An Application of Game Theory to Producers in Competition with Production and Market Price Risks: The Case of Turkey

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Abstract :

In view of deciding on production patterns, which will be profitable and sustainable, it is essential to develop strategies against fluctuations of production and market prices. Game theory is a strategy choice against the uncertainties and could be used to solve the problems of competitions, where a conflict of interest occurs among the decision makers.

This study is aimed at determining the plant enterprises with highest gross profit, which operate under production and market price risk conditions. The data of 2006 was collected from 162 producers of 279 different plant products in Bayındır, İzmir, Turkey.

Maximax, Wald, Regrets, Hurwicz, Utility and Laplace criteria of game theory were used in the study. These criteria were considered to have represented the major characteristics of producers.

Tomatoes had the highest gross profit per da with US Dolar 554.39 when the Maximax, Hurvicz and Laplace criteria were applied followed by pepper with US Dolar 182.50 provided that Wald and Utility criteria of game theory was employed. Taking into consideration the results obtained, we recommend to optimistic and pessimistic producers to concentrate on the production of tomato and pepper, respectively. We are in opinion that the results obtained from alternative criteria applied in this study will provide an opportunity for farmers to decide on product patterns in line with their risks perceptions. The database may also be beneficial for the related sectors and policy makers when they make decisions.

Key Words: Game Theory, Products Pattern, Producers Competition against Risks

Introduction

Generally farms operate under production and market price risk conditions. Among the production risks faced by farmers are climatic conditions, diseases, pesticides and production techniques applied. On the other hand, price fluctuations, marketing structures and legal arrangements are the major external factors, which are not under controls of farmers (Şahin, et.al., 2007). The farmers should pay special attention to the risk factors when choosing the production patterns and planning the stocks inventories. Product diversification is one of the

measures to be taken along with product insurance. However, full product insurances, which consist of all production and marketing price risks is not available in Turkey (Çetin, 2007). As a matter of fact, the cost of such insurance will be too high for farmers to undertake and application of it will be limited.

An efficient production and stock inventory planning has to do with alleviating some risk factors and thus optimizing the agricultural production under ecological, technical and economical conditions (Miran, 1990).

There exist many methods that the farmers use in their production and marketing planning. Production pattern may change according to risks perceptions of farmers while they decide on alternative planning methods (İnan, 2008). One of the most common methods used is linear programming. However, this programming method is applied without taking the lack of knowledge, risks and uncertainties into account. Alternatively, the game theory is a planning technique that evaluates the risks and uncertainties. By means of using this technique, production and marketing prices risks could be controlled to some extent (Miran ve Dizdaroğlu, 1994), and thus the success of farms in terms of profit maximization may be increased (Miran, 1990).

As a decision making or strategy choice game theory is a useful tool used in planning under uncertainties (Rasmusen, 2006). In addition, this technique is also applied in solving the problems of competitions where a conflict of interest occurs among the decision makers (Herath, 2006).

Game theory has been applied in different fields in the last two decades (Holsteiner, 2003; Başaran Uysal and Bölen, 2006; Lee and Kennedy, 2007). Apart from the political analysis such as crises between Turkey and Syria (Mumcu and Kahramaner, 2004); disputes regarding underground water uses in Mexico (Raquel et al., 2007) and frontier disputes between United States and Mexico (Frisvold and Caswell, 2001); game theory has also been applied to found solutions for economical problems including the agricultural sector. In this context, market competition of rice among U.S., Japan and South Korea (Lee and Kennedy, 2007); identification of duopoly market equilibrium (Ginevicous and Krivka, 2008); investigation of first-price and second-price auctions with asymmetric buyers in terms of profit maximization (Kirkegaard and Vergaard , 2008); the reasons of price dispersion

(Morgan et. al., 2006); international dairy marketing (Satti, 1998); competition among dairy enterprises concerning milk pricing and price discounts in Germany (Müller, 1999); decision on plant product pattern in Mediterranean part of Turkey (Özkan and Vuruş Akçaöz, 2002); the optimal selling time of some selected storable crops in Aegean region, Turkey (Miran, 1995) and beef and milk in western part of Turkey (Şahin, 2008) can be cited.

Many farm planning studies related to choosing the production pattern without taking risk considerations into account has been made (Esengün et. all., 1995; Cankurt and Konak, 2004; Günden, 2005; Biswas and Pal, 2005; Acs et.all., 2007). Some of the planning has been made under risk conditions (Ceyhan and Cinemre, 2004; Visagie and Ghebretsadik, 2005). However, studies concerning choosing the agricultural production pattern in Turkey under uncertainties and risks using game theory studies are limited (Vuruş Akçaöz, 2001). The most profitable cattle fattening breed for livestock farms in Aegean region of Turkey has been determined using some criteria of game theory (Şahin, et al., 2008b).

This study is aimed at determining the plant enterprises with highest gross profit, which operate under production and market price risk conditions in İzmir, Turkey based on gross profit of 10 products.

Material and Methods

The data of 2006 was collected from 162 producers, by means of questionnaires (face-by face with producers) in Bayındır, İzmir, Turkey. The questionnaires for 279 plant products were filled. The population was 5505 based on registration of Directory of Agriculture of Bayındır, İzmir, Turkey (Anonymous, 2004). The sample size were determined as 162 within 99 % confident interval and % 10 error percentage using the following proportional sample formula (Newbold, 1995; Miran, 2002).

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$$n = \frac{N\,p\,(1-p)}{(N-1)\sigma^{2}_{\hat{p}_x} + p\,(1-p)}$$

Where, n: sample size, N : population: p: proportion (0.5) $\sigma^{2}_{p_x}$: variance of proportion

In light of views of authorities working at Directory of Agriculture in Bayındır, İzmir, Turkey 10 settlement that represent the research area were determined.

The highest and the lowest gross profit of cotton, maize, wheat, barley, potato, tomato, pepper, and watermelon from the first product pattern; clover from perennial plants and cauliflower from the second products were taken as both the represent of a successful and an unsuccessful production period. Unsuccessful production period represented a bad situation where negative climatic conditions, low yields and low product prices were predominant. On the contrary, the successful production period represented a good situation where positive climatic conditions, high yields and high product prices were predominant. The game player which represents the Production or Market conditions has two strategies namely good conditions and bad conditions. On the other hand, the strategies of farmers are the 10 plant products that include in their product patterns. The farmer is supposed to prefer only one of these products based on gross profit to be obtained under good and bad market conditions. Game tables were arranged for farmers who are decision makers (Table, 1, 2).

Maximax, Wald, Regrets, Hurwicz, Utility and Laplace were determined as the major criteria of game theory considering that these criteria would explain the primary producers' characteristics (Miran, 2005; Şahin et al., 2008b; Altaylı, 1996).

Table 1.The Strategies and Characteristics of Farmers

Strategies	Criteria of Game Theory	Characteristics of Farmers	Explanation
A1 Cotton A2 Maize	Maximax	Optimistic	Production and marketing conditions will improve. The producer takes risks
A3 Wheat	Maximin (Wald)	Pessimistic	Production and marketing conditions will deteriorate. The producer averts risks
A4 Barley A5 Clover	Regrets	Minimum Regret	The producer minimize probable regrets
A6 Potato A7 Tomato	Hurwicz	Between Optimistic-Pessimistic	The producer is indecisive on being optimistic or pessimistic
A8 Pepper	Utility	Risk Averter	The producer has not much tendency towards risks
A9 Watermelon A10 Cauliflower	Laplace	Cautious	The producer evaluates the conditions prudently

It was accepted that the player has two strategies namely good conditions and bad conditions. These strategies have been constructed under two scenarios (Table 2).

Table 2. Strategies of Players which Represent the Production and Marketing Conditions

Scenarios	Strategies	Characteristics Production and Marketing Conditions
First Scenario	B1-Good Conditions	• Successful production and marketing • Positive effect of climatic conditions on production • Increases in product yield • Increases in product prices.
Second Scenario	B2-Bad Conditions	• Unsuccessful production and marketing • Negative climatic conditions on production • Decreases in product yield • Decreases in product price .

Results and Discussion

Maximax Criterion

According to Maximax criterion, the player chooses the best among the conditions determined at each strategy. The decision maker is optimistic about the production and marketing conditions (Şahin et.al.,2008b).

The maximax criterion showed that the tomato production had the highest gross profit with $ 554.39 per da. under the good conditions. However, this figure decreased to $ 96.58 per da. under bad conditions (Table 3).

Table 3. Game for Producer against Production and Marketing Conditions According to Maximax Criterion ($/da).

		B_1	B_2
Products		**Good Conditions**	**Bad Conditions**
A_1	Cotton	424.63	70.83
A_2	Maize	328.01	80.83
A_3	Wheat	295.71	58.57
A_4	Barley	144.83	54.13
A_5	Clover	289.63	88.41
A_6	Potato	231.16	176.94
A_7	Tomato	**554.39**	96.58
A_8	Pepper	312.50	182.83
A_9	Watermelon	267.54	62.87
A_{10}	Cauliflower	341.77	87.69

Maximin (Wald) Criterion

The producers choose a lower but a maximum price due to a lower risk. The producer is assumed to be pessimistic; therefore he accepts the maximum value of worst results (Miran, 2005; Şahin, et al, 2008b).

According to Wald criterion, the highest gross profit per da. was obtained from pepper production with $182.83. This figure is a quarantined value under bad conditions. The gross profit of producer is supposed to increase to $ 312.50 per da. under good conditions (Table 4).

Table 4. Game for Producer against Production and Marketing Conditions According to Wald Criterion ($/da).

		B_1	B_2
Products		**Good Conditions**	**Bad Conditions**
A_1	Cotton	424.63	70.83
A_2	Maize	328.01	80.83
A_3	Wheat	295.71	58.57
A_4	Barley	144.83	54.13
A_5	Clover	289.63	88.41
A_6	Potato	231.16	176.94
A_7	Tomato	554.39	96.58
A_8	Pepper	312.50	**182.83**
A_9	Watermelon	267.54	62.87
A_{10}	Cauliflower	341.77	87.69

Regret Criterion

The minimization of the possible regrets of producer was aimed with this criterion (Şahin, et.al., 2008b). For example, when the producer decides on cotton production will forgone the $ 554.39 per da that would be obtained from tomato production under good conditions, which is the best alternative in his production pattern. Therefore, the regrets of producer would be $ 554.39 – $ 424.63 = $ 129.76.

Regret values were calculated for each strategies of producer according to good and bad production and marketing conditions. Minimax criterion was applied to these regret values.

Tomato had highest gross profit per da with $ 96.58 (Table 5), which means the producer is at the lowest regret position.

Table 5. Game for Producer against Production and Marketing Conditions According to Regret Criterion ($/da).

		B_1		B_2	
	Products	**Good Conditions**		**Bad Conditions**	
A_1	Cotton	554.39-424.63=	129.76	182.83-70.83=	112.00
A_2	Maize	554.39-328.01=	226.38	182.83-80.83=	102.00
A_3	Wheat	554.39-295.71=	258.68	182.83-58.57=	124.26
A_4	Barley	554.39-144.83=	409.56	182.83-54.13=	128.70
A_5	Clover	554.39-289.63=	264.76	182.83-88.41=	94.42
A_6	Potato	554.39-231.16=	323.23	182.83-176.94=	5.89
A_7	Tomato	554.39-554.39=	0	182.83-**96.58**=	**86.25**
A_8	Pepper	554.39-312.50=	241.89	182.83-182.83=	0.00
A_9	Watermelon	554.39-267.54=	286.85	182.83-62.87=	119.96
A_{10}	Cauliflower	554.39-341.77=	212.62	182.83-87.69=	95.14

Hurwicz Criterion

According to Hurwicz criterion, the producer is between optimistic and pessimistic attitude. Each result was weighted according to optimistic coefficient. The highest and the lowest values of each strategy was multiplied by optimistic coefficient (α), and pessimistic coefficient (1- α), respectively and the difference between the two results was calculated. The highest calculated value was determined as the choice, which the producer will make the decision. A value for a little bit pessimistic producer was accepted as 0.4 (Şahin, et al.,2008b).

The highest gross profit calculated in light of this criterion belonged to tomato with $ 163.81 (Table 6).

Table 6. Game for Producer against Production and Marketing Conditions According to Hurwicz Criterion ($/da).

		B_1	B_2
Products		**Good Conditions**	**Bad Conditions**
A_1	Cotton	424.63 (0.4)-70.83 (0.6) =	127.35
A_2	Maize	328.01 (0.4)-80.83 (0.6) =	82.71
A_3	Wheat	295.71 (0.4)-58.57 (0.6) =	83.14
A_4	Barley	144.83 (0.4)-54.13 (0.6) =	25.45
A_5	Clover	289.63 (0.4)-88.41 (0.6) =	62.81
A_6	Potato	231.16 (0.4)-176.94 (0.6) =	-13.70
A_7	Tomato	554.39 (0.4)-96.58 (0.6) =	**163.81**
A_8	Pepper	312.50 (0.4)-182.53 (0.6) =	15.48
A_9	Watermelon	267.54 (0.4)-62.87 (0.6) =	69.29
A_{10}	Cauliflower	341.77 (0.4)-87.69 (0.6) =	84.09

Utility Criterion

This criterion assumes that the producer is risk averter. To determine the utility values, the lowest value of strategies was determined and subtracted from all the results of related strategy (Şahin, et.al., 2008b).

Pepper had the highest gross profit with $ 128.70 (Table 7). Therefore, the risk averter producer will prefer the pepper in light of this criterion.

Table 7. Game for Producer against Production-Marketing Conditions According to Utility Criterion ($/da).

		B_1		B_2	
	Products	**Good Conditions**		**Bad Conditions**	
A_1	Cotton	424.63-144.83=	279.80	70.83-54.13=	16.70
A_2	Maize	328.01-144.83=	183.18	80.83-54.13=	26.70
A_3	Wheat	295.71-144.83=	150.88	58.57-54.13=	4.44
A_4	Barley	144.83-144.83=	0.00	54.13-54.13=	0
A_5	Clover	289.63-144.83=	144.80	88.41-54.13=	34.28
A_6	Potato	231.16-144.83=	86.33	176.94-54.13=	122.81
A_7	Tomato	554.39-144.83=	409.56	96.58-54.13=	42.45
A_8	Pepper	312.50-144.83=	167.67	182.83-54.13=	**128.70**
A_9	Watermelon	267.54-144.83=	122.71	62.87-54.13=	8.74
A_{10}	Cauliflower	341.77-144.83=	196.94	87.69-54.13=	33.56

Laplace Criterion

According to Laplace criterion, when the probabilities of conditions are not known, the probabilities are accepted as equal. The probabilities of the good and bad conditions are equal. No condition has a priority to another one. Good and bad conditions were given ½ weights. The weighted value of each breed strategy was found by multiplying both of two conditions with 0.5 and then added together (Şahin, et.al., 2008b).

Since the highest weighted value was 325.49, the decision maker will choose the tomato production. The gross profit of producer will be $ 554.39 per da. under good conditions while this figure will decrease up to $ 96.58 per da under bad conditions (Table 8).

Table 8. Game for Producer against Production and Marketing Conditions According to Laplace Criterion ($/da).

		B_1	B_2	
	Products	**Good Conditions**	**Bad Conditions**	
A_1	Cotton	424.63 (0.5) + 70.83 (0.5) =		247.73
A_2	Maize	328.01 (0.5) + 80.83 (0.5) =		204.42
A_3	Wheat	295.71 (0.5) + 58.57 (0.5) =		177.14
A_4	Barley	144.83 (0.5) + 54.13 (0.5) =		99.48
A_5	Clover	289.63 (0.5) + 88.41 (0.5) =		189.02
A_6	Potato	231.16 (0.5) + 176.94 (0.5) =		204.05
A_7	Tomato	554.39 (0.5) + -96.58 (0.5) =		**325.49**
A_8	Pepper	312.50 (0.5) + 182.53 (0.5) =		247.52
A_9	Watermelon	267.54 (0.5) + 62.87 (0.5) =		165.21
A_{10}	Cauliflower	341.77 (0.5) + 87.69 (0.5) =		214.73

Maximax, Hurwicz and Laplace criterion provided the highest gross profit for tomato production with $554.39 per da followed by pepper production with gross profit of $ 182.83 when the Wald and Utility criteria were applied. The gross profit per da. was relatively low being the highest in tomato production with $ 96.58 when the regret criterion was applied in comparison with Maximax, Hurwicz and Laplace criteria (Table 9).

Maximax, Hurwicz and Laplace criteria were reported to provide the highest net profit for cattle fattening breed of Limuzun with $588.33 in İzmir, Turkey, which are consistent with the results found in this study (Şahin, et.all., 2008b). In a study conducted in Mediterrenean region of Turkey to determine the highest net profit under the worst conditions where Wald criterion was applied, cotton and peanut were reported as the riskiest products

(Özkan and Vuruş Akçaöz, 2002). Vuruş Akçaöz, 2001 reported that the risk level of products differed significantly in Mediterrenean region of Turkey in view of results obtained from the applied criteria and cotton and watermelon were enumerated as the riskiest products (Vuruş Akçaöz, 2001).

In a study, which Wald and Utility criteria were applied to determine the optimal selling times for certain products in İzmir, Turkey, the producers were reported as prudent (risk averters) and therefore they tended to apply a selling plan in accordance with Wald criterion (Şahin et all., 2008a).

Table 9. The Results of Game for Producer against Production and Marketing Conditions

Characteristics of Producer	Criterion	Gross Profit ($/da)	Preferred products
Optimistic	Maximax	554.39	Tomato
Pessimistic	Maximin (Wald)	182.83	Pepper
The Least Regrets	Regrets	96.58	Tomato
Between Optimistic and Pessimistic	Hurwicz	554.39 - 96.58	Tomato
Risk Averter	Utulity	182.83	Pepper
Prudent	Laplace	554.39 - 96.58	Tomato

Conclusion

Taking into consideration the results we obtained, in terms of profit maximization and risk minimization, we suggest tomato production for optimistic producers and pepper production for pessimistic producers. The optimistic and pessimistic producers will adopt the results of Maximax and Wald criterions, respectively.

We are in opinion that the results obtained from alternative criteria will provide an opportunity for farmers to decide on product patterns in line with their risks perceptions. The improvement in recording of production and marketing activities will make up a database, which could be used to apply advanced criteria of game theory. Thus, alternative plans regarding product patterns under different risk perceptions could be developed. These alternative product patterns will be a useful database for the related sectors and decision makers when they determine the priorities in terms of planning the stock inventories and reach the equilibrium.

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