaining the potential benefit in management strategies. In these structures, the management of production and marketing has more importance.

Tomato producers face with risk and uncertainty that have to manage it to reduce the externalities [2, 9]. Processing factories are the major tomato consumers that buy it via different procedures. Conclusion of contract with farmers for buying the products is one of the procedures. On the other hand, the farmers try to reduce their risks by drawing up contract. Using the agricultural contracts in developing and developed countries has increasing trend. Extending the production contracts modifies the nature of agriculture via establishing the balance between farmers and processing factories. So, contracts have been attracted the farmers', factories', policymakers' viewpoints [6]. These contracts have some beneficial items, such as low transaction costs, decreasing the symmetric information among producers and processors in production quality, better delivery programs, reducing the price and revenue risks of producers, providing the chemical factors, breeding and high quality seeds [4, 10-17]. Also, the contracts

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might lead to increasing productivity and yield by improving the factor quality through conveying the technical intelligence to producers, facilitating availability of farmers to credits and accepting the efficient technologies [3, 18].

Few years ago, there was not a serious attention to tomato farms management and follows that, the planning to direct sale or drawing up contract with processing factories. Also, there is a lack of applied research to investigate the effects of contracts on production. Really, one of important inquiries is which sale strategies have to consider by means of farmers to reduce the risk and increase profitability, contemporary? Although there are different methods for comparing two strategies (with contract and no-contract), but the game theory approach is able to compare strategies considering the risk and uncertainty conditions. The game theory is a convention to peruse the non-contingency and cooperation. Game theory expresses the reaction of integrated representatives including commercial institutes, factories or compound of them in specific periods.

Therefore, this study has two advantages; (1) there is no study in tomato marketing and sale that have been contained the producer and production characteristics. (2) The game theory has been used to consider the risk and uncertainty. With reference to importance of tomato in human nutritious diets and agricultural economics, the Wald and Laplace indices have been played to compare the effect of market sale and contract strategies on agricultural yield in khorasan razavi province of Iran.

MATERIALS AND METHODS

Game theory: Game is theory of rational behavior for interactive decision problems. In a game, several agents strive to maximize their (expected) utility index by choosing particular courses of action and each agent's final utility payoffs depend on the profile of courses of action chosen by all agents. The interactive situation, specified by the set of participants, the possible courses of action of each agent and the set of all possible utility payoffs, is called a game; the agents 'playing' a game are called the players [19].

Whenever an optimizing agent expects a reaction from other agents to his own actions, his payoff is determined by other player's actions as well and he is playing a game. Game theory provides general methods of dealing with interactive optimization problems; its methods and concepts, particularly the notion of strategy and strategic equilibrium find a vast number of applications throughout social sciences (including biology). Although the word 'game' suggests peaceful and 'kind' behavior, most situations relevant in politics, psychology, biology and economics involve rather strong conflicts of interest, competition and cheating, apart from leaving room for cooperation or mutually beneficially actions.

Based on a model of optimizing agents that plan individually optimal course of play, knowing that her opponents will do so as well, the basic objects of interest in strategic (or 'non-cooperative') game theory are the players' strategies. A player's strategy is a complete plan of actions to be taken when the game is actually played; it must be completely specified before the actual play of the game starts and it prescribe the course of play for each decision that a player might be called upon to take, for each possible piece of information that the player may have at each time where he might be called upon to act. A strategy may also include random moves. It is generally assumed that the players evaluate uncertain payoffs according to von Neumann Morgenstern utility. In addition to the strategic branch of game theory, there is another one that focuses on the interactions of groups of players that jointly strive to maximize their surplus. While this second branch represents the analysis of coalitional games, which centers on notions of coalitionally stable payoff configurations, we focus here on strategic game theory.

Given a strategic game, a profile of strategies results in a profile of (expected) utility payoffs. A certain payoff allocation or a profile of final moves of the players is called an outcome of the game. An outcome is called an equilibrium outcome if no player can unilaterally improve the outcome (in terms of his own payoff) given that the other players stick to their equilibrium strategies. A profile of strategies is called a (strategic) equilibrium if, given that all players conform to the prescribed strategies, no player can gain from unilaterally switching to another strategy. Alternatively, a profile of strategies forms equilibrium if the strategies form best responses to one another. Only equilibrium outcomes are reasonable outcomes for games, because outside equilibrium there is at least one player that can improve by playing according to another strategy. An implicit assumption of game theory is that the players, being rational, are able to reproduce any equilibrium calculations of anybody else. In particular, all the equilibrium strategies must be known to (as they are computed by) the players. Similarly, it is assumed that the whole structure of the game, in much the same way as the players' social context, is known by each player [20-24].

For achieving to objective of research, we applied Wald's and Laplace's criteria that presented in below.

Wald's criterion: The assumption underlying this criterion is that a player tries to do his worst to this opponent and, therefore, each player tries to choose the best of the worst so as to get the maximum of the minimum gains or suffer minimum of the maximum losses. This is done in the following manner.

The farmer takes the minimum in each row (i.e. worst outcome for his each strategy) and then chooses the strategy which provides him the maximum payoffs of these row minimums.

$$Let \underset{j}{Min}\, p_{ij} = l_i$$

$$If \underset{i}{Max}\, l_i = l_i$$

Then the farmer will choose his i*th strategy under Wald's criterion. Playing in this manner, the farmer assures himself of a certain minimum under the worst circumstances. Hence, he is a maximinimizer.

Laplace's criterion: The criterion is based on the assumption that the decision maker dose not have any knowledge of the "state of nature" that is going to prevail in the period for which he is to make a decision and, therefore, he should act as though each state of nature was "equally likely" to occur. In this criterion, equal probabilities are assigned to each state of nature j in the payoff matrix and then the strategy with the maximum expected payoff is chosen. As there are m possible states of nature in G, the weight assigned to each state of nature (column of P i.e. p_{ij} is the payoff matrix from the viewpoint of the farmer) is $1/m$ or m^{-1}.

Let k_i be the expected payoff to the farmer for his i^{th} strategy under Laplace's criterion. Then

$$k_i = \sum_{j=1}^{m} p_{ij}\, m^{-1} = m^{-1} \sum_{j=1}^{m} p_{ij}$$

If, $\underset{i}{Max}\, k_i \equiv k_i$ then the farmer will choose his i*th strategy [25, 26].

Data: The survey data has been gathered using random sampling from 90 tomato producers in Khorasan Razavi province of Iran on 2007.

RESULTS AND DISCUSSION

The tomato production function estimated by SHAZAM software. The results revealed that three factors namely farmer experience, labor and manure (with mean 9 years, 23 man-day and 1290 Kg, respectively) are significant affective on production level. Then, the farmers classified into two groups (contracted and no-contract). Also, each group separated into eight subgroups in terms of the experience, labor and manure levels (Table 1). In Table 1, the mean of tomato yield reported in groups.

Table 1: The mean tomato yield in contracted and no-contract farmers

Group code (state)	Production characteristics: Experience	Labor used	Manure used	Contract strategies: Contracted	No-contract
1	<9	<23	<1290	30.0	37.4
2	<9	<23	>1290	41.3	45.5
3	<9	>23	<1290	40.0	47.5
4	<9	>23	>1290	38.5	41.4
5	>9	<23	<1290	47.3	50.0
6	>9	<23	>1290	42.5	52.0
7	>9	>23	<1290	55.0	55.0
8	>9	>23	>1290	51.6	53.2

Table 2: Wald and laplace criteria in selecting optimal contract strategy

Contract strategy	Criteria: Wald	Laplace
Contracted	30.0	43.2
No-contract	37.4	47.8
Optimal strategy	No-contract	No-contract

Comparing the yields of contracted and no-contract groups shows that 7th group (experience level is more than 9 years, the labor and manure used are less than 23 man-day and 1290 Kg per hectare, respectively) have the most yield (55 ton/ha), while the minimum yield are (30 and 37.4 ton/ha) is in first group (exp<9, lab<23, man<1290). And also, the yield levels in no-contract subgroups are significantly more than the contracted.

The optimal strategy have selected via Wald and Laplace criteria as well as the results of first table. The optimal strategy has determined using the game theory approach (Table 2). The results revealed that the no-contract strategy is more effective in yield production. The contract has resulted in decreasing the tomato yield. So, this finding takes a stand on Ferdosi [3], Perry and Johnson [11]. This paradox can be made by different reasons. It may be of agricultural policies and factory-holders including the low level of tomato purchasing price by factories, purchasing in advance, which conclude to shortage, fall value of products, more factor productivity and profitability of farmers in no-contract strategy, etc.

On the other hand, the tomato processing factories have not tried to create the appropriate field in training of farmers and using the high yielding Seed selection and adopted technology in order to obtaining more level of yield production. Truly, the factories don't settlement any extension-supporting services to guarantee the production. They exclusively have been drawn up the contract. The contract strategy with factories is enjoyment the larger safety margin to obtain the minimum level of revenue and not retain the losses. Also, small size of tomato farms is an obstacle in drawing up the contract and selecting the desirable strategy. Therefore, it seems that the producing the small farms in the figure of local co-operations or drawing up as aggregate in village level (no individually) as aggregate small farms can be solve the present problems.

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