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THE OPTIMAL PRICING STRATEGY OF THE NOVELTY PRODUCT DETERMINED BY FUNCTION OF PRICE ELASTICITY OF DEMAND

The article considers approaches to determining the price elasticity of demand as a regression model of price dependence, and also the risks in pricing based on the models obtained. The process of obtaining price elasticity of demand as a regression model of price dependence is proposed to be performed in two stages. At the first stage, based on empirical information on prices for innovative products and sales volumes, models of demand-price dependency are obtained. At the second stage, based on the definition of elasticity by the methods of limit analysis, regression models are obtained for the price elasticity of demand versus price. The application of the proposed methodology is demonstrated in determining the optimal price for Smart House systems for an enterprise that plans to enter with them to the market of the city Odessa.

Keywords: regression dependence of demand on prices, models of price elasticity of demand versus price, risk assessment in pricing, optimal price for innovative products, marginal analysis in pricing.

Statement of the problem. Price elasticity of demand for goods and services is the foundation of modern pricing policy of the enterprise. It is especially important to determine the price elasticity of demand indicator when marketing high-tech innovative products. This is due to the fact that the demand for high-tech innovative products depends on many factors: forward, on the degree of novelty of products and availability of analogues in the market, as well as on the novelty's ability to satisfy consumer needs, from communication activities to promote products, from measures to stimulate sales and the like. All this set of factors determines the «recall» of the market in the form of demand for goods at a price that the seller determines.

Entering the market with new, especially high-tech product requires the company to carefully approach the assessment of possible risks in pricing. They can be evaluated by the reaction of customers in pilot surveys or observations, focus groups or personal interviews. It is also important to have the statistical evaluation tool of relation between sales volume and prices, price elasticity of demand and prices and the ability to determine the risks of increase or decrease in prices in a particular market situation.

Analysis of the recent research and publications. Modern scientific work considering the evaluation and application of price elasticity of demand index can be characterized by the certain range of positions and approaches. The authors` positions on the use of price elasticity of demand index in practice are diametrically opposite. They can be divided into two groups: the first is inclined to the idea of absolute unreasonableness of practical application of price elasticity of demand index and its purely theoretical perception [1]; the second group, on the contrary, convincing on the importance of practical use of price elasticity of demand index. Approaches to determine the coefficient of price elasticity also vary from verbal definition to the use of complex mathematical calculations [2–4].

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Ukrainian researchers use price elasticity of demand in the market research of different groups of products, as well as in making management decisions [5–10]. Price elasticity of demand in applied research is widely used by scientists from the United States [11–16]. Using price elasticity of demand index is relevant in the present studies of aggregate demand for certain groups of goods and services in the macroeconomic context.

Unsolved aspects of the problem. In our view, the price elasticity of demand index for high-tech innovation or novelty goods is not a constant as it is commonly interpreted in the classic sense. On the stage of goods entering the market and sales growth price elasticity of demand index will vary within certain boundaries. Its value and the corresponding market reaction are closely related to the current price. At the stage of maturity the market reaches saturation stage and the price elasticity of demand index undergoes much smaller fluctuations than in previous stages of the life cycle. When technical innovations from competitors or product obsolescence appear, that is the transition to the stage of decline then the price elasticity index once again demonstrates high volatility.

Statement of purpose. Метою статті є розроблення науково-методичних підходів до визначення цінової еластичності попиту як регресійної моделі залежності від ціни, розроблення інструментів оцінки ризиків ціноутворення за отриманими моделями, а також демонстрація застосування розробленої методики.

The main research. Assuming that the price elasticity of demand index is not constant and can be described by the certain model of depending on the price of goods or services then under these conditions we get the possibility to determine the period in which this rate varies, that can assess its probable value at certain prices and we are able to assess the risks of increase or decrease in prices that means determining the risks of their each possible level.

Suppose that there is some existing factual information on prices and related sales of novelty or new high-tech products for a short period of time. This may be pilot market research, trial sale and real or imitation experiment data. It is recommended to make the decision to adjust the prices depending on the type of relation between demand and prices. It is proposed to find this relationship by the regressive dependence of demand on the price.

Modelling price elasticity of demand and assessing the risks in pricing are conducted by the following stages:

a) obtaining a regression model of demand on the price dependence;

b) obtaining function of price elasticity of demand and risk assessment for her behavior.

Consider the situation where a manufacturer evaluates demand for innovative products according to sales. Such data may be obtained in the experimental sales of innovative products by the methods of test marketing or comparing sales and corresponding prices in the real conditions.

Stage 1. Regression model of demand on prices dependence is built from experimental data where the dependent variable is sales and independent or explanatory one is the price.

For approximation of experimental data standard regression models are commonly used: linear, hyperbolic and parabolic. It`s necessary to select the «best» among these models. In terms of statistics the «best» means the most accurate, reliable and adequate. The accuracy of the model is verified by the coefficient of determination R^2 and standard error of the model, the reliability is checked by Fisher F-criterion (the reliability of the overall model) and by Student t-criterion (the reliability coefficients), the adequacy of the model is verified by residues (for example, the autocorrelation coefficients residues).

The risks related to the qualifications of the researcher are possible at this stage. The first risk is connected with a sample that has to be representative, another one can occur due to the selection of model from experimental data. These risks are not subject to quantity assessment but have an impact on further research.

Stage 2. Getting the function of the price elasticity of demand and assessing risks of price changes depending on the graphics functions. Price elasticity of demand in terms of mathematical analysis is determined by the following formula [15]:

$$E_p(Q) = \frac{P}{Q(P)} Q^{/}(P),$$

where Q(P) is a known function of demand of some product;
P is the price of the product.

Certain basic models are used for regression models of the demand on price dependence. We find the price elasticity functions for linear, hyperbolic and parabolic patterns of demand and evaluate the risks of price changes for each of them. The term «function of price elasticity of demand» is introduced for convenience. It is clear that the relation between price elasticity of demand and price in all the following cases is not functional but regression. But the concept of «function of price elasticity of demand» allows using tools to research function at extremes for derived regression models.

a) Linear regression of demand on prices is: $\boldsymbol{Q = a_0 + a_1P}$. Its` derivative is: $\boldsymbol{Q^{/} = a_1}$.

The function of price elasticity of demand in this case is:

$$E_p(Q) = \frac{a_1P}{a_0 + a_1P}. \quad (1)$$

Fig. 1 graphs the function (1) modulo.

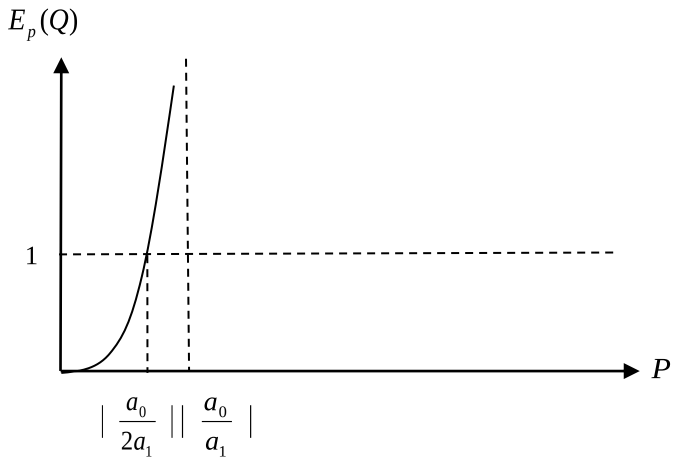

Figure 1 – The function of price elasticity of demand for the linear dependence of demand on price

Fig. 1 shows that the function of the price elasticity of demand for the linear model of dependence of the demand on price has a vertical asymptote, this point on the graph of demand on price corresponds to zero demand. That is when the demand that tends to zero the price elasticity index tends to infinity. At the point $\left|\frac{a_0}{2a_1}\right|$ graph of the elasticity function module

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intersects the line $E_p(Q)$ = 1 which corresponds to a single demand (the boundary between elastic and inelastic demand).

According to the graph of price elasticity of demand in the case of linear dependence of demand on price three risk pricing can be defined:

1) a low risk of price increases in the interval (0; $\left|\frac{a_0}{2a_1}\right|$); here price increase will lead to a slight decrease in sales, as demand for this range is inelastic (graph below single elasticity);

2) zero risk of decrease in the price is in the vicinity of the point $P = \left|\frac{a_0}{a_1}\right|$, price elasticity of demand index there tends to infinity, that is sales will grow at a much higher percentage than prices decrease;

3) in the interval ($\left|\frac{a_0}{2a_1}\right|$, $\left|\frac{a_0}{a_1}\right|$) the risk of prices decrease evenly reduced, i.e. with the greatest risk reduction in price in the right vicinity of the point $\left|\frac{a_0}{2a_1}\right|$ to zero in the left vicinity of the point $\left|\frac{a_0}{a_1}\right|$. In this interval the demand is elastic and price elasticity index increases as can be seen from the graph function.

b) Inverse or hyperbolic regression dependence of demand on prices is characterized by the equation $\mathbf{Q = a_0 + a_1 / P}$. Derivative function is $\mathbf{Q^{/} = -\frac{a_1}{p^2}}$. The function of price elasticity of demand for hyperbolic dependence of demand on prices has the form

$$E_p(Q) = \frac{P}{a_0 + a_1 / P} \times \left(-\frac{a_1}{P^2}\right) = -\frac{a_1}{a_0 P + a_1}\,. \qquad (2)$$

Investigating the behavior of function of price elasticity of demand of the price we conclude that the hyperbolic function always describes elastic demand. Minimum modulo value that is equal to 1, the function of price elasticity of demand reaches in the point P = 0, it will continue to increase with acceleration (Fig. 2).

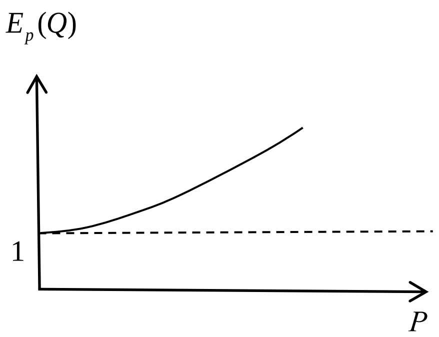


Figure 2 – The function of price elasticity of demand for hyperbolic (inverse) dependence of the demand on price

That is, when determining the first stage hyperbolic regressive dependence of the demand on price, elasticity index of price to any of the graphic point is more than one and the demand is elastic.

c) Parabolic (quadratic) regression model of the dependence of demand on price is: $Q = a_0 + a_1 P^2$. Derivative of the parabolic function is: $Q^{/} = 2a_1 P$. The function of the price elasticity of demand

$$E_p(Q) = \frac{2a_1P^2}{a_0 + a_1P^2}\ . \qquad (3)$$

Graph of the module of obtained function of elasticity of demand (Fig. 3) shows two intervals with different pricing risks:

– Low risk of price increase in the interval (0, $\sqrt{-\frac{a_0}{3a_1}}$). This follows from the fact that the demand function is inelastic there. Graph of the function is below the line with single elasticity.

– Low risk of price decrease in the interval ($\sqrt{-\frac{a_0}{3a_1}}$, $\sqrt{-\frac{a_0}{2a_1}}$). Price elasticity index increases from one to two here, characterizing elastic demand.

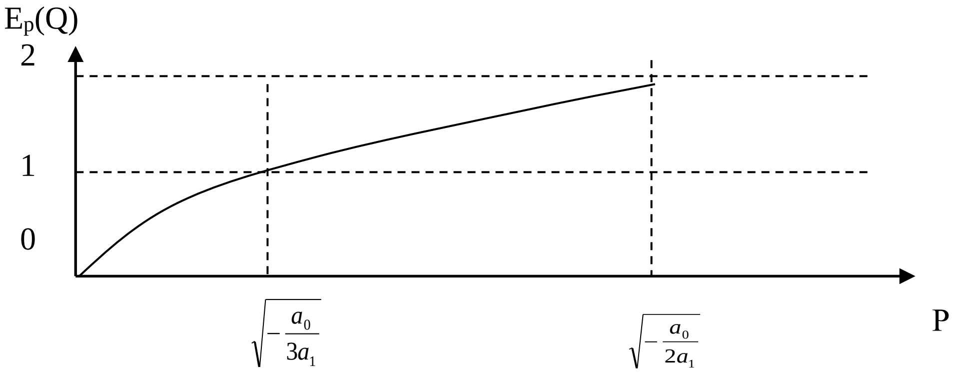


Figure 3 – The function of price elasticity of demand for parabolic (quadratic) model of the dependence of demand on price

Summarizing the proposed modeling of the price elasticity of demand and the risk assessment in pricing, we obtain Table 1.

Table 1 – Types of dependence of demand on price and the respective functions of price elasticity of demand and prices

Stage	Index	The linear dependence of demand on prices	Hyperbolic dependence of demand on prices	Parabolic dependence of demand on prices
1	Dependence model	$Q = a_0 + a_1P$	$Q = a_0 + a_1/P$	$Q = a_0 + a_1 P^2$
2	Regression model of price elasticity of demand, $E_p(Q)$	$E_p(Q) = \frac{a_1P}{a_0 + a_1P}$	$E_p(Q) = -\frac{a_1}{a_0P + a_1}$	$E_p(Q) = \frac{2a_1P^2}{a_0 + a_1P^2}$

Consider the application of the above methodology on the example of the Odessa enterprise, which plans to enter the market of the city of Odessa using intelligent management technology «Smart House». In Europe, the «Smart Home» system has long been an everyday reality. Its acquisition is considered a profitable investment. According to this technology, the consumer receives:

– reduction of operating costs – 30%;
– reduction of payments for electricity – 30%;
– reduction of payments for water – 41%;
– reduction of payments for heat – 50%;
– Reduction of CO2 emissions – 30%.

The volume of the world market of intelligent systems for the house is growing every year. In 2013, it reached $ 25 billion. According to a new report from the company «Research and Markets», it is expected that the volume of the world market of smart house systems will overcome the mark of $ 60 billion until 2021. Intellectual systems «Smart House» in the market of Odessa are offered by several companies.

The company under consideration- at the expense of its own project capabilities has the advantages of creating a more accessible intellectual system and entering the market segments «high» and «high plus».

To determine the optimal price for products and the corresponding volumes of sales of Smart House systems, we will use the data on sales of Smart Home systems of the company's competitors and average prices for them in the market of Odessa in the segment house, cottage, country house (Table 2).

Table 2 – The prices for Smart House systems in 2016 and the corresponding sales volumes [according to the regional statistics committee]

	May	June	July	August	September	October	November	December	January
Sales volumes, seasonally adjusted, units	339	267	407	425	459	300	273	419	362
Seasonal indices	0,66	0,64	1,25	0,92	1,25	1,01	0,81	1,46	0,73
Sales volumes adjusted for the season, units	514	417	326	462	367	297	337	287	496
Price, USD	6190	6550	8711	7583	7993	7825	7350	8170	6228

To obtain adjusted for the season sales, we will use seasonal sales indexes. We divide the sales volumes, taking into account seasonality (real data) for seasonal indices, as a result we will receive sales volumes adjusted for the season (data for obtaining the demand curve).

According to Table. 2 we will construct a diagram of the dispersion of prices for the Smart House systems and the corresponding sales volumes adjusted for the season. The points on the diagram are rather cohesive, which gives grounds for obtaining a model that connects the demand with the price (fig. 4).

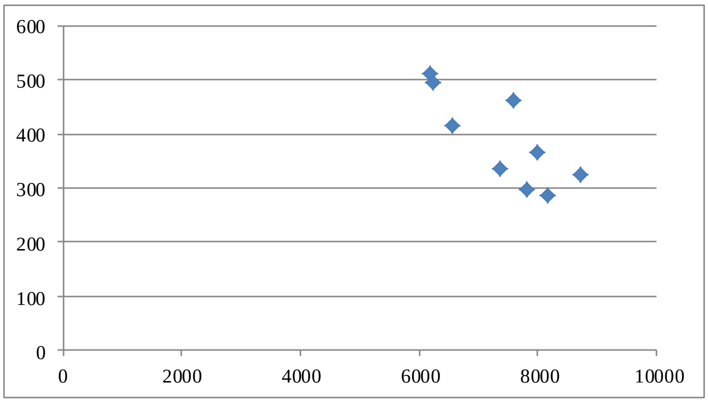
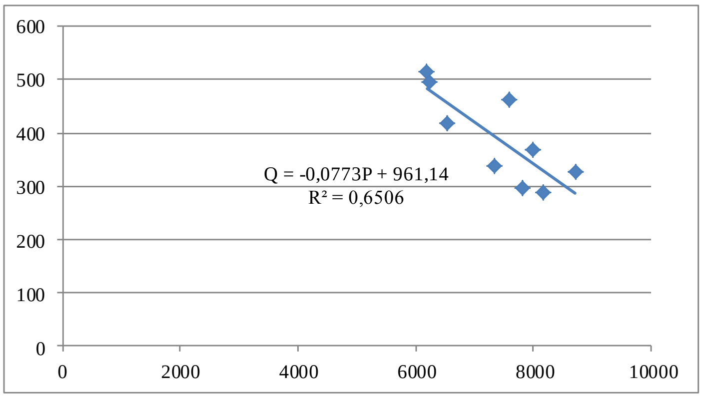


Figure 4 – Dependence of demand on the price of «Smart House» systems, X-axis – price (USD), Axis B – sales volumes adjusted for the season (units),

In Fig. 4 axis B – seasonal sales volumes (Q), X axis - price(P), this arrangement differs from the canonical one, but we consider the sales volume as a function of the price, so according to the mathematical point of view, such a schedule is correct.

Next, let's use the price optimization technique given above.

Stage 1. To approximate the experimental data, standard regression models are usually used: linear, hyperbolic and parabolic. For the example under consideration, these models are accurate enough – R^2 in all cases is greater than 0,6 (fig. 5).

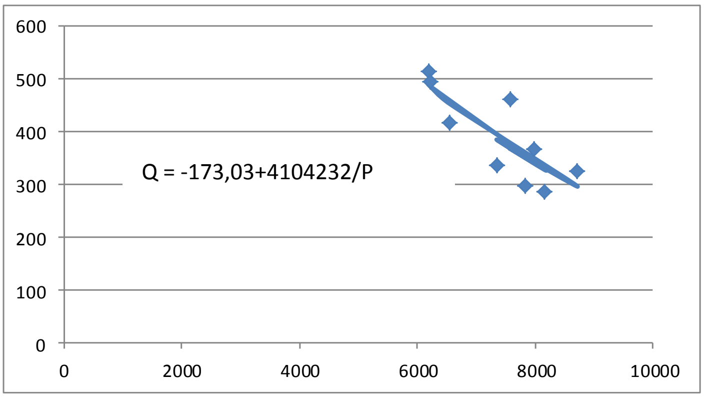


a) Linear regression model

a)The linear dependence of demand on prices

$$Q = a_0 + a_1 P.$$

The parameters of the linear model $a_0 > 0$, $a_1 < 0$ indicate that when the price decreases, the demand increases evenly (with the speed a_1).

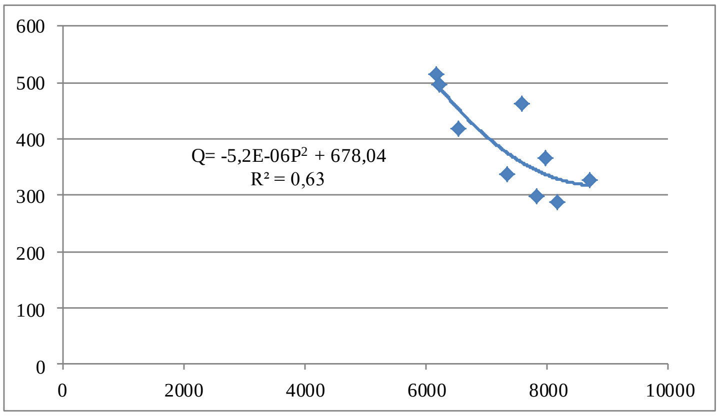


b) Hyperbolic (inverse) regression model

b) The inverse or hyperbolic dependence of demand on prices

$$Q = a_0 + a_1 / P$$

The hyperbola parameter a_1 is positive. The demand varies unevenly, at a rate of $- a_1 / P^2$.



c) Parabolic regression model

c) The parabolic (quadratic) dependence of demand on price

$$Q = a_0 + a_1 P^2.$$

In this case we obtain only one branch of the parabola-decreasing. Unlike the linear model, the increase in demand with a decrease in prices here is not uniform, but accelerated - with a speed $2a_1P$.

Figure 5 – Approximation of the experimental data of the regression model

Among these models, you must choose the «best». In terms of statistics, the «best» is the most accurate, reliable and adequate. The model is checked for accuracy using the coefficient of determination R^2 and the standard error of the model, the reliability by the за F-criterion of Fisher (for the reliability of the model as a whole) and by the Student's t--criterion (on the reliability of the model coefficients), the adequacy of the model is checked by residuals (for example , by the autocorrelation coefficients of the residues). All the models that were obtained in the first stage are accurate enough. The greatest value of R^2 has a parabolic trend, but this model is not reliable (Table 3).

Table 3 – Estimation of models of approximation of the demand curve of "Smart House" systems

models	equations	R^2	Evaluation of reliability	Assessment of adequacy
Linear	$Q = -0,0773P + 961,14$	0,65	The model as a whole and its coefficients are reliable	The model is adequate
Hyperbolic	$Q = -173,04 + 4104232/P$	0,67	The model as a whole and its coefficients are reliable	Модель адекватна
Parabolic	$Q = -5,2*10^{-6}P^2 + 678,04$	0,63	The model as a whole and its coefficients are reliable	Модель адекватна

The parabolic model turned out to be the least accurate. The most accurate is the hyperbolic model. To demonstrate the work on the second step, we will not exclude from consideration any of the models of Table. 3.

2 stage. Get the function of price elasticity of demand and assess the risks of price changes depending on the schedule of the function.

We will find the price elasticity functions for linear, hyperbolic and parabolic demand models and we will estimate the risks of price change for each of them first analytically, and then for the example in question. Price elasticity of demand from the price of «Smart House» systems for linear dependence is as follows:

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$$E_p(Q) = \frac{-0{,}077P}{961{,}14 - 0{,}077P}.$$

By substituting prices in the equation of price elasticity of demand, we find that the value of the function $E_p(Q)$ is smaller for lower prices, and larger ones for larger ones (Table 4).

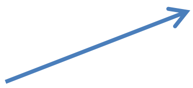
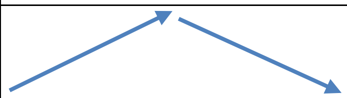
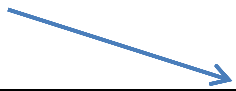
Table 4 – Price elasticity of demand for the linear demand-price model for the «Smart House» systems

P, USD	6190	6550	8711	7583	7993	7825	7350	8170	6228
$E_p(Q)$	0,98	1,10	2,31	1,55	1,78	1,68	1,43	1,89	1,00

Three risks in pricing with the linear dependence of demand on prices have such an interpretation:

1) low risk of price increase on the gap (0; 6241) USD ($\left|\frac{a_0}{2a_1}\right| = 6241$). At this interval, demand is inelastic and an increase in prices will lead to a slight decrease in sales (Table 5). If the manufacturer aims to increase profits from the sale of systems, that is, adheres to the «cream-skimming» strategy, then an increase in prices at this interval will slightly reduce sales volumes.

Table 5 – Price strategy with minimal risks for «Smart House» systems

	(0; 6241)	(6241; 12482)	(12482; ∞)
Price stratgy	price increase	– increase in price near the left border; – price reduction near the right border	Price reduction
Risk	minimal	– minimal in case of price reduction; – small case of its increase	minimal
Demand profile	inelastic	elastic $E_p(D)$ from 1 to ∞	elastic $E_p(D) \rightarrow \infty$
Price shedule			

2) Zero risk of price reduction in the vicinity of the point P = 12482 дол. ($\left|\frac{a_0}{a_1}\right| = 12482$). Here demand has an infinite elasticity and price reduction will lead to a significant increase in sales. Prices close to 12482 dollars in the experimental data was not. Such a result can be explained by the inaccuracy of the linear demand model.

3) In the interval (6241, 12482), the coefficient of price elasticity of demand varies from one to infinity. The risk of getting losses, reducing the price, the minimal at the right end of the interval. The risk of getting losses by increasing the price, the minimal at the left end of the interval. If the manufacturer adheres to the price strategy of seizing the market or penetrating the market, a decrease in prices in this interval will significantly increase sales.

б) The inverse or hyperbolic dependence of demand on prices. In our example, the function of price elasticity of demand for hyperbolic dependence has the form

$$E_p(Q) = \left| -\frac{4104232}{4104232 - 173{,}04P} \right|.$$

According to the example, considered for large prices, we get a greater coefficient of price elasticity of demand, for smaller ones – less (Table 6). To increase sales, prices should be reduced, especially this effect is noticeable for high prices: $ 8,711 and $ 8170.

Table 6 – Price elasticity of demand for the inverse dependence of demand on prices for «Smart House» systems

P, USD	6190	6550	8711	7583	7993	7825	7350	8170	6228
$E_p(Q)$	1,35	1,38	1,58	1,47	1,51	1,49	1,45	1,53	1,36

The risk of reducing the price and obtaining losses is minimal for the maximum prices for which the model of demand-price dependence is obtained.

c) Parabolic (quadratic) model. The function of price elasticity of demand for the parabolic dependence of demand on prices for the «Smart House» systems has the form

$$E_p(Q) = \frac{-10{,}4*10^{-6}P^2}{678{,}04 - 5{,}2*10^{-6}P^2}.$$

A low risk of an increase in the price in the gap (0, 6588) USD ($\sqrt{-\frac{a_0}{3a_1}}$ =6588). For the price values from this interval, the demand is inelastic and the price increase will lead to a slight decrease in sales. If the company follows the strategy of «cream-skimming» on this interval, the price should be increased. Low risk of price reduction on the gap (6588, 8068) USD ($\sqrt{-\frac{a_0}{3a_1}}$ = 8068). At this interval, the coefficient of price elasticity increases from one to two, that is, the demand is elastic in price. Therefore, the closer the price to the right end of the interval, the lower the risk of its decrease (Table 7). If the company complies with the strategy of seizing the market or entering the market, prices on this interval should be reduced to increase sales.

Table 7 – Price elasticity of demand for the parabolic dependence of demand on prices for «Smart House» systems

P, USD	6190	6550	8711	7583	7993	7825	7350	8170	6228
$E_p(Q)$	0,83	0,98	2,79	1,58	1,93	1,78	1,42	2,10	0,85

With the technique considered, which is demonstrated by the example of the dependence of demand on the price of «Smart House» systems, we see that according to the same data, several regression models of the dependence of demand on prices can be obtained. Three models were obtained: linear, hyperbolic and parabolic. The function of price elasticity of demand for these models can provide quite contradictory forecasts regarding the risks of raising or lowering the price. Thus, according to the linear dependence of demand on prices, a price gap was obtained with inelastic demand (0,6241) dollars, and for parabolic demand (0,6588) dollars. In hyperbolic dependence, elastic demand is everywhere.

All three variants of the demand-price relationship for the «Smart House» systems were considered for demonstrating the work on the proposed Pricing Risk Estimation Methodology for the regression dependence of demand on prices. Usually, at the first stage, you need to choose one - the best from the statistical point of view - the function for modeling the dependence of demand on prices and then get the function of price elasticity of demand and assess risks.

In this example, the most accurate, reliable and adequate hyperbolic model of the dependence of demand on prices, so we can assume that the demand for the Smart Home system is elastic.

Research conclusions and recommendations for further research. As a result of the research it is important to note that the approach based on the existence of functional dependence of price elasticity of demand for the price of high-tech and novelty products provides more opportunities for risk assessment in pricing when determining the regression dependence of demand on price. According to this approach: at first, regression dependence of the demand on price is determined using factual data of sample sale or sales data obtained by other methods of marketing research; secondly, for each model of dependence of demand on price function of price elasticity of demand is obtained, for which, using methods of mathematical analysis, intervals of high and low risk of variation of prices in one or another direction are determined.

The proposed modeling of price elasticity of demand and risk assessment in pricing allows companies with different pricing strategies, such as the strategy of «cream skimming» or market capturing strategy, to assess pricing risks.

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Оптимальна цінова стратегія товару-новинки за функцією цінової еластичності попиту

У статті розглянуто підходи до визначення цінової еластичності попиту як регресійної моделі залежності від ціни, а також визначено ризики у ціноутворенні за отриманими моделями. Процес отримання цінової еластичності попиту як регресійної моделі залежності від ціни запропоновано виконувати в два етапи. На першому етапі, ґрунтуючись на емпіричній інформації про ціни на інноваційну продукцію та обсяги її продажу, отримують моделі залежності попиту від ціни. На другому етапі, ґрунтуючись на визначенні еластичності методами граничного аналізу, отримують моделі регресійної залежності цінової еластичності попиту від ціни. Застосування запропонованої методики продемонстровано на визначенні оптимальної ціни на системи «Розумний дім» для підприємства, яке планує вийти з ними на ринок м. Одеси.

Ключові слова: регресійна залежність попиту від ціни, моделі залежності цінової еластичності попиту від ціни, оцінка ризиків у ціноутворенні, оптимальна ціна на інноваційну продукцію, граничний аналіз у ціноутворенні.

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