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A Regret Minimization Approach in Product Portfolio Management with Respect to Customers' Price-sensitivity

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Abstract

In an uncertain and competitive environment, product portfolio management (PPM) becomes more challenging for manufacturers to decide what to make and establish the most beneficial product portfolio. In this paper, a novel approach in PPM is proposed in which the environment uncertainty, competitors' behavior and customer's satisfaction are simultaneously considered as the most important criteria in achieving a successful business plan. In terms of uncertainty, the competitors' product portfolios are assumed as different scenarios with discrete occurrence probabilities. In order to consider various customer preferences, three different market segments are assumed in which the sensitivity of customers towards the products price are considered as high, medium and low and modeled by means of a modified utility functions. The best product portfolio with minimum risk of loss and maximum customer satisfaction is then established by means of a novel regret minimization index. The proposed index aims at finding the best product portfolio which minimizes the total possible loss and regret of the manufacturer, with respect to the other competitors of the market. To better illustrate the practicality of the approach, a numerical example is presented. The results show that the selected products in the suggested portfolio have the highest utility value in all market segments and also they are expected to achieve the highest expected payoff in each possible marketing scenario.

Keywords: Product portfolio management; Price-sensitivity; Regret minimization; Customer satisfaction; Utility function; Uncertainty.

1. Introduction

The implementation, adjustment and selection of the products existing in a portfolio are very costly and that's why the product portfolio management (PPM) and selection of the right products play an important role in the firm's success. It is one of the most important decisions which the management should deal with in which the production costs and customer preferences must be simultaneously taken into account in order to achieve highest market share(Schön, 2010, Liu et al., 2015).

PPM is usually used by the manufactures to maximize their profit by choosing the best set of products. Making a balance between resource constraints and customer preferences is the most challenging issue for the manufacturers (Zapata et al., 2008, McNally et al., 2009). The most desired product/service is the one which has the least cost and an acceptable level of quality which fulfills the customers' requirements. The uncertainty of the product portfolio offered by other competitors of the market is also another concern which is less considered.

In literature, PPM has been widely focused by the researchers (Cooper et al., 1999, Day, 1977, McNally et al., 2009, Song and Kusiak, 2009). Liu et al. developed a game-theory based model for establishing the most beneficial product portfolio (Liu et al., 2015). The problem is assumed as a Stackelberg game in which one new entrant firm plays as a leader in market by offering new products and the competitor reacts by adjusting its existing product portfolio in a way that he decides to offer

As the product variety enhances the customer satisfaction, firms prefer to offer product portfolios instead of single products to the customers (Jiao et al., 2007). However, the product variety increases the customer satisfaction; but the profitability of portfolio is also an important issue which should be considered. It is believed that for most firms, the Pareto principle applies in a way that 20% of products produce 80% of the benefits (Jiao et al., 2007, Sadeghi et al., 2011).

In competitive markets, the customer preferences have a great impact on some factors such as product price, volume of trade and velocity of money (Giraud, 2003). Besides various preferences, the degree of price-sensitivity widely varies among customers of different market segments. In other words, a group of customers intensively react towards trivial price changes in a way that it can strictly influence their decision whether to buy the product or not. Such customers are categorized as customers with high level of price-sensitivity. On the other hand, there are a group of customers who are not that much affected by price fluctuations and their sensitivity to the price changes is low. To modelsuch customer behaviors, price-sensitivity is considered by means of modified utility functions with specific characteristics which properly differentiate the customers of different market segments (Bulmuş and Özekici, 2012, Çanakoğlu and Özekici, 2010, Yang et al., 2013, Gleibner et al., 2013). According to uncertainty of other manufacturers' product portfolio, the PPM can be modeled as a scenario-based approach which was first discussed by Dantzig(Dantzig, 1955). In this approach, the final decisions should gain the least deviation from the

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desired targets based on the uncertain environment (Yager, 2004, Oh et al., 2012). To achieve that, the concept of regret minimization is suggested by (Li et al., 2012). Regret is considered as the negative feeling experienced by decision makers when one (or more) alternative which is not selected, outperforms the selected portfolio in terms of benefit-related attributes (van Cranenburgh et al., 2015).

The concept of regret minimization is widely used in business and marketing literature in different areas such as portfolio selection (Hazan and Kale, 2015), reserve price optimization in a second-price auction (Nicol et al., 2013), freight transport application (Boeri and Masiero, 2014), computer science (Hyafil and Boutilier, 2004) and game theory context (Halpern and Pass, 2012, Renou and Schlag, 2010). Regret minimization models are generally developed based on the psychological notion that is considered as an eminent issue in determining the choice behavior of decision makers (Loomes and Sugden, 1982). Decision makers try to select those alternatives which will provide minimum regret in the trade-off between available alternatives. In uncertain environments, regret minimization selectsthose options with least expected loss.

There are two perspectives in forming product portfolio: marketing perspective (Belloni et al., 2008) and engineering perspective (Simpson, 2004). Marketing perspective considers the customer preferences to optimize the product portfolio that aimsto maximize the total profit and sales of products. Engineering perspective, on the other hand, focuses on the cost and flexibility of the portfolio products aiming to reduce the cost and sophistication of the products' design. Jiao and Zhang have proposed a model in which the customer preferences and engineering costs are integrated. Their model selects those products which fulfill the customer preferencesmore with least production costs (Jiao and Zhang, 2005). In this case,Sadeghi and Zandieh have considered the utility of each portfolio for customers based on experts' opinion (Sadeghi and Zandieh, 2011).The fact is that when the expert's opinion interferes, there occurs some inevitable judgmental errors in selecting the right products.

1.1. *Motivation and significance*

It is believed that a more successful product portfolio is the one which benefits from both marketing and engineering perspectives simultaneously with a close consideration between marketing and engineering issues, called as customer-engineering considerations (Jiao and Zhang, 2005, Luo, 2011, Michalek et al., 2011). In this paper, the engineering perspective is covered by considering the total production costs of product(s) and the marketing perspective is focused by involving the degree of customers' price-sensitivity in different market segments which displays the customer preferences towards price fluctuations. In other words, price-sensitivity reveals how customers would react in making a balance between the quality and the price of the products.

In order to measure the reactions of various customers towards product price, three different market segments are considered in which the price-sensitivity of the customers are assumed as high, medium, low. A high price-sensitive customer is reluctant to buy an expensive product with higher (or the same) quality, while the low price-sensitive customer does care about the quality and higher price does not significantly affect his decision for buying the product. The medium price-sensitive customer is the one whose behavior is in between and has a more moderate reaction towards price changes. A set of modified utility function for each market segment is considered which clearly illustrates how the customer preferences towards product prices changes.The advantage of using utility functions instead of using the expert's opinion for utility determination is that specific utility functions are precisely modified for different customers with various preferences towards product price. Moreover, the personal opinion and judgment of the experts can interfere in determining the real amount of the customer's utility. As a result, utility functions in comparison with expert's opinion are more reliable determinants for measuring the customers' preferences.

In addition to customer-engineering issues, the proposed approach considers the possible product(s) of other competitors which will be released to the market and suggests the portfolio with least expected loss with minimum regret for the manufacturer. The competitors' probability of releasing their product portfolios are assumed in separate scenarios as an estimatedvalue which is achieved based on their historical and recent production activities. The proposed approach helps the manufacturer to consider all the other market competitors and makes the best decision by considering the customer-engineering issues and beneficial perspectives. Although the idea of regret is not new, to the best of our knowledge, this paper is the first study which additionally considers the expect regret minimization in establishing the most beneficial product portfolio.

In summary, the main aims of the paper are as following:

- Developing an approach in which the environment uncertainty, competitors and customers preferences are simultaneously taken into account.
- Considering three market segments to enhance the customer satisfaction in terms of price-sensitivity.
- Using utility functions to model the customers preferences towards product price in different market segments.
- Developing a regret minimization approach in which the best product portfolio with minimum risk of loss is suggested to the manufacturer.

Table 1 gives a brief comparison between some recent conventional studies and the current paper and reveals the novel aspects considered in the research.

Table 1
Comparison between the highlights of the current research and recent conventional studies

	Competitive market	Customer preferences	Production costs	Loss minimization	Regret minimization	Customer utility modeling	Market segmentation
(Ward et al., 2010)		*	*	*			
(Otten et al., 2015)		*	*	*			
(Liu et al., 2015)	*	*	*	*			*
(Ma, 2016)	*	*	*	*			*
(Takami et al., 2016)			*	*			
Current research	*	*	*	*	*	*	*

The rest of the paper is organized as follows: Notations and parameter definitions are given in Section 2.Section 3 represents the model formulation. To verify the proposed approach, a numerical example is then given in Section 4 and the conclusions and further research directions are presented in Section 5.

2. Notations and Assumptions

This section introduces the notation of the model, parameters and the required assumptions.

2.1. Notations

Table 2 represents all of the used notations and parameters in the proposed approach.

Table 2
Parameter description

Index	Description
M	Number of manufacturers in market
N_i	Maximum number of possible products for *i* th manufacturer, *i*=1,2,…,M
N_i'	Number of products produced by *i*th manufacturer, *i*=1,2,…,M
N_{all}	Number of all products in market
P^i	Set of productsas for*i*th manufacturer, *i*=1,2,…,M
p_n^i	*n*th product of *i*th manufacturer, *i*=1,2,…,M
Z^i	Set of portfolios for *i*th manufacturer, *i*=1,2,…,M
z_k^i	*k*th portfolio as for *i*th manufacturer, *i*=1,2,…,M
K_i	Maximum number of possible portfolios for *i*th manufacturer, *i*=1,2,…,M
P_{jk}^*	Optimal portfolio when the *j*th manufacturer selects his *k*th portfolio, *j*=1,2,…,M ; *k*=1,2,…,z_k^i
$R(z_k^i)$	Regret index for portfolio z_k^i
S	Set of market segments
G	Number of market segments
s_g	*g*th segment of the market
Q_g	Size of *g*th segment of the market
C_n^i	Production cost for *n*th product of *i*th manufacturer, *i*=1,2,…,M
P_n^i	Offered price for *n*th product of *i*th manufacturer, *i*=1,2,…,M
U_g	Utility function for *g*th market segment
u_{gn}^i	Utility of the gth segment for the *n*th product of *i*th manufacturer, *i*=1,2,…,M
μ	Scaling parameter
α_{jk}	Probability of selecting *k*th portfolio by *j*th manufacturer, *j*=1,2,…,*m; j≠I;* (the probability that the *k*th scenario for *j*th manufacturer will occur)
β	Customer preference scale for different market segment utility function
F_i	Payoff matrix for *i*th manufacturer, *i*=1,2,…,M
$f_i(z_k^i, z_{k'}^j)$	Payoff function for *i*th manufacturer when chooses the portfolio z_k and the other manufacturer chooses portfolio $z_{k'}$, *i*=1,2,…,M, j≠i , *k*=1,2,…,K_i , *k'*=1,2,…,K_j'.

2.2. Assumptions

The proposed approach is based on the following assumptions:

1- There are M manufacturers who produce similar types of products.
2- Each manufacturer i (i=1,2,…,M) is capable to produce maximum $N_i$products.
3- There are different market segments $S = \{s_1, \dots, s_g, \dots, s_G\}$ with a certain size of (Q_g) which are determined based on different customers' types and their degree of price-sensitivity.
4- The probabilities of releasing each product portfolio (scenario) by other competitorsare determined based on probability distributions achieved by their historical and recent production activities.

3. Problem Formulation

Consider a manufacturer (manufacturer i) is going to decide what product portfolio is the most appropriate one for him to be launched in market, with respect to the other competitors probable product portfolios. Manufacturer$i$is capable of producing maximum N_i products. Therefore, the feasible product set for the manufacturer $i$is defined as given in (1):

$$P^i = \left\{p_1^i, p_2^i, \dots, p_{N_i}^i\right\} \tag{1}$$

where all the possible product portfolios for the manufacturer i are defined as all possible subsets of P^i. In other words, the number of feasible portfolios for manufacturer i (K_i) equals$2^{N_i} - 1$, and the product portfolio set for the manufacturer i is created as presented in (2):

$$Z^i = \{z_1^i, z_2^i, \dots, z_{k_i}^i\} \tag{2}$$

Each product, p_n^i, is considered to have a certain production cost as C_n^i. Moreover, the probability of selecting kth portfolio by jth competitor (j=1,2,…,M ; $j≠i$) is determined as (α_{jk}). In fact, there are$k$ scenarios with probability $\alpha_{jk}$for the competitors represented by index j. To maximize the payoff, manufacturer $i$determines the best portfolio by considering the probable portfolios which are going to be launched in market by other existing competitors.

The best portfolio for the manufacturer will be obtained based on the following steps:

Step 1: Calculating the payoff

Manufacturer i should first calculate the payoff of the portfolios in presence of the other competitors' products in market. Equation (3) is used to obtain the payoff of each portfolio of manufacturer i(Sadeghi and Zandieh, 2011). It calculates the utility of the proposed portfolio by manufacturer i in presence of all the other existing products in the market (denominator contains all the existing products' utilities).

$$f_i(z_k^i, z_{k'}^j) = \sum_{g=1}^{G}\sum_{n=1}^{N'} \frac{u_{gn}^i}{C_n^i} \times \frac{e^{\mu u_{gn}^i}}{\sum_{c=1}^{N_{all}}\left[e^{\mu u_{gc}^i} + e^{\mu u_{gc}^j}\right]} \times Q_g \tag{3}$$

$$i = 1,2,\dots,M; \forall j \neq i; k = 1,2,\dots,K_i; k' = 1,2,\dots,K_j$$

According to the third assumption, there are different market segments with different customers with various degree of price-sensitivity. It is suggested to use a set of proper utility functions which appropriately represent these preferences (Çanakoğlu and Özekici, 2010, Bulmuş and Özekici, 2012). According to the customers' behaviors in each market segment, the proposed utility function is modified as given in (4):

$$U(x) = K \exp\left(\frac{-x}{\beta}\right) + C \tag{4}$$

In which x is the independent variable (price), K and C are the parameters of the function which are determined a priory. Note that parameter β determines the degree of sensitivity which varies according to the customers' reactions towards products' price in each market segment. In fact, parameter β determines the shape of the function and its curvature. As the value of β increases, the degree of sensitivity decreases. Figure 1 illustrates how β variation impacts the shape of price utility function.

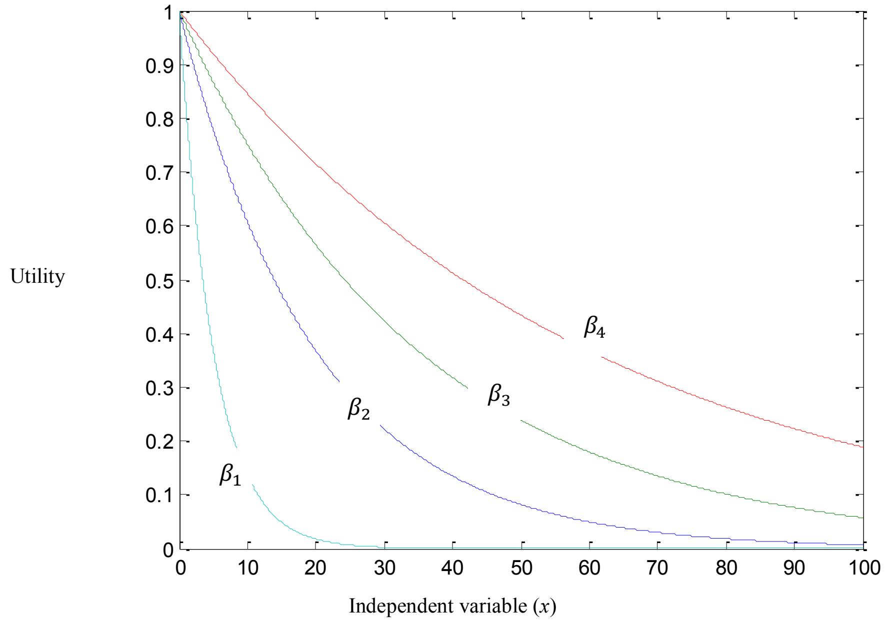

Fig. 1. Utility Function ($\beta_1 < \beta_2 < \beta_3 < \beta_4$)

Step 2: Best response specification

For each portfolio of manufacturer i (i=1,2,…,M), the value of the $f_i(z_k^i, z_{k'}^j)$, is calculated and placed in the following structure displayed in (5):

$$F_i = \begin{array}{ccccc} & \alpha_{j1} & \alpha_{j2} & & \alpha_{jk'} \\ & z_1^j & z_2^j & \cdots & z_{k'}^j \\ z_1^i & f_i(z_1^i, z_1^j) & f_i(z_1^i, z_2^j) & \cdots & f_i(z_1^i, z_{k'}^j) \\ z_2^i & f_i(z_2^i, z_1^j) & f_i(z_2^i, z_2^j) & \cdots & f_i(z_2^1, z_{k'}^j) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ z_k^i & f_i(z_k^i, z_1^j) & f_i(z_k^i, z_2^j) & \cdots & f_i(z_k^i, z_{k'}^j) \end{array} \qquad (5)$$

Each column of (5) shows the possible scenarios of the competitors and the best portfolio of the manufacturer $i$is selected regarding the calculated payoffs. For instance, if kth scenario occurs, what is the best product portfolio for manufacturer i? Obviously, the largest value in each scenario (column) is assumed as the best selection for manufacturer i.

Step 3:Calculating the regret index for all alternatives

In this step, a novel index is proposed to reduce the manufacturer i's regret of his portfolio selection. Manufacturer i will choose the best option that has the least expected loss and is the most reliable choice among all of the present alternatives. Therefore, the proposed regret index for each of the product portfolios is separately calculated and then the final decision will be made. In other words, the expected regret of each portfolio is first calculated based on all the other competitors' actions (scenarios). The proposed regret index is defined in (6):

$$R_{z_k^i} = \sum_{j \neq i} \sum_{k'=1}^{K_j} \alpha_{jk'} \left[f_i\left(z_k^i, z_{k'}^j\right) - P_{jk'}^* \right] \qquad (6)$$

$$i, j = 1,2,\ldots,M; \forall j \neq i; k = 1,2,\ldots,K_i; k' = 1,2,\ldots,K_j$$

Step 4: Choosing the portfolio with least regret value

The proposed index considers all possible scenarios and tries to involve each probable aspect of market, the customers' behaviors and preferences. The best portfolio for the manufacturer i will be finally selected based on expression given in (7):

$$Z_i^* = \left\{ z_k^i \,\middle|\, k = \arg Min\left(\left| R_{Z_k^i} \right| \right) \right\} \qquad (7)$$

Figure 2 briefly illustrates the proposed approach of the paper.

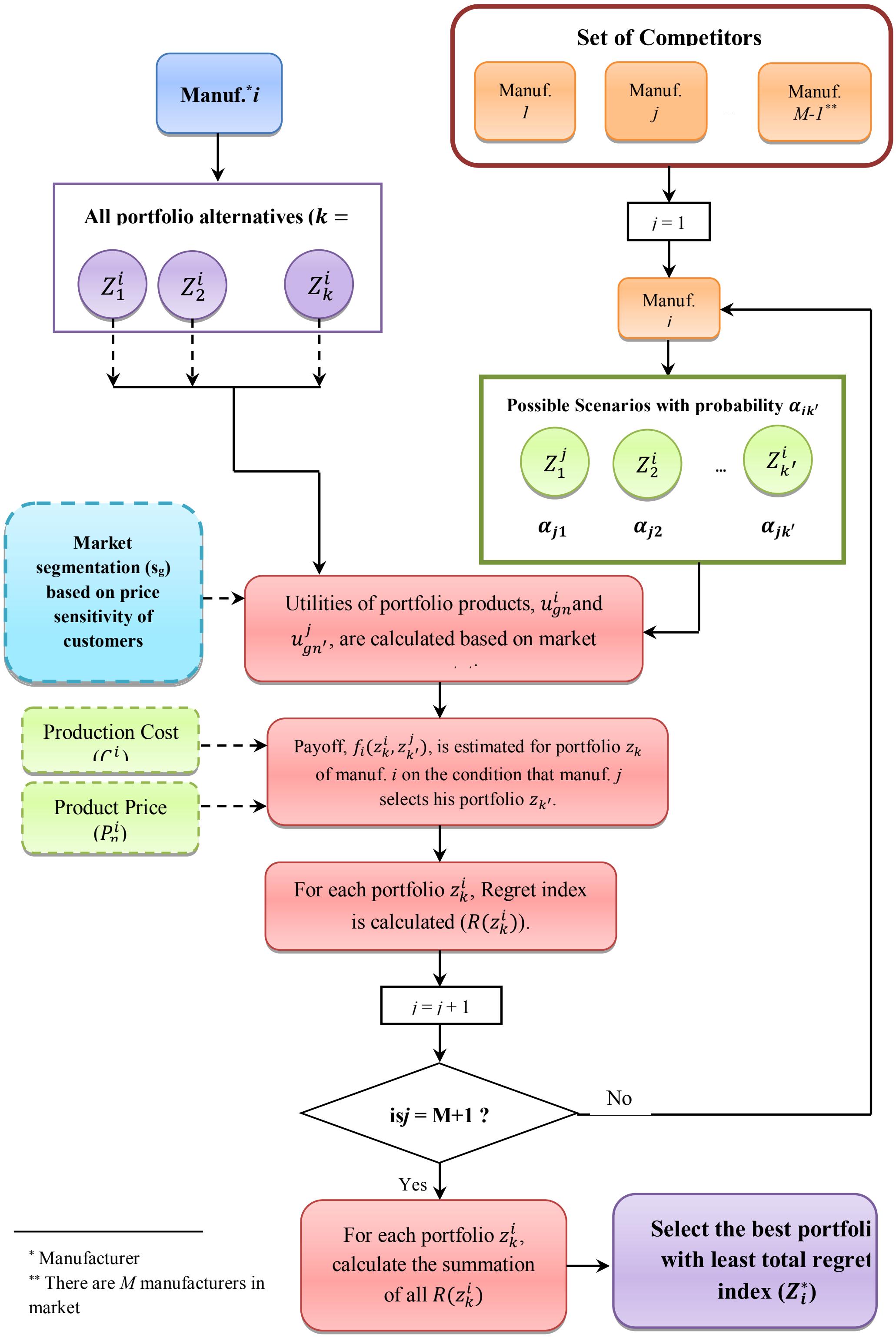

Fig . 2. The graphical abstract of the proposed approach

4. Numerical Example

In this section, a numerical example is presented to better understand the proposed approach. Suppose there are three market segments in which the customers' sensitivity towards product price are different and there exists different customers who have various reactions towards changes in product prices.One group may not care (low price-sensitive), one group may avoid that product and switch to a similar product with lower price (high price-sensitive). The latter customer results in losing the benefits and market share. The third group stands in between with a more balanced reaction towards price fluctuations (medium price-sensitive). The size of each market segment (Q_1, Q_2 and Q_3) is assumed to be 30, 45 and 25. For each segment, three different utility functions are modified which have their own specific parameters. Parameter β in the proposed utility function defines the function shape based on each market segment with various customer price sensitivities. Therefore, three levels for β are considered as 10, 30 and 60 and the parameters C and K are assumed 0 and 1, respectively. The relative utility functions are illustrated in Figure 3.

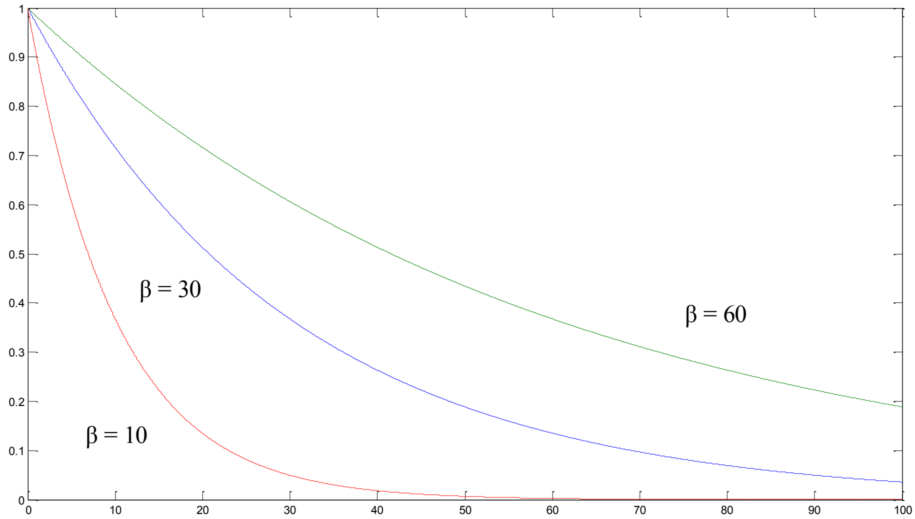

Fig. 3. Utility functions for price-sensitivity in different market segments

In the example, the best portfolio for manufacturer 1 (M=2,i=1, j=2) only have one competitor in market. Each manufacturer produces three kinds of products ($N_{i,j} = 3$). As a result, there are 7 possible portfolios for each manufacturer. The scaling parameter (μ) is assumed0.7 andfurther information is given in Table 3. The proposed procedure shows how the best product portfolio of the manufacturer regarding to the scenario probabilities will be determined.

Table 4 shows the obtained payoff for manufacturer 1 by using equation (3).

Table 3
Cost, price and utility data for manufacturer's products

	Products	Cost	Price (Pr_n^i)	Utilities in each market segment		
	(p_k^i)	(C_n^i)		**S₁ (β = 10)**	**S₂ (β = 30)**	**S₃ (β = 60)**
Manufacturer 1	(p_1^1)	32	54	1.0032	1.1227	1.3293
	(p_2^1)	20	41	1.0113	1.1968	1.4256
	(p_3^1)	52	79	1.0002	1.0518	1.2079
	($p_{k'}^j$)	(C_n^j)	(Pr_n^j)	**S₁ (β = 10)**	**S₂ (β = 30)**	**S₃ (β = 60)**
Manufacturer 2	(p_1^2)	49	67	1.0008	1.0782	1.2595
	(p_2^2)	42	69	1.0007	1.0727	1.2481
	(p_3^2)	18	38	1.0158	1.2197	1.4518

Table 4
Portfolio payoff calculations for manufacturer 1

		Z_1^2	Z_2^2	Z_3^2	Z_4^2	Z_5^2	Z_6^2	Z_7^2
		$\{P_1^2\}$	$\{P_2^2\}$	$\{P_3^2\}$	$\{P_1^2, P_2^2\}$	$\{P_1^2, P_3^2\}$	$\{P_2^2, P_3^2\}$	$\{P_1^2, P_2^2, P_3^2\}$
		(0.14)	(0.25)	(0.17)	(0.12)	(0.1)	(0.15)	(0.07)
Z_1^1	$\{P_1^1\}$	0.2786	0.2848	0.2653	0.1132	0.1079	0.1082	0.0823
Z_2^1	$\{P_2^1\}$	**0.6521**	0.5189	0.4847	0.4441	0.4240	0.4250	0.3250
Z_3^1	$\{P_3^1\}$	0.0951	0.0955	0.0886	0.0627	0.0596	0.0597	0.0452
Z_4^1	$\{P_1^1, P_2^1\}$	0.6197	**0.6212**	**0.5934**	0.4718	**0.4557**	**0.4560**	**0.3722**
Z_5^1	$\{P_1^1, P_3^1\}$	0.2542	0.2550	0.2423	0.2656	0.1845	0.1847	0.1860
Z_6^1	$\{P_2^1, P_3^1\}$	0.5030	0.5114	0.4880	**0.4788**	0.3682	0.3731	0.3021
Z_7^1	$\{P_1^1, P_2^1, P_3^1\}$	0.4672	0.4700	0.4504	0.3774	0.3667	0.3674	0.3088

In the next step, the regret index is obtained for each manufacturer 1's portfolios using (6). First, the best portfolio for manufacturer 1 in each scenario is determined and marked as a bold value. For instance, if manufacturer 2 launches his first product portfolio (scenario Z_1^2 occurs), then the best selection for manufacturer 1 is z_2^1 which has the largest payoff in column one. $z_2^1$is marked as P_{21}^* (the bold number in each column). Based on the defined scenarios for manufacturer 2 and their related probabilities, the regret index for manufacturer 1's first portfolio,Z_1^1, is obtained as below:

$$\mathrm{R}_{z_1^1} = 0.14 \times (0.2786 - 0.6521) + 0.25 \times (0.2848 - 0.6212) + \cdots + 0.07 \times (0.0823 - 0.3772) = -0.3432$$

For other manufacturer 1's portfolios, the regret index is calculated as shown in Table 5

.

Table 5
Regret index calculations

Portfolio	Z_1^1	Z_2^1	Z_3^1	Z_4^1	Z_5^1	Z_6^1	Z_7^1
Regret value	-0.3432	-0.0593	-0.4670	-0.0053	-0.3133	-0.0923	-0.1267

Based on (7), the largest value in Table 4, belongs to Z_4^1 which contains products $\{P_1^1, P_2^1\}$. Note that the best portfolio is the one with smallest value regardless to the negative sign (smallest absolute value). As much as the index is close to zero, the portfolio is more appropriate and beneficial. On the other hand, the third portfolio,Z_3^1, is expected to be the most risky choice among all of the portfolios in hand.

Based on Table (3) It is interesting to note that the value of selected portfolio, Z_4^1, is bolded in all scenarios except the first and forth one with a trivial difference. In fact, the proposed regret index is rather tries to find the most reliable product portfolio among all alternatives which has almost the maximum payoff for the manufacturer in all possible scenarios. Moreover, the selected products have the highest utilities in all market segments. Moreover, though the third product (p_3^1)has the highest benefit among all, but it is not selected in the final portfolio. The reason is that this product is not preferred by customers as much as the other two products. In this case, by producing the first and second products, the benefits and customer satisfactions can be simultaneously taken into account.

5. Conclusions

In an uncertain environment, selecting the most appropriate products with maximum compliance with customer preferences is one of the most challenging problems in product portfolio management (PPM) area. In this paper, a novel approach in PPM is proposed regarding production costs, customers' degree of price-sensitivity and uncertainty of the other existing competitors' product portfolio. The customers' sensitivity towards product price are considered in three categories as low, medium and high, and they are modeled by means of modified utility functions in each market segment. A novel regret index is also proposed which calculates the probable loss of each possible portfolio and suggests the best portfolio with least expected loss. The final results show that the proposed approach finds the most reliable product portfolio among all alternatives with almost the maximum payoff for the manufacturer and highest customer satisfaction in all possible scenarios.

For future directions, there are many scopes in extending the present work. For instance, it is suggested to consider uncertainties in product price, manufacturing costs, the customer utilities and behaviors in different market segments as random or even fuzzy parameters. In other words, the customers' utilities can be considered as qualitative parameters and by means of fuzzy logic, such qualitative parameters can be quantified and applied in the model.

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