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THE USE OF MATHEMATICAL METHODS FOR DECISION MAKING IN OPTIMAL PRICING STRATEGY FOR ENTERPRISES

Problem Statement. At the present stage of transformation of economic system of Ukraine the pricing policy of the company plays an important role in maintaining the required level of the enterprise competitiveness. Increased competition and lowering solvency of the population is forcing companies – manufacturers to make more and more concessions to consumers and middlemen in marketing with the help of the pricing policy. In addition, the objective factor of increasingly important role of pricing policy is that the advertising efficiency goes down because of the rising costs of advertising and tightness in the media. Therefore, a growing number of companies resort to the effective pricing policy, as a means which can effectively support the company's competitiveness.

Analysis of Researches and Publications. Sufficient attention is given to the problem of pricing (I.D. Paderin, G.Yu. Kramarenko, V.I. Yanchuk, G.V. Yanchuk, L.A. Shkvarchuk et al.). Classical methods of pricing (cost and market) are often used in practice. Pricing methods and models develop, modify and adapt according to conditions the price is formed in. The variability of the external operating environments (political and economic) determines the topicality of choosing the optimal pricing strategy under uncertainty and risk.

The objective of the study is to develop a model of the optimal pricing strategy for industrial enterprise in the conditions of uncertainty and risk.

Presentation of the Main Material. The company may form a numerous. possible pricing strategies, such as:

– Strategy 1 – the formation of prices with cost method, taking into account 20% of the profits;

– Strategy 2 – the formation of prices with cost method, taking into account 0% of the profits;

– Strategy 3 – the formation of prices in order to accumulate their own funds.

The choice of the company will depend on the projected sales volume for the next period and the company's management attitude to the economic risk.

According to [1-2] Gross profit PV can be defined as the difference between revenues *B* and expenses *Z*. We assume that:

$$B = \sum_{r=0}^{m} X_{n-r} \cdot a_r \cdot P^{(1)}; \quad (1)$$

$$Z = X_n \cdot U_n + Z_n, \quad (2)$$

where Z_n – the fixed costs of production; U_n – variable cost for one unit; X_n – the number ofunits produced in the *n*-th period;

$$PV = B - Z = \sum_{r=0}^{m} X_{n-r} \cdot a_r \cdot P^{(1)} - \left[X_n \cdot U_n + Z_n \right], \quad (3)$$

where $P^{(1)}$ – the price of one item.

Profit Index p is determined by the ratio of the profit PV to the cost *C*:

$$p = \frac{PV}{C} = \frac{B - Z}{Z} = \frac{B}{Z} - 1 = \frac{\sum_{r=0}^{m} X_{n-r} \cdot a_r \cdot P^{(1)}}{X_n \cdot U_n + Z_n} - 1. \quad (4)$$

At the profit of zero in the period $n = 0$ the price *U* (1) is determined this way:

$$P_0^{(1)} = \frac{X_n \cdot U_n + Z_n}{\sum_{r=0}^{m} X_{n-r} \cdot a_r}. \quad (5)$$

When $X_{n-r} = const = X_n$, $P_0^{(1)} = U_n + \frac{Z_n}{X_n}$.

When $p \neq 0$ the expression for the price *C* (1) takes the form:

$$P^{(1)} = \frac{(1+p) \cdot \left[X_n \cdot U_n + Z_n \right]}{\sum_{r=0}^{m} X_{n-r} \cdot a_r}. \quad (6)$$

When $X_{n-r} = const = X_n$, $P^{(1)} = (1+p) \cdot \left[U_n + \frac{Z_n}{X_n} \right]$.

Relation (7) and (8) are used to determine p and *C* (1), providing the enterprise accumulation of new own funds for the period n at the expense of the profit, and take into account the rate β_{np} of income tax:

$$P^{(1)} = \frac{X_n \cdot U_n + Z_n + C_n / (1-\beta_{np})}{\sum_{r=0}^{m} X_{n-r} \cdot a_r}; \quad (7)$$

$$p = \frac{\left[X_n \cdot U_n + Z_n + C_n / (1-\beta_{np})\right]}{X_n \cdot U_n + Z_n} - 1. \quad (8)$$

To determine the minimum level of retail and wholesale prices, on the basis of the method used for pricing at the enterprise, the ration is used (for a cost-based method for setting the price):

$$P_p^{(1)} = \left(Z_{np} + Z_{накл}\right) \cdot 1,2, \quad (9)$$

where $P_r^{(1)}$ – the minimum retail price of one item, UAH; Z_{dc} – the direct costs of one item, UAH; Z_{overh} – the overhead costs of one item, UAH:

$$Z_{dc} = \frac{(Z_{sal\_b} + O_{ded\_Z_{sal}})}{1000} + \frac{S}{V}, \quad (10)$$

where Z_{sal_b} – basic salary at the rate of 1000 units, UAH$ O_{ded_sal} – deductions from the basic salary, UAH; S – the cost of materials for the production of a given output, UAH; V – the volume of production of one kind, items.

$$S = \sum_{i=1}^{k} S_i = \sum_{i=1}^{k} \left(\frac{V \cdot N_i}{1000} \cdot P_i \right), \quad (11)$$

where S_i – the cost of i-th kind of materials, UAH; k – the number of kinds of materials; N_i – the consumption rate of i- th kind of material for 1000 units, units; P_i – the cost of i-th kind of material, UAH.

Overhead costs are determined by the formula:

$$Z_{overh} = \frac{Z_{overh\_dir} + Z_{ad\min} + Z_{market}}{1000}, \quad (12)$$

where Z_{overh_dir} – direct overhead costs are determined as the percentage of the basic salary, UAH; $Z_{ad\min}$ – administrative costs, determined as a percentage of the basic salary, UAH; Z_{market} – marketing costs, determined as a percentage of the basic salary, UAH.

Minimum wholesale price is set at the level:

$$P_{opt}^{(1)} = \left(Z_{dc} + 0,3 \cdot Z_{overh}\right) \cdot 1,2, \quad (13)$$

where $P_{opt}^{(1)}$ – minimum wholesale price of one unit, UAH.

It was noted earlier that the choice of pricing strategy depends on the strategic objectives of the enterprise and the fact, what management's expectations on the level of demand will be. This situation can be represented as a statistical game where players on the one hand are the company's management, and on the other hand – the level of demand (the planned volume of sales) for the company's products.

The level of demand is characterized as possible states of the economic environment. The strategies are considered as the possibility of setting the price at the level of 20%, 0% and 40%, respectively. Then, it is advisable to use the gross profit from sales of products as the elements of the payment matrix, the matrix of the game, taking into account the risk of receiving less profit and the storage costs of the product, provided that it will not be marketed during the year.

The elements of the payment matrix a_{ij} will be determined by the formula:

$$a_{ij} = P_{ij} - Z_{ij} = d_j \cdot \sum_{l=1}^{L} P_{li}^{(1)} \cdot V_l - (R_i + Z\_h_i) \cdot (1-d_j) \cdot \sum_{l=1}^{L} P_{li}^{(1)} \cdot V_l, \quad (14)$$

where P_{ij} – the gross income from sales, UAH; Z_{ij} – the expenditures, related with the risk of receiving less profit, and the storage costs of the unsold products, UAH; d_j – demand for products with j - th state of the economic environment, the share; $P_{li}^{(1)}$ – The price of unit of products of l - th kind and i - th strategy, UAH; V_l – planned annual sales volume of products of l-th kind, units.; L – the total number of kinds of products of enterprise; R_i – the risk of receiving less profit, share; Z_h_i – the share of the storage costs of unsold goods during the year, share.

The storage costs of the unsold products are assumed to be 27% of the total cost of unsold products.

Under the risk of receiving less profit we mean insurance of working capital in order to ensure the efficient organization of the production process.

Initial data for the determination of the payment matrix are represented in the table 1.

The criteria for selection of the optimal pricing strategy of the enterprise are:

– Bayes criterion, providing an alternative choice, taking into account the unequal probability of economic environment states and expressing a choice of optimistic point of view;

– Laplace criterion that characterizes alternatives from the standpoint of average gain;

– Wald criterion, which gives an idea about the best alternative in extreme conditions.

Bayes criterion for a positive evaluation of the functional $F = F^+$:

$$s_{i_0} : B^+(s_{i_0}; P) = \max_{s_i \in S} B^+(s_i; P) \quad (15)$$

Table 1

Initial data

Strategy	The volume of selling 100%		The volume of selling 75%		The volume of selling 50%		The volume of selling 20%	
	R_i	Z_h_i	R_i	Z_h_i	R_i	Z_h_i	R_i	Z_h_i
Strategy 1 (profit 20%)	0,10	0,20	0,10	0,20	0,10	0,20	0,10	0,20
Strategy 2 (profit 0%)	0,05	0,20	0,05	0,20	0,05	0,20	0,05	0,20
Strategy 3 (profit 40%)	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
Probability of demand (variant 1)	0,10		0,45		0,35		0,10	
Probability of demand (variant 2)	0,25		0,25		0,25		0,25	

where $B^+(s_i;P)=\sum_{j=1}^{n} p_j a_{ij}^+$ – Bayesian estimation of solutions (strategies) s_i $(i=1..m)$;

p_j – probability of j - th state of the economic environment;

$S=(s_1,...,s_m)$ – a set of possible strategies.

Laplace criterion differs from the Bayes criterion in probability vector only:

$$p_j \approx \hat{p}_j = \frac{1}{n}, j=1..n. \quad (16)$$

Wald criterion defines the optimal strategy in the worst conditions:

$$s_{i_0} : a_{i_0}^+ = \max_{s_i \in S} a_i^+ = \max_{s_i \in S} \min_{\theta_j \in \Theta} a_{ij}^+, \quad (17)$$

where $\theta_j \in \Theta (j=\overline{1..n})$ – a set of states of the economic environment.

Payment matrix and results of selection of alternatives are shown in table 2.

Table 2

Selection of the optimal pricing strategy

	The volume of selling 100%	The volume of selling 75%	The volume of selling 50%	The volume of selling 20%	Average income (B)	Average income (L)	Minimum income (B)
Strategy 1 (profit 20%)	399439,26	269621,50	139803,74	-15977,57	208607,15	198221,73	-15977,57
Strategy 2 (profit 0%)	335458,39	230627,64	125796,90	0,00	181357,19	172970,73	0,00
Strategy 3 (profit 40%)	469641,75	293526,09	117410,44	-93928,35	210751,73	196662,48	-93928,35
The probabilities of the states of the economic environment (Bayes criterion)	0,1	0,45	0,35	0,10	–	–	–
The probabilities of the states of the economic environment (Laplace criterion)	0,25	0,25	0,25	0,25	–	–	–

According to the criterion of Bayes the optimal strategy of pricing is that one, that takes into account 40% of the profit. In monetary terms the profit will be:

$$s_{i_0} : \max_{s_i \in S}(208607,15;\ 181357,19;\ 210751,73) = 210751,73 \text{ UAH.}$$

By the criterion of Laplace the optimal strategy of pricing is the strategy, that takes into account 20% of the profit. In monetary terms the profit makes up:

$$s_{i_0} : \max_{s_i \in S}(198221,73;\ 172970,73;\ 196662,48) = 198221,73 \text{ . UAH}$$

By the criterion of Wald the optimal strategy of pricing is the strategy, that takes into account 0% of the profit. In monetary terms the profit makes up:

$$s_{i_0} : \max_{s_i \in S} \min_{\theta_j \in \Theta}(-15977,57;\ 0;\ -93928,35) = 0 \text{ UAH.}$$

Conclusions. Selection of the optimal strategy depends on the projected volume of selling for the next period and the company's management attitude to the economic risk.

The proposed mathematical model of pricing based on different rates of profit and seasonality described by varying the volume of sales, in different conditions of the economic environment, will make it possible to design different pricing scenarios, allowing to increase the efficiency of the price policy of the enterprise.

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Шевченко Н. Ю., Гудкова К. Ю. Використання математичних методів прийняття рішень при формуванні оптимальної цінової стратегії підприємства

Відмічено, що розвиток, модифікація і адаптація методів і моделей ціноутворення відбувається з урахуванням умов, в яких формується ціна. Зазначено, що мінливість зовнішніх умов функціонування підприємств (політичних і економічних) визначає актуальність питання вибору оптимальної цінової стратегії в умовах невизначеності і ризику. Поставлено завдання розробки моделі формування оптимальної цінової стратегії виробничого підприємства в умовах невизначеності і ризику із сформованої множини стратегій. Наголошено, що вибір підприємства залежатиме від прогнозованого об'єму реалізації на майбутній період і відношення керівництва підприємства до економічного ризику. Вказана ситуація представлена у вигляді статистичної гри, де гравцями виступають з одного боку керівництво підприємства, а з іншого – рівень попиту (планований об'єм реалізації) на продукцію підприємства. Вибір оптимальної стратегії пропонується здійснювати за допомогою критеріїв прийняття рішень: Байєса, Вальда і Лапласа.

Ключові слова: цінова стратегія, моделювання, ризик, прибуток, статистична гра, критерії прийняття рішень.

Шевченко Н. Ю., Гудкова К. Ю. Использование математических методов принятия решений при формировании оптимальной ценовой стратегии предприятия

Отмечено, что развитие, модификация и адаптация методов и моделей ценообразования происходит с учетом условий, в которых формируется цена. Указано, что изменчивость внешних условий функционирования предприятий (политических и экономических) определяет актуальность вопроса выбора оптимальной ценовой стратегии в условиях неопределенности и риска. Поставлена задача разработки модели формирования оптимальной ценовой стратегии производственного предприятия в условиях неопределенности и риска из сформированного множества стратегий. Отмечено, что выбор предприятия будет зависеть от прогнозируемого объема реализации на будущий период и от отношения руководства предприятия к экономическому риску. Указанная ситуация представлена в виде статистической игры, где игроками выступают с одной стороны руководство предприятия, а с другой – уровень спроса (планируемый объем реализации) на продукцию предприятия. Выбор оптимальной стратегии предлагается осуществлять с помощью критериев принятия решений: Байеса, Вальда и Лапласа.

Ключевые слова: ценовая стратегия, моделирование, риск, прибыль, статистическая игра, критерии принятия решений.

Shevchenko N., Gudkova E. The use of mathematical methods for decision making in optimal pricing strategy for enterprises

It is noted that the development, modification and adaptation of methods and pricing models takes place according to the conditions in which the price is formed. It is indicated that the variability of the external conditions of functioning of enterprises (political and economic) determines the relevance of the issue of choosing the optimal pricing strategy under uncertainty and risk. The task of developing a model of the optimal pricing strategy of industrial enterprise in the conditions of uncertainty and risk of the generated sets of strategies. It is indicated that the choice of the enterprise will depend on the projected sales volume for the next period and the ratio of the company's management to the economic risk. This situation is presented in the form of a statistical game where players act on the one hand the company's management, and on the other - the level of demand (the planned volume of sales) in the company's products. Choosing the optimal strategy is proposed to carry out with the help of decision criteria: Bayes, Wald and Laplace.

Keywords: pricing strategy, modeling, risk, profit, statistical game, the criteria for decision-making.

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