International Journal of Industrial Engineering & Production Research September 2020 Vol. 31, No. 3: 387-396
DOI: 10.22068/ijiepr.31.3.387

RESEARCH PAPER

Two-Player Continuous Game Theory for Product Portfolio Management in a Competitive Manufacturing Market

Ramin Sadeghian[*1], Maryam Esmaeili[2] & Maliheh Ebrahimi[3]

Received 28 June 2019; Revised 25 April 2020; Accepted 13 July 2020; Published online 30 September 2020

ABSTRACT

Nowadays, the variety of new products will run serious competitions among manufacturers. Product Portfolio Management (PPM) as an appropriate tool can influence the customer's taste and increase the profit of firms. In this paper, the factors of PPM, production planning, and a two-player continuous game theory are considered simultaneously. Some constraints are also assumed including the availability of raw materials and demand of each product based on some specific criteria. Two firms have offered same products and competed with each other. The relationships between two producers are modeled by a non-zero two- player game. A numerical example is also presented. The proposed model is run within a single period with the inventory equal to zero at the beginning and end of this period. The objective functions show the profit of products and the constraints represent the utility of products for each customer, market's share as a function of the probability of customer selection for each section, type of distribution function for sale quantity, accessible quantity of the sum of used materials by two producers, etc.

The results showed a change in demand would affect the profit of two players and the second player would be more vulnerable to this effect than the first one. In addition, a change in the sale price affects the profit of two players and the first player is more influenced by this change than the first one. The obtained data showed that with an increase in the extra sale price, the profit of the first player would increase while the profit of second player would remain approximately constant.

KEYWORDS: *Game theory; Product portfolio management (PPM); Bi objective programming.*

1. Introduction

Nowadays, choosing an optimum Product Portfolio (PP) is regarded a pivotal decision for each producer in a competitive environment because producing a suitable set of products plays a key role in the survival of a producer. Of note, making a decision about presenting a new product portfolio entails some risks; therefore, the concept of Product Portfolio Management (PPM) as a business concept can be taken into consideration to simultaneously analyze both power of production and potential of market. The PPM can determine the best set of PP (Sadeghi et al., 2011).

In recent studies, PPM has been surveyed as a theoretical, conceptual, and economical research interest.

Some researchers investigated product management in some fields such as customer satisfaction, life cycle, and etc. (Back-Hock, 1992; Calantone et al., 1995; Iribarren et al., 2010; Xiang et al., 2013).

Stettina et al. (2014) presented an empirical perspective for agile portfolio management. Zhu et al. (2014) introduced portfolio management with robustness in both prediction and decision. Ruiz et al. (2014) and zhao (2007) utlized dynamic portfolio management in practice. Moreover, there are other similar studies on portfolio management (Knight et al., 2014; Lu et al., 2013; Tudor, 2012; Metaxiotis et al., 2012; Killen et al., 2012; Smith et al., 2011).

* Corresponding author: *Ramin Sadeghian*
sadeghian@pnu.ac.ir

1. *Associate Professor at Department of Industrial Engineering, Payame Noor University, PO BOX 19395-3697, Tehran, Iran.*
2. *Associated Professor at Industrial Engineering Department, Alzahra University, Tehran, Iran .*
3. *M.Sc. at Industrial Engineering Department, Bu ali Sina University, Hamedan, Iran.*

Kraiczy et al. (2014) presented a method for product portfolio performance in family firms. Makinen et al. (2014) and Li et al. (2014) used the decision-making and design of product portfolio. The project portfolio management was also applied in many researches (Brook et al., 2014; Gutierrez et al., 2014; Hyvari, 2014; Pajares et al., 2014; Alketbi et al., 2014; Kaiser et al., 2014; and Daniel et al., 2014).

Zhao et al. (2013) presented a game between manufacturers and government in a cleaner production. Moreover, Ma et al. (2014) introduced a dynamic non-cooperative game model for closed-loop supply chain. Cooper et al., (1999), McNally et al., (2009), and Smith et al. (2011) also studied product portfolio management.

Roshtin et al. studied the PP in pharmaceutical industry in the field of economic engineering and proposed a two-steps dynamic programming model (Roshtine et al., 1999). Jiao et al. inspected the PP selection by considering the dimensions of consumer absorption and product engineering (Jiao et al. 2005). Further, Sadeghi et al. used a discrete game theory for the PP selection in a competitive environment (Sadeghi et al., 2011).

Of note, a wide variety of products can confuse customers. In this regard, Berry et al. evaluated the cost of product's variety and its marginal profits (Berry et al., 1999). Carlo et al. presented two concepts such as the width of change and extent of change to measure the PP's variety. They surveyed the effects of these concepts on the success or failure of PPs (Carlo et al., 2006). The effects of two factors such as dissolution and business on PP's variety were inspected by Srini et al. (Srini vasan et al., 2008). Closs et al. presented a model to examine the effects of PP or PPM on the value of profit (Closs et al., 2008). In addition, Salhieh (2007) presented a systematic method was presented for transforming a non-homogenous portfolio into a homogenous portfolio.

Some researchers have studied the inventory and production management regarding the game theory. For instance, Wang et al. used game theory for a single-period supply chain with three retailers (Wang et al., 1994). A dynamic and non-dynamic game for inventory management with two players was proposed by Wu et al. (Wu et al., 2011). Bai et al. presented a dynamic game for production scheduling (Bai et al., 1997).

In a majority of articles, the competition between the salesmen and retailers have been studied, while the competition among several producers has been almost neglected. Generally, the studies on PPM have been limited to only PP selection and most of these papers have not considered several factors such as the quantities or constraints of production in the PP. In addition, game theory has been less used in PP selection and PPM. Therefore, the present study aims to examine the PP selection through a two-player continuous game and consider some constraints such as the rate of production, accessible resource, demand of each product, utility of each product for each customer, etc. For example, the utility of each product for each customer is evaluated based on the features of each product and customer.

In the following, the proposed model, assumptions, parameters, decision variables, and their corresponding numerical example are presented.

2. The Proposed Model

2.1. Assumptions

- The proposed model is run within a single period in which inventory is equal to zero at the beginning and end of the period. In other words, the productions of each period will be sold in the same period (Parlar et al., 2006).
- The demand is well-known.
- There are two producers whose products are similar, their product prices are the same, but the costs of materials are different for each producer.

2.2. The Parameters

D_j : The potential demand of product j

Q_i : The market size of customer i

S_j^m : The quantity sold from product j by producer m

P_j^m : The price of product j for producer m

c_j^m : The setup cost of product j for producer m

r_j^m : The price of product j for producer m (This parameter is defined for products with no demand)

Z_j^m : The feature of product j for producer m

x_i : The feature of customer for section i

u_{ij}^m : The utility of product j for producer m and section's customer i

f_j^m : The market share of product j for producer m

f_{jk}^m : The quantity of needed resource k of product j for producer m

B_k : The accessible quantity of resource k

L_j^m : The minimum production level of product j for producer m

V_j^m : The maximum selling potential of product j for producer m

Pm_j^m : The cost of resource k for product j and producer m

2.3. The decision variables

t_j^m : A binary variable (zero and one) for making a decision about producing or not producing product j of producer m

y_j^m : The quantity of production of product j for producer m

2.4. The model

Consider two producers who product similar products. They would like to select an optimum PP to maximize their profit. To this end, a bi-objective programming model is designed. Each objective function shows the profit of each producer including the incomes, costs, and penalties. The proposed model can be written as follows:

$$Max\ E_1 = \sum_{j=1}^{N}\sum_{n_1=0}^{D_j}[P_j^1 S_j^1 t_j^1 p\{S_j^1 + n_1 / D_j\} - (t_j^1 c_j^1 + \sum_{k=1}^{K} y_j^1 m_{jk}^1 Pm_j^1) + (r_j - P_j^1)(y_j^1 - S_j^1) p\{S_j^1 + n_1 / D_j\}] \quad (1)$$

$$Max\ E_2 = \sum_{j=1}^{N}\sum_{n_2=0}^{D_j}[P_j^2 S_j^2 t_j^2 p\{S_j^2 + n_2 / D_j\} - (t_j^2 c_j^2 + \sum_{k=2}^{K} y_j^2 m_{jk}^2 Pm_j^2) + (r_j - P_j^2)(y_j^2 - S_j^2) p\{S_j^2 + n_2 / D_j\}] \quad (2)$$

St:

$$u_{ij}^m = -\left|Z_j^m - x_i\right| \quad (3)$$

$$f_j^m = \sum_{i=1}^{I} \frac{e^{u_{ij}^m}}{\sum_{j=1}^{N} e^{u_{ij}^m t_j^m} \times e^{u_{ij}^{m'} t_j^{m'}}} Q_i \quad (4)$$

$$p\{S_j^1 + n_1 / D_j\} = \binom{D_j}{n_1}(1-f_j^1)^{D_j - n_1}(f_j^1)^{n_1} \quad (5)$$

$$\sum_{j=1}^{N} y_j^1 m_{jk}^1 + \sum_{j=1}^{N} y_j^2 m_{jk}^2 \le B_k \tag{6}$$

$$y_j^1 + y_j^2 \ge D_j \tag{7}$$

$$L_j^1 t_j^1 \le y_j^1 \le V_j^1 t_j^1 \tag{8}$$

$$L_j^2 t_j^2 \le y_j^2 \le V_j^2 t_j^2 \tag{9}$$

$$y_j^1 > f_j^1 D_j t_j^1 \tag{10}$$

$$y_j^2 > f_j^2 D_j t_j^2 \tag{11}$$

$$t_j^1, t_j^2 = 0,1 \quad y_j^1, y_j^2 \ge 0 \tag{12}$$

Equations (1) and (2) are the objective functions for each producer. Their first, second, and third parts show the selling income, production cost, and the profit of products with no demand, respectively.

The Constraint (3) obtains the utility of products for each customer. The minus sign before absolute was used since u_{ij}^m in Equation (4) was applied as exponential.

Constraint (4) shows the market share (Tang et al., 2010; Jiao et al., 2005; and Sadeghi et al., 2011). The market share is a function of the probability of customer selection for section i, product j, and producer m. The probability of customer selection can be defined as a matrix similar to that in Equation (13):

$$D_{gn}^m = \frac{e^{\mu U_{gn}^m}}{\sum_{c=1}^{N_{com}} e^{\mu U_{gn}^m}} \tag{13}$$

Since the strategy of the proposed model is continuous, t_j^m is obtained with its related utilities to affect the market share and sale probability.

Constraint (5) considers a bi-nominal distribution for sale quantity because the customer sells its products to a producer or its competitor. Based on the model assumptions, the demand of any product is well-known but producers are not aware of the sale quantity for their competition (Bai et al., 1997). To simplify this problem, the sale quantity can be replaced by the mean of sale quantity or mean of bi-nominal distribution:

$$S_j^1 \cong \sum f_j^1 D_j \tag{14}$$

$$S_j^2 \cong \sum f_j^2 D_j \tag{15}$$

Therefore, the objective functions are reformed as shown below:

$$Max\ E_1 = \sum_{j=1}^{N} \sum_{n_1=0}^{D_j} [P_j^1 f_j^1 D_j t_j^1 - (t_j^1 c_j^1 + \sum_{k=1}^{K} y_j^1 m_{jk}^1 Pm_j^1) + (r_j - P_j^1)(y_j^1 - f_j^1 D_j t_j^1)] \tag{16}$$

$$Max\ E_2 = \sum_{j=1}^{N} \sum_{n_2=0}^{D_j} [P_j^2 f_j^2 D_j t_j^2 - (t_j^2 c_j^2 + \sum_{k=2}^{K} y_j^2 m_{jk}^2 Pm_j^2) + (r_j - P_j^2)(y_j^2 - f_j^2 D_j t_j^2)] \tag{17}$$

Constraint (6) shows that the sum of the used materials by two producers should not be more than the accessible quantity. This constraint is a function of both two producers.

Constraint (7) is applied to cover the whole demand of product j on behalf of two producers. This constraint is also a function of both two producers.

Constraints (8) and (9) are supposed to check the minimum and maximum potential of production. Constraints (10) and (11) demonstrate that the difference of the sale mean from production quantity should be positive.

3. Numerical Examples

Assume that two producers can produce four types of different products. They tend to find a suitable PP and quantity of productions. Any product has its own specific demand and two producers should cover the total demands. The products may be supplied in four sections of a market with their customers and utilities. Obviously, the utility of any product affects any producer's market share of. In addition, there are some limitations such as the potential of production, accessible materials, product demand, etc. The values of parameters are presented in the appendices.

Since the proposed model is a bi-objective programming, the L-P metric method is employed to analyze the status of the problem. Table 1. shows non-dominated solutions obtained by L-P metric method for different P's. Their charts are also presented in the appendices.

Tab. 1. Non-dominated solutions obtained by L-P metric method

P	x	f_1	f_2
P=2	x_1	866	2040
P=4	x_2	2867	2036
P=6	x_3	2872	2031
P=8	x_4	203	933
P=10	x_5	764	1822

With regard to Table 1. and concept of payoff dominance for determining Nash equilibrium, the obtained non-dominated solutions for P = 8, 10 (i.e. x_4, x_5) cannot be Nash equilibrium, because their solutions are dominated by other solutions such as x_1, x_2, and x_3.

Berry et al. used the ranking methods to suggest the most proper solution (Berry et al., 1999), while through Nash equilibrium law, the second strategy (i.e. x_2) can be a Nash equilibrium solution. Therefore, the quantities of production for all products can be seen in Table 2.

Tab. 2. the quantities of production for strategy x_2

Producers	Product 1	Product 2	Product 3	Product 4	Profit
Producer 1	0	11	18	60	2867
Producer 2	60	39	22	0	2036

4. Discussions

In this section, a sensitivity analysis on the objective functions is performed which entails the profit of players (producers) based on some parameters such as total demand, sale price for any product, and sale price for extra products. The obtained results are presented in Figs. (1-3).

Figure 1 shows that demand changing affects the profits of two players, and the second player is more influenced than the first one. Therefore, uncertain demands are likely to damage the profit of the second player. In this case, profit stability is ensured for the first player; however, more precise methods for forecasting demand are still required.

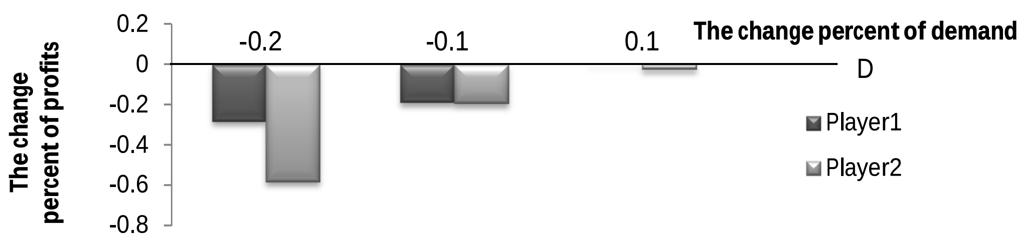

Fig. 1. The effects of demand on the profit of players

Figure 2 demonstrates that the sale price changing affects the profit of two players, especially the first player. Therefore, uncertain sale price may damage the profit of the first player. Therefore in this case, the risk management techniques can be useful. In addition, though ensured, the profit of the second player is reduced under competitive conditions.

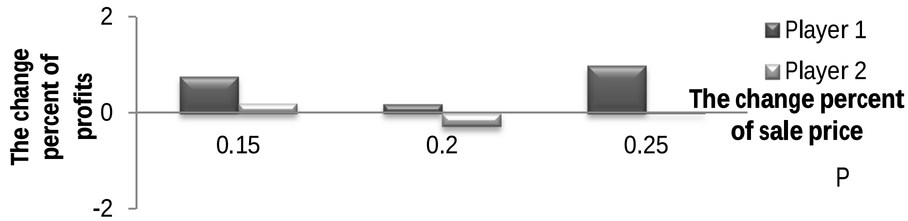

Fig. 2. The effects of sale price on the players' profit

Figure 3 shows that with an increase in an extra sale price, the profit of the first player increases while the profit of second player remains constant. Hence the first player can increase his profit by increasing extra sale price; however, this idea may not be fruitful for the second player.

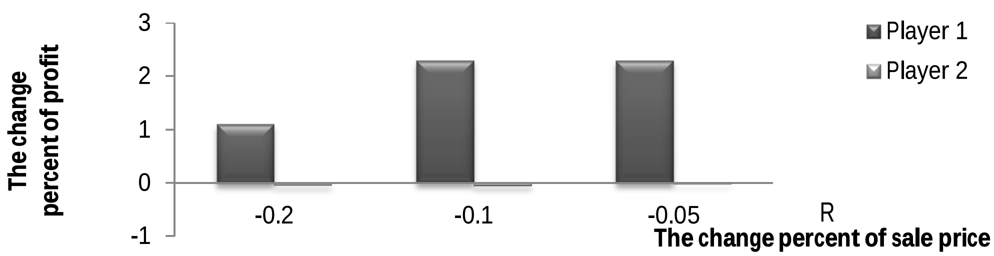

Fig. 3. The effects of extra sale price on the profit of players

5. Conclusions

The PP selection can be analyzed regarding selling and producing. In this paper, a continuous game theory approach with two players is used that entails a bi-objective programming with independent objective functions. Further, some characteristics of both product and customer were taken into consideration to describe the constraints and objective functions in detail. In the presented model, while the demand of any product is certain and well-known, the sale quantity is unknown. Since the model's environment is competitive with to participating two producers, it is assumed that the sale quantity is determined by bi-nominal distribution. To illustrate this issue, a numerical example is also presented below. This example is analyzed based on L-P metric method and Nash equilibrium. Then, a sensitivity analysis is performed on some parameters such as demand, sale price, and extra sale price.

6. Appendixes

6.1. Appendix 1: Input data for numerical example

Tab. 3 The data of market share, total demand, sale price, and extra sale price

	Customer 1	Customer 2	Customer 3	Customer 4
Market Share	0.45	0.25	0.23	0.07
Total Market Demand	60	50	40	60
Sale Price	25	30	43	40
Extra Sale Price	20	26	40	31
Customer Attribute	1	3	2	6

Tab. 4. The setup cost of producers

	Product 1	Product 2	Product 3	Product 4
Setup Cost of Producer 1	3	2	2	3
Setup Cost of Producer 2	3	8	2	5
Product Attribute of Producer 1	1	4	2.5	6
Product Attribute of Producer 2	1.5	3	2	4

Tab. 5. The required materials and their unit cost for producer 1

(Required Quantity , Unit Cost)	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6
Product 1	(0.5, 1)	(0.25, 1)	(0, 0)	(0, 0)	(0, 0)	(0, 0)
Product 2	(0.55, 0.75)	(0, 0)	(0, 0)	(1.5, 0.35)	(0, 0)	(0, 0)
Product 3	(0.55, 1)	(0, 0)	(22.2, 0.58)	(0, 0)	(0, 0)	(0, 0)
Product 4	(0.5, 0.65)	(0, 0)	(0, 0)	(0, 0)	(0.4, 2.2)	(0.55, 0.5)

Tab. 6. The required materials and their unit cost for producer 2

(Required Quantity, Unit Cost)	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6
Product 1	(1.5, 0.5)	(0. 5, 0.55)	(0, 0)	(0, 0)	(0, 0)	(0, 0)
Product 2	(1, 0.25)	(0, 0)	(0, 0)	(0.45, 1.7)	(0, 0)	(0, 0)
Product 3	(1.5, 0.5)	(0, 0)	(0.6, 1.7)	(0, 0)	(0, 0)	(0, 0)
Product 4	(0, 0)	(0, 0)	(0, 0)	(0, 0)	(0.2, 0.59)	(0.75, 0.55)

Tab. 7. Accessible materials

	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6
Accessible Quantity	1200	450	300	250	300	150

6.2. Appendix 2: Output data from numerical example

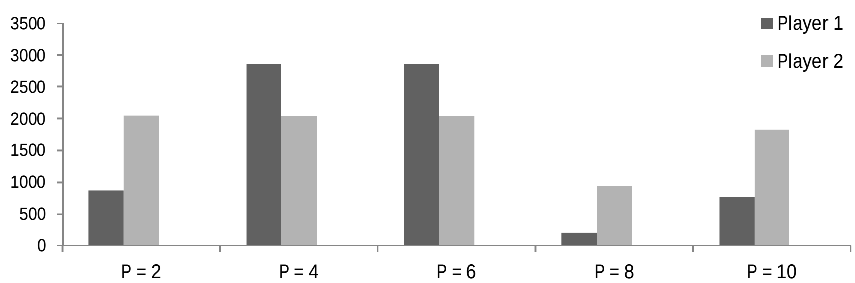

Fig. 4. Non-dominated solutions obtained from L-P metric

Tab. 8. The obtained solutions by P = 4

(Producer 1, Producer 2)	Product 1	Product 2	Product 3	Product 4
y_j^1	(0, 0)	(10, 26)	(18, 18)	(60, 47)
t_j^1	(0, 0)	(1, 1)	(1, 1)	(1, 1)
y_j^2	(60, 60)	(40, 24)	(22, 22)	(0, 13)
t_j^2	(1, 1)	(1, 1)	(1, 1)	(0, 1)

References

[1] Alketbi S. and Gardine P. R., "Top Down Management Aapproach in Project Portfolio Management", Procedia - Social and Behavioral Sciences, Vol. 119, (2014), pp. 611-614.

[2] Back-Hock A., "Towards strategic accounting in product management: Implementing a holistic approach in a data and methods base for managerial accounting", European Journal of Operational Research, Vol. 61, Nos. 1-2, (1992), pp. 98-105.

[3] Bai S. X., Tsai Y. K., El Hafsi M. and Deng K. "Production Scheduling in a Price Competition", PII: s0898-1221: (1997), pp. 5-19.

[4] Berry William L. and Cooper Martha C. "Manufacturing flexibility: methods for measuring the impact of product variety on performance in process industries", Journal of Operations Management, Vol. 17, (1999), pp. 163-178.

[5] Brook J. W. and Pagnanelli F., "Integrating sustainability into innovation project portfolio management – A strategic perspective", Journal of Engineering and Technology Management, In Press (2014).

[6] Calantone R. J., Di Benedetto C. A. and Haggblom T., "Principles of new product management: Exploring the beliefs of product practitioners", Journal of Product Innovation Management, Vol. 12, No. 3, (1995), pp. 235-247.

[7] Carlo Filippo Wezel and Van Witteloostuijn Arjen. "From Scooters to Choppers: Product Portfolio Change and Organizational Failure", Long Range Planning, Vol. 39, (2006), pp. 11-28.

[8] Closs David J., Jacobs Mark A., Swink Morgan and Webb G. Scott. "Toward a theory of competencies for the management of product complexity: Six case studies", Journal of Operations Management, Vol. 26, (2008), pp. 590-610.

[9] Cooper R. G., Edgett S. J. and Kleinschmidt E. J., "New product portfolio management: practices and performance", Journal of Product Innovation Management, Vol. 16, No. 4, (1999), pp. 333-351.

[10] Daniel E. M., Ward J. M. and Franken A., "A dynamic capabilities perspective of IS project portfolio management", The Journal of Strategic Information Systems, Vol. 23, No. 2, (2014), pp. 95-111.

[11] Gutierrez E. and Magnusson M., "Dealing with legitimacy: A key challenge for Project Portfolio Management decision makers", International Journal of Project Management, Vol. 32, No. 1, (2014), pp. 30-39.

[12] Hyvari I., "Project Portfolio Management in a Company Strategy Implementation, a Case Study", Procedia - Social and Behavioral Sciences, Vol. 119, (2014), pp. 229-236.

[13] Iribarren D., Moreira M. T. and Feijoo G., "Implementing by-product management into the Life Cycle Assessment of the mussel sector", Resources, Conservation and Recycling, Vol. 54, No. 12, (2010), pp. 1219-1230.

[14] Jiao Jianxin and Zhang Yiyang. "Product portfolio identification based on association rule mining", Computer-Aided Design, Vol. 37, (2005), pp. 149-172.

[15] Kaiser M. G., El Arbi F. and Ahlemann F., "Successful project portfolio management beyond project selection techniques: Understanding the role of structural alignment", International Journal of Project Management, In Press (2014).

[16] Killen C. P., Jugdev K., Drouin N. and Petit Y., "Advancing project and portfolio

management research: Applying strategic management theories", International Journal of Project Management, Vol. 30, No. 5, (2012), pp. 525-538.

[17] Knight L., Tu Y. H. and Preston J., "Integrating skills profiling and purchasing portfolio management: An opportunity for building purchasing capability", International Journal of Production Economics, Vol. 147, (2014), pp. 271-283.

[18] Kraiczy N. D., Hack A. and Kellermanns F. W., (2014), "New product portfolio performance in family firms", Journal of Business Research, Vol. 67, No. 6, pp. 1065-1073.

[19] Li Y. M., Chen H. M., Liou J. H. and Lin L. F., "Creating social intelligence for product portfolio design", Decision Support Systems, Vol. 66, (2014), pp. 123-134.

[20] Lu F. Q., Huang M., Ching W. K. and Siu T. K., "Credit portfolio management using two-level particle swarm optimization", Information Sciences, Vol. 237, (2013), pp. 162-175.

[21] Ma J. and Wang H., "Complexity analysis of dynamic noncooperative game models for closed-loop supply chain with product recovery", Applied Mathematical Modelling, In Press (2014).

[22] Makinen S. J. and Vilkko M. K., "Product portfolio decision-making and absorptive capacity: A simulation study", Journal of Engineering and Technology Management, Vol. 32, (2014), pp. 60-75.

[23] McNally R. C., Durmusoglu S. S., Calantone R. J. and Harmancioglu N., "Exploring new product portfolio management decisions: The role of managers' dispositional traits", Industrial Marketing Management, Vol. 38, No. 1, (2009), pp. 127-143.

[24] Metaxiotis K. and Liagkouras K., "Multiobjective Evolutionary Algorithms for Portfolio Management: A comprehensive literature review", Expert Systems with Applications, Vol. 39, No. 14, (2012), pp. 11685-11698.

[25] Pajares J. and Lopez A., "New Methodological Approaches to Project Portfolio Management: The Role of Interactions within Projects and Portfolios", Procedia - Social and Behavioral Sciences, Vol. 119, (2014), pp. 645-652.

[26] Parlar Mahmut and Weng Z. Kevin. "Coordinating pricing and production decisions in the presence of price competition", European Journal of Operational Research, Vol. 170, (2006), pp. 211-227.

[27] Rotstein G.E., Papageorgiou L.G. and Shah N. "A Product Portfolio Approach in the Pharmaceutical Industry", Computers and Chemical Engineering Supplement, (1999), pp. 5883-5886.

[28] Ruiz V., Perez M. A. and Olasolo A., "Dynamic Portfolio Management Strategies based on the Use of Moving Averages", Procedia - Social and Behavioral Sciences, Vol. 109, (2014), pp. 1277-1281.

[29] Sadeghi A. and Zandieh M., "A game theory-based model for product portfolio management in a competitive market", Expert Systems with Applications, Vol. 38, No. 7, (2011), pp. 7919-7923.

[30] Salhieh Sa'ed M. "A methodology to redesign heterogeneous product portfolios as homogeneous product families", Computer-Aided Design, Vol. 39, (2007), pp. 1065-1074.

[31] Smith B. V. and Ierapepritou M. G., "Modeling and optimization of product design and portfolio management interface",

Computers & Chemical Engineering, Vol. 35, No. 11, (2011), pp. 2579-2589.

[32] Srini vasan Raji, Lilien Gary L. and Rangaswamy Arvind. "Survival of high tech firms: The effects of diversity of product–market portfolios patents and trademarks", International Journal of Research in Marketing, Vol. 25, (2008), pp. 119-128.

[33] Stettina C. J. and Horz J., "Agile portfolio management: An empirical perspective on the practice in use", International Journal of Project Management, In Press (2014).

[34] Tang Christopher S. "A review of marketing–operations interface models: From co-existence to coordination and collaboration", International Journal of Production Economics. Vol. 125, (2010), pp. 22-40.

[35] Tudor C., "Active Portfolio Management on the Romanian Stock Market", Procedia - Social and Behavioral Sciences, Vol. 58, (2012), pp. 543-551.

[36] Wang Qinan and Parlar Mahmut. "A three-person game theory model arising in stochastic inventory control theory", European Journal of Operational Research, Vol. 76, (1994), pp. 83-97.

[37] Wu H. and Parlar M. "Games with incomplete information: A simplified exposition with inventory management applications", International Journal of Production Economics, Vol. 133, (2011), pp. 562-577.

[38] Xiang Z., Li X. and Yang J., "Customer Satisfaction Scoring for Innovative Product Management based on Extenics", Procedia Computer Science, Vol. 17, (2013), pp. 1178-1185.

[39] Zhao R., Neighbour G., McGuire M. and Deutz P., "A software based simulation for cleaner production: A game between manufacturers and government", Journal of Loss Prevention in the Process Industries, Vol. 26, No. 1, (2013), pp. 59-67.

[40] Zhao Y., "A dynamic model of active portfolio management with benchmark orientation", Journal of Banking & Finance, Vol. 31, No. 11, (2007), pp. 3336-3356.

[41] Zhu S., Fan M. and Li D., "Portfolio management with robustness in both prediction and decision: A mixture model based learning approach", Journal of Economic Dynamics and Control, Vol. 48, (2014), pp. 1-25.

Follow This Article at The Following Site:

Sadeghian R, Esmaeili M, Ebrahimi M. Two-Player Continuous Game Theory for Product Portfolio Management in a Competitive Manufacturing Market. IJIEPR. 2020; 31 (3) :387-396

URL: http://ijiepr.iust.ac.ir/article-1-917-en.html