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Investigation of Various Prediction Models of Demand on the Market of Innovations

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ABSTRACT

The formation of demand forecasting models is important in understanding the transition from the raw to the innovative model of the economy. The aim of the study is to analyze and evaluate the different innovation demand forecasting models and the mathematical substantiation of the directions of their development. On the basis of the Bass model, we explore forecasting the spread of innovative products with the addition of such factors as prices, advertising, and market potential for the purpose of application of applied models in assessing the demand for high-tech products at the market launch of innovative products. Mathematical justification of the problem of demand for high-tech products presented in the context of the theory of diffusion of innovation and developed technique in forecasting of high-tech products sales, which allows in calculating the number of purchases to a specific point in time. A model for innovation demand prediction by logistic regression, which can improve the classification of consumer preferences of high-tech products.

Keywords: Innovation, Sales Forecast, Marketing High-tech Products, Consumer Behavior, Economic Growth
JEL Classifications: O, O3, Q55

1. INTRODUCTION

High-tech development scenario involves the formation of an effective national system of high-tech and the introduction of long-term programs and projects that will ensure its leading position in the high-tech product market. In this regard, all the more relevant ways of modeling the formation predict the future demand for high technology. The success of the companies that produce high-tech is impossible without forecasting demand for their products, as the work of such companies is focused to increase its competitiveness. Quantification of the demand is hampered by the lack of concepts that adequately explain the patterns of its occurrence and variation. It is limited by the weak standing of elaboration of methods and models for the prediction of their dynamics and systems. In the methodical plan in forecasting demand, traditional, classic and modified approaches can be used (Egorova and Mudunov, 2000).

The preferred method is the modified approaches, since they are based on creating demand considering multiple interconnected complex factors (Mironov, 2012). This multi-factorial approach, which in each case need to find the demand function, most showing the situation and containing as an argument is the set of factors which greatly affects the demand for high-tech products presented.

Also, the problem of the demand for high-tech products from the perspective of its mathematical justification is most logical to be considered in the context of the theory of diffusion of innovations in order to identify the features of innovative products during implementation (Derunova, 2012). The basis of the theory of diffusion of innovation was laid out by E. Rogers. In his view, the spread of high-tech products is carried out on a model that provides a graphical view of an S-shaped curve. The scientist attributed to the fact that consumers are divided into groups depending on their perception of fast information.

It should be noted that the theory of diffusion of innovations led to a qualitative model of the output of high-tech products. However, for companies it is significant not so much as the qualitative model as the quantitative model of the dynamics of sales of new products.

Since the 1960's, in the light of the work of famous scientists such as Fourt and Woodlock (Fourt and Woodlock, 1960), Mansfield (Mansfield, 1961), Floyd (Floyd, 1962), Rogers (Rogers, 1962), Chow (Chow, 1967) and Bass (Bass, 1969), the key themes of research works were modeling, forecasting the propagation velocity of high-tech and high-tech products. Scientists Bass and Fourt in their scientific reasoning used the concept of "high-tech product."

In recent years, more research has been focused on the study of modeling the demand for high-tech products. The starting and product design evaluation of high-tech design and its costs are influenced by the magnitude of supply and risks. The forecast cost of the project for the development of high-tech products will be more accurate with high precision forecasting of parameters.

Eight basic models of the diffusion of high-tech products were developed in the 1970's but only six simulation models are applied currently. Significant contribution to the development of these six models occurred in the past 35 years. The authors of these models are as follows: Meade (Meade, 1984) Mahajan, Peterson Mahajan (Mahajan and Peterson, 1985), Miller and Bass (Mahajan et al., 1990), Baptista (Baptista, 1999), Mahajan et al. (Mahajan et al., 2000), Mead and Islam (Meade and Islam, 2001). Improvements have been made on a number of key issues: The reliability: The model should have a clear boundary of "saturation" of innovation and reliability of statistics the estimation of the parameters of the model; it is necessary to conduct a series of studies and tests, as well as predictive models the credibility of the forecast, and the availability of a certain level of uncertainty. The ideal would be the presence of a range of values with a certain degree of probability.

The path taken by a high-tech product from the stage of emergence until market saturation stage is an S-shaped curve (confirmed by tests and fully corresponds to market reality).

2. METHODOLOGY

We will explore different approaches to forecasting demand for innovation. We will first focus on a few basic models on which will be the basis for possible simulation.

Model Bass: People affected by the desire for high-tech (s - innovation factor), the desire to imitate (d - coefficient of imitation), the population of people n - innovators (tend to acquire innovation s-factor) and imitators (prone to acquire innovation depending on the previous experience of acquisitions), $d\left(\frac{A_{t-1}}{n}\right)$.

In this case, the probability density function of the acquisition for the potential buyer of high-tech products for the time it is given by:

$$f(t)=(s+dF(t)(1-F(t))) \quad (1)$$

(s+dF(t))– The likelihood of high-tech product consumption potential consumer in time t. F(t) - The share of high-tech consumer products corresponding to the time t. The effect is similar to an epidemic, or in a "contagion effect." Excluding these variables (s> 0, d = 0), the diffusion of change is carried out at an exponential rate:

$$A_t=a\exp\left(\frac{1}{yt}\right) \quad (2)$$

If you do not take into account the effect of addiction to high-tech (s = 0, d> 0) diffusion will vary according to the logistic curve:

$$A_t=x\exp\left(-z(\exp(-yt))\right) \quad (3)$$

Parameter (s+d) - the scale, (s/d) - the shape of the curve. The curve has a shape S, sure to satisfy the condition: $\frac{d}{s}>1$

Form s-curve also forms the uneven distribution of incomes of the population (Bass, 1994): The proliferation of high-tech product increases as the price is reduced because more people can afford to make the purchase. There is evidence of a positive correlation s/d, and the inequality of income distribution Gini index (Van den Bulte and Stremersch (2004)).

Distribution of high-tech product occurs at a rate, which is the slope of the logistic curve, or the time it takes to make the transition to a new level of penetration of high-tech product. Analysis of retrospective behavior in the period from 1923 to 1996 shows a significant increase in the velocity of propagation of high-tech products and high-tech as a whole. This phenomenon can be explained by the increased purchasing power and demographic changes.

The spread of any high-tech product is affected by several environmental conditions: Competition, market and macroeconomic factors. The propagation of high-tech products is significantly affected by the product price, cash cost of sales promotion, as well as the promotion's effectiveness.

Here is a case of possible adaptation of the Bass model with the inclusion of the price factor. In this case the formula is as follows:

$$e(t)=(\alpha_0+\alpha_1 F(t))\exp(-\alpha_2 S(t)) \quad (4)$$

Where – S(t) – price index (S(0)=1).

The formula has been checked for accuracy, used in the course of inspections of strategies for educational prices of high-tech products (Minakov et al., 2013). Results for: Marginal efficiency of the approach to the formation of prices for high-tech product (at the start of the sales price is high, further down) lower than that of the other two approaches, when the price is set at a constant high-tech product; when set low price, and then increases to a peak and then declines.

Another option is to adjust the Bass model, which includes a model of the effect of advertising (Mahajan et al., 1990).

$$e(t)=(\alpha_0+\alpha_1 F(t))+\alpha_2 \ln(B(t))) \quad (5)$$

Where – B(t) – the function of distribution of advertising time t. The coefficients α_0, α_1, α_2 measured level of publicity, the so-called "word of mouth" advertising, respectively.

3. DATA

To combine data models, taking into account factors like advertising and price, scientists have developed a generalized model of Bass (Fruchter and Van den Bulte, 2011). In the generalized model, there is a new variable – "the current position in the market." Now Bass model takes the following form:

$$e(t)=(s+dF(t))a(t) \tag{6}$$

Where:

$$a\left(t\right)=1+\alpha_1\frac{\partial S(t)}{\partial t}+\alpha_2\max\left(0.\frac{\partial X(t)}{\partial t}\right) \tag{7}$$

Index a(t) - the market potential is denoted n.

Bass is useful in finding attractive model parameters (s, d, n) by the method of least squares. This conclusion is based on the properties of the discrete model - binominal expectations about the number of new consumer innovations to time t.

$$B_t\text{-}B_{t-1}=\left(s+\frac{d}{n}B_{t-1}\right)\left(n\text{-}B_{t-1}\right) \tag{8}$$

in that the number of consumers at time t-1 will be equal. Using empirical evidence shows that often the method of least squares produced inaccurate estimates.

For this reason, another method has been developed for estimating the parameters of the model - the method of maximum likelihood. the likelihood function in this case:

$$K=(1\text{-}J(t\text{-}1))^{(N\text{-}B_{t-1})}$$

$$\prod_{i=1}^{t}(J\left(i\right)\text{-}J(i\text{-}1))^{B_i\text{-}B_{i-1}}$$

Where J(t)=lF(t), l - the probability of a possible acquisition. Each situation is "acceptance" or "rejection" of high-tech product is a Bernoulli trial with the changing time of purchase probability. The advantage of this approach is the prediction accuracy is higher than that of the least squares method (Marshalkin, 2015). There is also a third approach - a nonlinear least squares method. The method is to minimize the quadratic residues: $\sum v_t^2$

$B_t\text{-}B_{t-1}=n(F(t)\text{-}F(t\text{-}1))+v_t$,

Where F(t) is determined by the cumulative function of the number of high-tech product buyers Bass:

$$F\left(t\right)=\frac{1\text{-}\exp(\text{-}(s+d)t)}{1+\exp\left(\frac{d}{s}\right)(\text{-}(s+d)t)}$$

The results of both methods (non-linear method of least squares and maximum likelihood method) are approximately equal and at the same time, provide more precise results than the method of least squares.

The Bass models can predict the spread of high-tech products (Minakov et al., 2012). The limitation is closest to reality prediction can only be obtained within 5 years with these Bass models. The article can be considered as developing the most common model in practice of forecasting the diffusion of high-tech products. A better model is to combine the Bass Model with nonlinear least-squares model for forecasting future sales of high-tech products. Also, the Russian statistical studies should be carried out, similar to the above, which relate to the spread of high-tech products. We will use Russian statistics, more accurate forecasting, the gradual adaptation of the model for estimating the cost of projects for the creation of high-tech products (Derunova et al., 2016).

In Kolmanovskii research (Kolmanovskii, 1999) model of diffusion of innovations is becoming more perfect form. It introduced a new index - the time it takes for the dissemination of information related to high-tech products. However, it does not take into account that in the process of disseminating information may change the disseminated information itself, which, in turn, alters the process of its distribution.

In Serkov research (Serkov, 2009) by means of a synergistic approach understands the model of high-tech process, the presence of noise in drawing conclusions, the larger the objects participating in the innovation process, the lesser the noise. However, the overall model used by researcher, does not take in account of any structure or features of high-tech processes.

LK Guriev (Guriev, 2005) considers the theory of diffusion of innovations from the standpoint of its development. Research carried out in the framework of the analysis of the internal laws of the theory and framework of "spatial" aspects of diffusion. The study is of great interest for understanding the current state of development of the theory of diffusion.

Y. Bulgakov and Zinin (Bulgakov and Zinin, 2011) offers on the basis of differential equations Bass apply simulation of processes of diffusion of innovations using Simulink module software system, MatLab.

In EV Semynitch scientific research (Semynitch, 2011) is confirmed by the adequacy of the use of the product life cycle theory to practice in order to predict the dynamics of sales of new products. Built a mathematical model that describes the life cycle of products as follows:

$$A_d = B_1\cdot c^{\alpha_1(d\Delta)} + B_2\cdot c^{\alpha_2(d\Delta)} + F_d$$

Where:
A_d - sales;
B_1, B_2, α_1, α_2 - coefficients of the model;
d=1,n - number of observations, n - sample sizes;
Δ - step;

F_d - the magnitude of the error in the step d.

With this model it is possible to determine the life cycle of products (model determines the level of applicability of the product). However, this method of forecasting the dynamics of sales of new products due to fluctuations (noise) real data at the initial stage it must constantly readjust lifecycle.

The Semiglazov research to determine the life cycle of high-tech products used normal distribution curve:

$$q(t,T,H) = G \cdot e^{\frac{(t-T)^2}{2H^2}}$$

Where:
G - maximum sales for the entire period of product life cycle;
t - time;
F - the maximum time sales;
H - RMS characteristics.

Thus, if we consider the high-demand products in the context of innovation diffusion theory, it can be concluded that the characteristics of the commercialization of products, in this case, are not fully taken into account. Researchers Baev and Drozin attempt to develop a system of methods for predicting the dynamics of demand, which will take into account the peculiarities of the formation (Baev, 2014).

The main requirements for methodological tools address planning and managing the implementation of high-tech products has been reduced to demand disclosure of the formation of its mechanisms. These mechanisms are reduced to a phased system of decision-making on acquisition potential consumers of high-tech products.

We distinguish 4 stages within the analyzed approach:

- In the 1st stage: A potential customer receives information about the high-tech products;
- In the 2nd stage: A potential customer evaluates the possibilities of acquisition on the basis of his ability to pay;
- On the 3rd stage: A potential customer decides to purchase the product, which depends on his psyche;
- On the 4th stage: A potential customer buys a high-tech product.

Based on the stages of decision-making potential consumers to purchase goods produced by life cycle stages determine the dynamics of the volume of its implementation.

4. RESULTS

Methods of forecasting sales of high-tech products, which allow in calculating the number of purchases to a certain point in time, based on which the model with the following indicators has been developed:

1. The number of potential customers who receive information about new products per unit of time.
2. The volume of potential consumers who have information about a new product, and who are willing to buy it at fair value or below.
3. The volume of potential consumers who purchase products over time (after get information about it).

Methods of forecasting sales of high-tech products are expressed in the following formula (Baev, 2015).

$$F(X)=\iint z(x)\cdot G(R)\cdot e(c)\cdot kxkc$$

Where:
F (X) - the number of purchases of high-tech products to a specific point in time;
x, c - c and time - delay line with = X - x;
z (x) - the number of potential users who receive information about the new product per unit of time;
G (R) - the amount of potential customers who have information about a new product, and who are willing to buy it at fair value or below;
e (c) - the amount of potential consumers who purchase products through time after c, how to get information about it.

The number of potential consumers z (x), which receive information on the new product per unit time can be determined by the following formula:

$$z(x)=\begin{cases} \dfrac{kY_{i_1;i_2;\ldots i_{k-1};i_k}(x)}{nx}=\left(\alpha\cdot\delta_{i_n,n}+\beta\cdot y_{i_n}(x)\right)\times\sum\limits_{j=i_{k-1}}^{i_n-1} Y_{i_1;i_2;\ldots i_{n-1};j}(x)- \\ -\sum_{j=i_{n+1}}^{n}(\alpha\cdot\delta_{i_n,n}+\beta\cdot y_j(x))\times Y_{i_1;i_2;\ldots i_{n-1};i_n}(x) \\ (i_n\neq i_{n-1}); \\ Y_{i_1;i_2;\ldots i_{n-1};i_n}(x_{n-1})=0. \end{cases}$$

$(0\leq i_f\leq f, i_{f-1}\leq i_f\ (1\leq f<n))$

$$\sum_{j=i_{n-1}}^{i_n-1} Y_{i_1;i_2;\ldots i_{n-1};j}(x)=Y_{i_1;i_2;\ldots i_{n-1};i_n}(x_{n-1})$$

$$\sum_{j=i_{n-1}}^{i_n-1} Y_{i_1;i_2;\ldots i_{n-1};j}(x)=Y_{i_1;i_2;\ldots i_{n-1};i_n}(x_{n-1})$$

$(0\leq i_f\leq f, i_{f-1}\leq i_f\ (1\leq f<n-1))$

Where:

$N_{i_1;i_2;\ldots i_{n-1};j}(t)$ - number of potential consumers in the subset $\{i_1;i_2;\ldots i_{n-1};i_n\}$ at time t;

y_j- the number of media product cost P_j;

$$y_j=\sum_{i_1;i_2;\ldots i_{n-1}} Y_{i_1;i_2;\ldots i_{n-1};j}$$

$0 \le i_f \le f, i_{f-1} \le i_f, 1 \le f < n$

The function G (R) is expressed by consumer demand:

$$P(R) = \int_{R}^{+\infty} G(v) gv$$

P(R) - the volume of potential customers who are willing to buy products at a cost of R and below. Designation «v» corresponds to R.

e Function (c) shows the volume of potential customers who will purchase the products after a certain time (after get information about it). There are reasons to believe that this feature will have a dome-shaped appearance (Baev and Drozin, 2005).

Thus, the test of this approach in practice proves the feasibility of its use in finding the criteria and indicators of the dynamics of high-tech products demand and, consequently, in the planning of production.

5. CONCLUSIONS

To predict the demand for these high-tech products, we use the following content model:

1. Study of the main factors affecting the quantity demanded, revealed the following components: The cost of production, advertising budget, scope of commercial outlets, qualitative indicator of production;
2. The assumption of the form depending on the above factors on the level of demand is set out as follows:
   a. The cost of production is required to be inversely proportional to the impact on the volume of demand;
   b. A power function of the quality factor of production is proportional to the size of the demand;
   c. The scope of commercial outlets is commensurate impact on demand;
   d. The size of the advertising budget has a more complex effect on the size of the demand, as an increase in demand due to the promotion of maximum for the period of its implementation, and then decreases to a certain constant.

The mathematical form of the constructed model of demand for high-tech products has the form of a modified approach, since it is based on the formation of the demand in view of the complex associated factors. Product quality is an integral index, which includes the evaluation of products, and customer analysis of conformity of products with the necessary standards (Lebedev, 1997).

Consider the method of forecasting sales of goods, novelties by logistic regression. During first time since its launch, the first 6 months, forecasting products, new products are based on the reaction of potential consumers, their willingness to buy. A particular success in predicting the probability of selection of a product uses logistic regression model, (Arkhipova and Aleksandrov, 2014), (Afanasyev et al., 2005), (Ayvazyan and Berndt, 2005), (Demidenko, 1981), it allows you to predict a possible likelihood of purchase of goods by potential buyers.

Dependent variable - binary variable b - proof of purchase of a new product the prospective buyer:

$$b = \begin{cases} 1, & \text{new product purchased} \\ 0, & \text{was not bought} \end{cases}$$

Thus, we have a model of multiple variances. Methods of construction of the linear multiple regression model $y^N \tilde{A}$, of classical type or generalized multiple regression model for this type of tasks cannot be used due to the lack of clarity of how to carry out the interpretation of the regression values measured in the continuous quantitative scale.

Thus, in order to explore the statistical relationship between the probabilities of acquisition of goods, new items b and influencing factors make it the construction of a special regression $R\left\{b=\frac{1}{\tilde{A}}\right\}$ model, depending on the shape of the probability of a linear type $y^N \tilde{A}$. Description linear probability function is inappropriate because in that case the predicted probabilities may be both negative and greater than unity. Simulate the value $R\left\{b=\frac{1}{\tilde{A}}\right\}$ functions, in which the range of values is the interval [0, 1], a linear form - an argument of a function

$$R\left\{b=\frac{1}{\tilde{A}}\right\}=F(y^N \tilde{A})$$

- Models of the second type - usually binary choice model. The most common models are binary choice logit and probit model (Bolch and Huang, 1979).

Logit model. The model of the second type is Logit model only if F (d) - logistic function

$$R\left\{b_i=1/\widetilde{A_i}\right\}=\frac{e^{y^N \widetilde{A_i}}}{1+e^{y^N \widetilde{A_i}}}$$

This function is symmetrical relative to point $y^N \tilde{A}=0$

$\Lambda(-d)=1-\Lambda(d)$

Where

$$n(d)=\frac{e^d}{1+e^d}$$

Probit model. The model of the second type refers to the probit model in case F(d) –a probability distribution function Φ(d) of the standard type:

$$R\left\{b_i=1/\widetilde{A_i}\right\}=\$ \,(y^N \widetilde{A_i})$$

Where,

$$\Phi(d) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{d} e^{-\frac{a^2}{2}} da$$

Similarly functions Λ(d), the normal probability function distribution Φ(d) is symmetrical about $d = 0$().

Similarly functions a normal probability distribution function Φ(d) is symmetrical with respect to $d = 0$.

The model and the coefficients are significant on statistical criteria. The adequacy of the model is confirmed by the normal distribution of features that are included in the model, as well as the proximity of the covariance matrices of features for different groups.

The model has a quite high predictive properties. As a result of the application of the model to the elements of the sample can be judged on the correct classification of approximately 90% of the results of consumer preference.

Thus, it is possible to obtain a prediction of behavior of end consumers of the goods by the values statistically occupied properties. The results of logistic regression were used for sales forecasting model of high-tech products. Produced representative sample of potential buyers, as well as indicators that are included in the logistic model, the expectation is estimated share of consumers who are willing to purchase an innovative product-a novelty. For purchase rate, adopted by peer review, it coincides with the average frequency of purchase.

The next step is to build a balanced distribution of the forecast. For this we calculated the volume of the population for which there will be the implementation of the goods, or new items. Forecast sales of new products, product is calculated as follows: Sales (t) = T(t)·K·P·S, where - the proportion of retail outlets in Russia, where the goods, a novelty in the week t will be presented;

K - Russia's population, people;

P - percentage of potential consumers who make purchases with greater probability (estimated by logistic regression model);

S - number of acquisitions per week units.

Using logistic regression model, you can find a solution to the underlying problem of forecasting the demand of end consumers in the novelty, even though you lack the historical data needed to build statistical models. Logistic regression gives an estimate of the proportion of target consumers who are ready to make a purchase. By improving the accuracy of prediction of goods, innovative company gets the opportunity to introduce high-tech products at the lowest cost. This ensures the availability of the goods, a novelty in the required amount, at the right time and right place.

Predict-a novelty item for the first 6 months since the beginning of its production using classical models is not possible to predict because of the lack of statistical data on the components of a time series.

To draw up a plan of sale of goods, new items, proposed to consider the logit model, the base of which is forecasting the share of potential buyers who are ready to make a purchase, depending on the parameters: Gender, age, average income, participation in the past incentive programs of the company, the population in the place of residence. As a result of the logit model to predict product, sales of new products can significantly improve the classification of consumer preferences in comparison with the data of the average relative error module forecast expert evaluations, obtained as a result of a comparative approach.

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