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MODELS OF INNOVATIVE PRODUCT DISTRIBUTION: GLOBAL PC SALES MARKET

The article considers various models of the distribution of an innovative product. Models based on the Bass model are proposed, taking into account external socio-economic factors. The commodity price function is considered, taking into account the rate of its cost reduction. Numerical results of sales of computers are received, taking into account the change in its price. Based on the results obtained from the two models, a forecast is made for the future unit sales to the global PC market (2017–2020).

Keywords: innovation models, generations of innovation models, innovation management, forecasting, price function.
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Problem statement. For successful competing activities of the company in the modern market, it is necessary to use innovations as a form of new technologies, and the form of new methods of work. When creating new products, you need to evaluate their life cycle and simulate their successful promotion in the existing market. The questions of the firm's strategy with the goal of winning the market depend on many factors: price policy, the solvency of potential users, the activities of competitors, regional conditions, advertising, etc.

The relevance of the chosen research direction is that innovations are the main criterion of competitive struggle in the market and the constructed models allow to predict the distribution of the product depending on socio-economic factors. The received forecasts allow to carry out the weighed strategy of optimum development of firm.

Analysis of recent research and publications. In their article Kotsemir & Meissner [16] consider the process the evolving understanding and conceptualization of innovation process models. The main focus of analysis in this approach is on advantages and disadvantages of different innovation models in their ability to describe the reality of innovation processes. The paper focuses on the advantages and disadvantages as well as potentials and limitations of the approaches and also proposes potential future developments of innovation models as well as the analysis of driving forces that underlie the evolution of innovation models recently (Marinova & Phillimore [17]).

A reasonable share of innovation management literature describes the innovation process as somewhat linear approaches including linear innovation diffusion (Table 1).

Under the process of diffusion of innovations is meant a diffusion process. The term "diffusion of innovations" was first proposed by Rogers [21].

Table 1 – **Innovation models evolution in historical perspective** ([16, 23])

Generation	Period	Authors of fundamental ideas	Innovation model	Essence of the model
1	1950-s – late 1960-s		Tehnology push	Linear process
2	Late1960-s first half of 1970-s	Myers & Marguis [20]	Market (Need) pull	R&D on customer wishes
3	Second half of 1970-er end 1980-s	Mowery & Rosenberg [18]	Coupling model	Interaction of different functions
		Rothwell & Zegveld [23]	Interactive model	Interaction with research institutions and market
4	End of 1980-s –early 1990-s	Kline & Rosenberg [15]	Integrated model	Simultaneous process with fedback loops; "Chain-linked Model"
5	1990-s	Rothwell [22]	Networking -model	System integration and network (SIN)
6	2000-s	Chesbrough [6,7]	Open innovation	Innovation collaboration and multiple exploitation paths
7 (emergging, not formed yet)	2010-s		Open innovator	Focus on the individual and framework conditions under which to become innovatiive

According to Rogers's innovation diffusion theory, adopters of any new innovation or idea could be categorized as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%), based on Bell curve mathematic division.

In the process of innovation/diffusion, the innovation characteristically exhibits an *S* pattern. The stages along the innovation process are characterized by the efforts of the innovator to adapt a technological development (invention) for transformation into an innovation (commercial product). The summary of studies on the innovation development process is shown in Table 2.

Table 2 – **Major studies on the innovation development process** ([29])

	Scholars	Principal Concepts
1	Rogers [21]	The innovation development process comprises of 6 stages: (i) problem definition, (ii) research (basic and applied), (iii) development, (iv) commercialization, (v) adoption and diffusion, (vi) consequences
2	Cooper & Kleinschmidt [8]	The innovation development process of the manufacturing industry comprises of: (i) preliminary assessment, (ii) detailed investigation (problem definition), (iii) development, (iv) testing and validation, and (v) commercialization
3	Kline & Rosenberg [15]	The Chain-Link model represents the process of innovation – a set of linked activities, which may occur in a variety of sequences. A model includes the innovative activities as well as the elements of research, knowledge, and market
4	Schmookler [24]	The development of technological innovation depends on the evolution of the market demand. The pull from the demand side influences the development of the product life cycle in technological innovation

An essential shortcoming of Rogers E. M. model is the ignoring of the time factor, which does not allow to analyze the development of diffusion of innovations. This deficiency was eliminated in the model proposed by Bass [1].

Franses [11], in his work consider a variable that measures sales of durable product. Usually, the pre-sample observations are equal to zero as then the product was not yet available. At one moment sales start to increase, then they reach a peak, and eventually sales die out to zero. This pattern implies the familiar *S*-shape for cumulative sales.

The Bass [1] theory starts with a population of m potential adopters. For each of these adopters, the time to adoption is a random variable with a distribution function *F(t)* and density *f(t)*, such that the hazard rate satisfies:

$$\frac{f(t)}{1-F(t)} = p + qF(t), \tag{1}$$

where *t* refers to continuous time. The parameters *p* and *q* are associated with innovation and imitation, respectively.

The cumulative number of adopters at time *t*, denoted as *N(t)*. The function *N(t)* satisfies the differential equation:

$$n(t) = \frac{dN(t)}{dt} = (p + \frac{q}{m}N(t))[m - N(t)], \tag{2}$$

The solution of this differential equation for cumulative adoption is

$$N(t) = mF(t) = m\left[\frac{1-\exp(-(p+q)t)}{1+\frac{q}{p}\exp(-(p+q)t)}\right], \tag{3}$$

and for adoption itself it is

$$n(t) = mf(t) = m\left[\frac{p(p+q)^2\exp(-(p+q)t)}{(p+q\exp(-(p+q)t))^2}\right]. \tag{4}$$

Analyzing these two functions reveals that *N(t)* indeed has a sigmoid pattern, and hence that *n(t)* has a hump-shaped pattern.

Based on the obtained formulas, you can predict the timing of peak sales and their number.

The timing of peak sales can be derived from

$$T^* = \frac{1}{p+q}\ln(p/q). \tag{5}$$

Denoting *m** as the amount of cumulative sales the timing of peak sales, and writing f = m* / m,

$$f = 0.5 - \frac{p}{2q}. \tag{6}$$

Franses [10] derives that

$$p = (2f-1)\frac{\ln(1-2f)}{2T^*(1-f)}\ ;\ q = -\frac{\ln(1-2f)}{2T^*(1-f)}. \tag{7}$$

The transition from a continuous model to a discrete one can be carried out in several ways. Bass [1] proposes to consider the regression model:

$$X_t = p(m - N_{t-1}) + \frac{q}{m} N_{t-1}(m - N_{t-1}) + \varepsilon_t = a + bN_{t-1} + cN_{t-1}^2 + \varepsilon_t \cdot \quad (8)$$

where *a = pm; b = q – p; c = –q / m*; it is assumed that ε_t is an independent and identically distributed error term with mean zero and common variance σ^2.

Derives the values *p, q, m* from the estimated *a, b, c* as follows:

$$p = \frac{a}{m};\ q = -cm;\ m = [-b \pm (b^2 - 4ac)^{1/2}]/(2c) \cdot \quad (9)$$

Boswijk & Franses [4] have proposed an alternative ratio:

$$X_t = a + bN_{t-1} + cN_{t-1}^2 + dX_{t-1} + \varepsilon_t \cdot \quad (10)$$

Srinivasan & Mason [25] proposed the following model of diffusion of the innovative product:

$$X_t = m[F_t(p,q) - F_{t-1}(p,q)] + \varepsilon_t, \quad (11)$$

where F_t is the cumulative function of the number of consumers of Bass's innovative product:

$$F_t(p,q) = \left[\frac{1 - \exp(-(p+q)t)}{1 + \frac{p}{q}\exp(-(p+q)t)} \right]. \quad (12)$$

The parameters of the Bass model *p, q, m* can be found in several ways: Bass [1] proposes to use ordinary least squares (OLS); maximum likelihood method; non-linear least squares (NLS).

When using NLS, it is necessary to minimize the quadratic residues $\Sigma\ \varepsilon_t^2$, obtained in the model proposed by Srinivasan & Mason [25].

Chandrasekaran & Tellis [5] in their work presented an overview of some numerical results of the Bass diffusion model parameters.

The innovation / simulation parameters for some product categories are presented in Table 3.

Table 3 – **Parameters of innovation / simulation of some products** ([26])

	Product/Technology	Innovation parameter	Imitation parameter
1	B&W TV	0.028	0.25
2	Color TV	0.005	0.84
3	Air conditioners	0.010	0.42
4	Clothes dryers	0.017	0.36
5	Water softeners	0.018	0.30
6	Record players	0.025	0.65
7	Cellular telephones	0.004	1.76
8	Steam irons	0.029	0.33
9	Motels	0.007	0.36
10	McDonalds fast food	0.018	0.54
11	Hybrid corn	0.039	1.01
12	Electric blankets	0.006	0.24

The analysis of the obtained results is presented in the following form (Table 4).

Table 4 – **Analysis of innovation / simulation parameters** ([26, 27, 28])

	Model parameters	Analysis of model parameters
1	Coefficient of Innovation	The mean value for a new product lies between 0.38 and 0.53: 0.001 for developed countries and 0.0003 for developing countries. It is higher for European countries than for the United States
2	Coefficient of Imitation	The mean value for a new product lies between 0.0007 and 0.03: 0.51 for developed countries and 0.56 for developing countries. Industrial/medical innovations have a higher coefficient than consumer durables and other innovations
3	Market Potential	The average market penetration potential ceiling of a new product is 0.52 for developed countries and 0.17 for developing countries. It takes about nineteen years on average for a new product to reach peak sales in developing countries and the average of sixteen years for developed countries

Restrictions on the Bass model.

• created for really new product categories;

• the binary structure of the decision to purchase;

• repeated purchases were not included in the model;

• the change in the parameters *p* and *q* was not taken into account in time and under the influence of the external environment;

• aggregated sales data are not related to individual consumer behavior;

• the appearance of substitute product categories was not taken into account.

Further improvement of models, taking into account economic and social factors affecting the process of distribution of an innovative product, led to the creation of the Generalized Bass Model (GBM) and its modifications.

The purpose of the article is to review existing models of the distribution of innovative products, as well as to forecast the global market for the sale of PC, taking into account socio-economic factors. Under the innovative product, you can consider not only the product (product innovation), but also the innovative service or the new technology being the object of sale.

Basic material. Bass et al. [2] include both price and advertising to give what they call, the GBM, where in:

$$\frac{f(t)}{1-F(t)} = [p + qF(t)]x(t) = [p + qF(t)][1 + \beta_1 x_1(t) + \beta_2 x_2(t) + \ldots], \tag{13}$$

where $x_1(t)$ and $x_2(t)$ are marketing mix variables.

The function $x(t)$ can be represented as:

$$x(t) = 1 + \beta_1 \Delta \mathrm{Pr}_t / \mathrm{Pr}_{t-1} + \beta_2 \Delta A_t / A_{t-1}, \tag{14}$$

where $x_i(t)$ is the current marketing effort that reflects the impact of price (*Pr*) and advertising (*A*) on the conditional probability of product adoption at time *t*; $\Delta Pr_t = Pr_t - Pr_{t-1}$; $\Delta A_t = A_t - A_{t-1}$.

The total number of adopters of innovation is described by the relation:

$$N(t) = mF(t) = m\left[\frac{1 - \exp(-(p+q)\int_0^t x(t)dt)}{1 + \frac{q}{p}\exp(-(p+q)\int_0^t x(t)dt)}\right]. \tag{15}$$

You can consider the Bass model by including the price factor in it:

$$\frac{f(t)}{1-F(t)} = [p + qF(t)]\exp(-\beta P(t)), \tag{16}$$

where *P(t)* – price index (*P*(0) = 1)).

Fruchter & Van den Bulte [12] developed a modified GBM, which introduces a new variable – "current position in the market":

$$x(t) = 1 + \beta_1 \frac{\partial \Pr(t)}{\partial t} + \beta_2 \max(0, \frac{\partial A(t)}{dt}), \tag{17}$$

where *Pr(t), A(t)*– function of price and advertising respectively.

In the work of Guseo et al. [13] proposed to simulate the interference function *x(t)* by means of several exponential discontinuities (shocks):

$$x(t) = 1 + c_1 \exp(b_1(t-a_1))I_{t-a_1} + c_2 \exp(b_2(t-a_2)I_{t-a_2}, \tag{18}$$

where a_i– break time, b_i– duration effect, c_i – controls the intensity of disturbances.

Boehner & Gold [3] in the generalized Bass model includes a mixed market effect:

$$X(t) = \left[pm + (q+q)N_{t-1} - \frac{q}{m}N_{t-1}^2\right]Z_t. \tag{19}$$

Taking into account that $N_t = X_t + N_{t-1}$, we obtain the relation for N_t:

$$N_t = pmZ_t + (1 + (q-p)Z_t)N_{t-1} - \frac{q}{m}Z_t N_{t-1}^2, \tag{20}$$

where Z_t – a variable that reflects a mixed market effect.

The market potential *m* can be estimated by the formula:

$$m = s\Pr^{-e} A^a, \tag{21}$$

where *s*– scale factor, *Pr*– price, *A* – advertising costs, *e* – coefficient of elasticity for price, *a* – coefficient of elasticity for advertising investments.

According to a number of studies, the value of the advertising coefficient is in the range from 0 to 1, and the coefficient of price elasticity is from low elasticity (-0.33) to high (-3.15) (Foekens et al. [9]).

Kandler & Steele [14] proposed a model in which the decision to accept innovation depends on social influence. It is assumed that the price of innovation decreases depending on the time, and the individual *i* will take an innovation if its price is lower than the individual's threshold value θ_i, depending on his income. One of the possible ways to describe the price threshold is to use the gamma distribution function. It is said that a random variable *θ* has a gamma distribution with parameters *a* and *b* if the distribution of a random variable *θ* is given by the probability density in the form:

$$f(\theta) = \frac{1}{b\Gamma(a)}\left(\frac{\theta}{b}\right)^{a-1}\exp(-\theta/b),\ \theta \ge 0, \tag{22}$$

where *Γ(a)* – the Euler gamma function; *b* – scale factor.

It is assumed that $\theta = cI$ $(0 \le c \le 1)$, where *I* is the income of the individual, *c* – describes his propensity to spend on innovation.

The share of users who have adopted the innovation at time t , we find by the formula:

$$F(t) = 1 - F_{\theta}(\rho(t)), \tag{23}$$

where $F_{\theta}(t)$ – threshold distribution function; $\rho(t) = \rho_0 exp(-\beta t)$ – the price of innovation.

This model assumes that the preference for taking innovation is not dependent on income.

Muller & Yogev [19] proposed a model in which the spread of innovation occurs in two markets: early and basic. In the early market (N_1), the distribution of the product is described using the Bass model:

$$\frac{dN_1(t)}{dt} = \left(p_1 + q_1 \frac{N_1(t)}{m_1} \right)(m_1 - N_1(t)), \tag{24}$$

where $p_1$and q_1 have the usual meaning of the parameters of innovation and simulation; m_1 – potential of the early market. The spread of innovation in the main market (N_2) is described by the model:

$$\frac{dN_2}{dt} = \left(p_2 + \frac{q_2}{m_1 + m_2} N_2(t) + \frac{q_{21}}{m_1 + m_2} N_1(t) \right)(m_2 - N_2), \tag{25}$$

where N_2 – main market potential; p_2 – parameter of innovation of the main market; q_2– basic market simulation parameter; q_{21} – parameter of the influence of the early market on the primary.

As an example, consider the process of distribution of an innovative product on a time interval [t_0, T].

Consider the finding of the final characteristics of the Bass model as a function of the influence of external disturbances (price). We will consider GBM:

$$\frac{f(t)}{1 - F(t)} = [p + qF(t)]x(t). \tag{26}$$

Let's consider some variants.

Option A.

It is necessary to predict the purchasing power of an innovative product with known sales at some historical period [t_0, t_l] (t_l < T). In this case, the parameters of the Bass model *p, q, m*are found in the classical way, and the external disturbance can be represented as a function of the price:

$$x(t) = C \cdot PR = C \cdot \rho_0 \exp[-\beta\, t], \tag{27}$$

where ρ_0, β– price parameters; $C = \rho_T exp(\beta T)$ – scale factor.

Option B.

Consider the process of forecasting the distribution of a completely new innovative product on a time interval [t_0, T]. To calculate the parameters of the Bass model *p, q* it is necessary to forecast the peak sales time of the product T^* by the total sales frequency by this time $f^* = m^* / m$. The parameters of the model *p* and *q* can be found from formulas (7). To obtain the amount of peak sales at time T^*, you need to estimate the overall market.

Numerical results.

Consider the forecast of unit sales to global PC market for the period 2017–2020. We have historical data for the period 1981–2016 (Figure 1).

In all variants of calculation, we set: $\rho_T = \frac{1}{\rho_0^2}$; ρ_0 = 1; T = 2020.

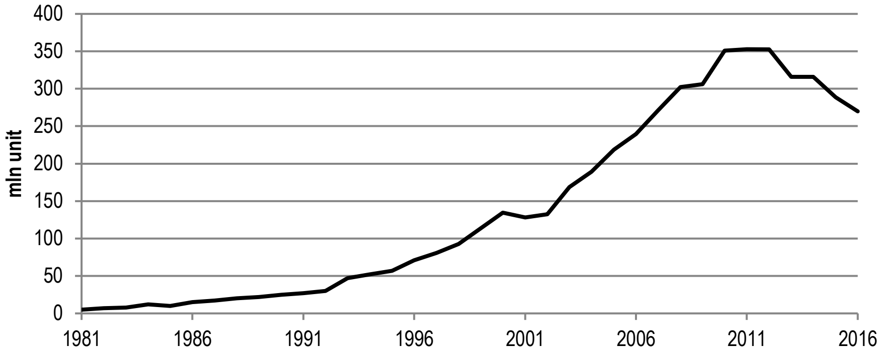

Figure 1 – **Unit sales to global PC market ([30])**

Option A.

For the calculation, we will use the values of the historical period [1981, 2005]. Let us find the parameters of the Bass model: p = 0.001057; q = 0.178831; m = 6628.267 million unit. We calculate the indicator of profitability of sales of the product in the period under study in the form of revenue from sales of products in the form of:

$$VC = n \cdot PR. \tag{28}$$

Consider the options for distributing the product under different scenarios.

Figure 2 shows the distribution of an innovative product in the gap [1981,2020]. At the same time, the base price remains almost constant.

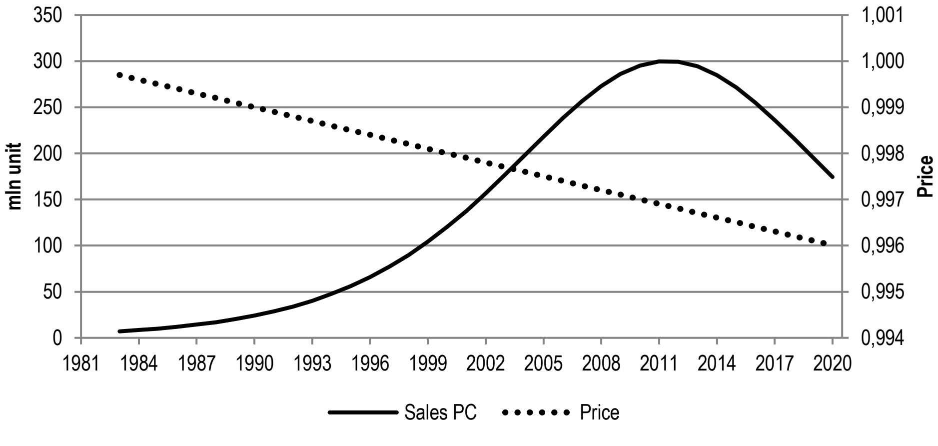

Figure 2 – **Product distribution** (β = 0.0001; VC = 5523)

Figure 3 shows the dynamics of product distribution in β = 0.01. This chart shows the possible sales of computers with a reduction in the base price. At the same time, the overall sales market remains unchanged.

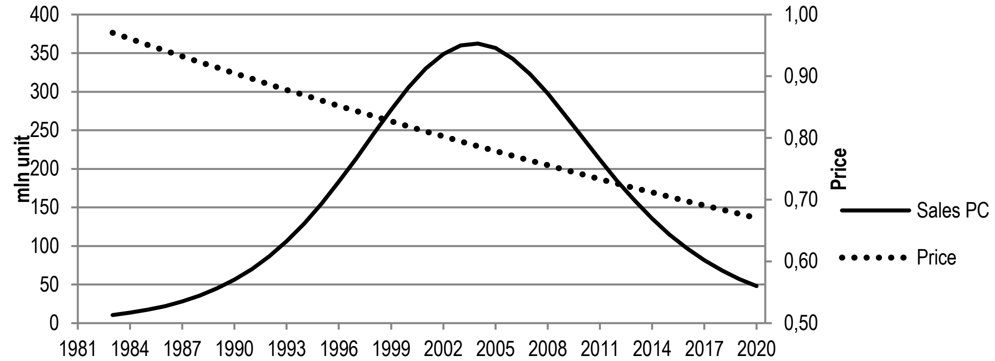

Figure 3 – **Product distribution** (β = 0.01; *VC* = 5043)

Option B.

It is necessary to obtain the characteristics of the Bass model, which allow obtaining the most optimal distribution of the innovative product in the historical interval 1981–2016. We introduce the following characteristics of the sales market: T^* = 2012; f = 0.499; m = 7200 million unit. The parameters of the Bass model are: p = 0.000388; q = 0.193819. In Figures 4-5 shows the distribution of the product until 2020.

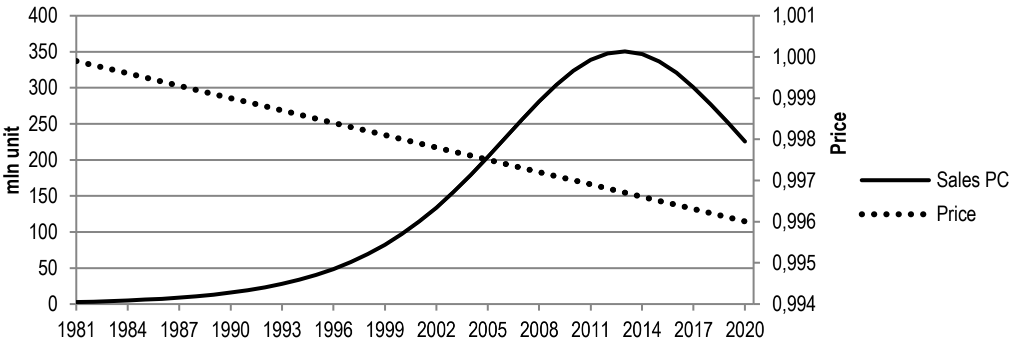

Figure 4 – **Product distribution** (β = 0.0001; *VC* = 5726)

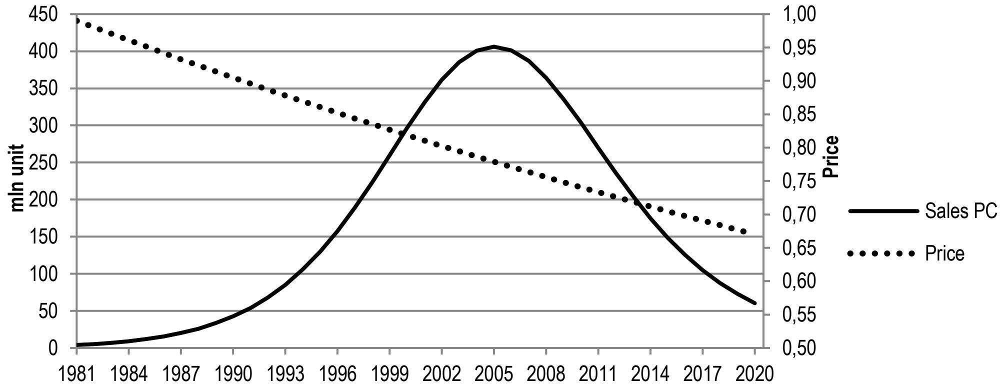

Figure 5 – **Product distribution** (β = 0.01; *VC* = 5373)

In Figure 5 received one of the options to spread worldwide PC sales with a decrease in the base price of computers.

Figure 6 shows the forecast of global sales of PC in 2017–2020, which is based on two models.

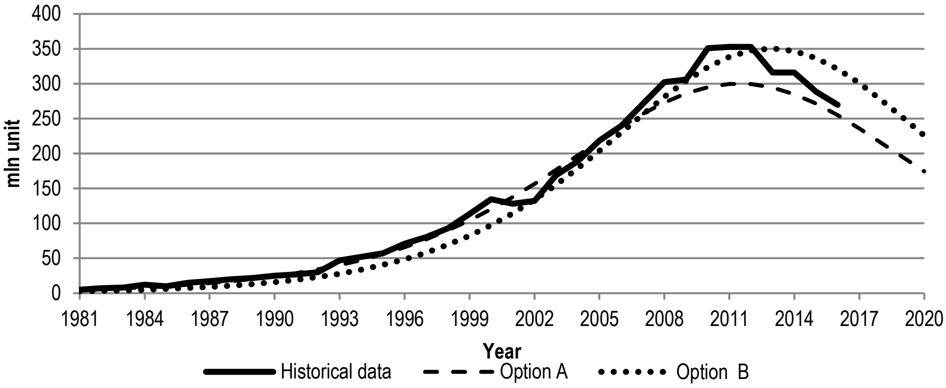

Figure 6 – **Unit sales to global PC market** (β = 0.0001)

Results and Discussion. The research results show that a decrease in the price of the product leads to a reduction in the peak sales period and an increase in the number of peak sales. The pricing policy of an enterprise depends on many factors: the purchasing power of consumers; activity of competitors in the market; the presence of a brand; advertising, etc. In this paper, the influence of the price factor on product promotion is analyzed. The proposed models describe the data well in the historical period and give an opportunity to estimate future sales. Based on the results obtained, it can be concluded that the application of the Bass model allows you to predict product promotion in the market. Depending on the function of external influence, we obtain models for the distribution of the innovative product. The form of the external function is controversial in terms of its structure and functional dependence between its components. The nature of this impact is also determined by its available numerical characteristics. Considering different models, you can get a generalized characteristic of the indicator of future sales.

Conclusions and results of further research. The analysis of the obtained results shows that the influence of external influence on the process of product distribution can be significant. The choice of the function of this influence is one of the main tasks in the construction of the diffusion model. If we consider the price of a product as an external influence, then the trend of a price decrease over time affects the gross revenue of the enterprise and shortens the time to "conquer" the potential market. If the indicator of sales proceeds is used as a criterion for estimating sales, then on the basis of the calculations obtained it can be concluded that there is an optimal price for the product that maximizes this indicator. The question of finding this price can be one of the subjects of further research. As an improvement to the model of distribution of an innovative product, one can consider the influence of competitors and the purchasing power of potential users with this product. It is also necessary to take into account the influence of the early market on the trend of the main market. Forecasting of the future sales market for a new product must be carried out on the basis of a corresponding analogue or by setting the basic parameters of the Bass model.

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Моделі поширення інноваційного продукту: глобальний ринок продажів комп'ютерів

У статті розглядаються різні моделі поширення інноваційного продукту. Пропонуються моделі, засновані на моделі Басса, з урахуванням зовнішніх соціально-економічних чинників. Розглядається функція ціни товару, що враховує темп зменшення його вартості. Отримано чисельні результати продажів комп'ютерів, з урахуванням зміни його ціни. На підставі результатів, отриманих за двома моделями, робиться прогноз майбутніх продажів комп'ютерів (2017–2020).

Ключові слова: інноваційні моделі, покоління інноваційних моделей, інноваційний менеджмент, прогнозування, функція ціни.

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Модели распространения инновационного продукта: глобальный рынок продаж компьютеров

В статье рассматриваются различные модели распространения инновационного продукта. Предлагаются модели, основанные на модели Басса, с учетом внешних социально-экономических факторов. Рассматривается функция цены товара, учитывающая темп уменьшения его стоимости. Получены численные результаты продаж компьютеров, с учетом изменения его цены. На основании результатов, полученных по двум моделям, делается прогноз будущих продаж компьютеров (2017–2020).

Ключевые слова: инновационные модели, поколения инновационных моделей, инновационный менеджмент, прогнозирование, функция цены.

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