Discrete Dynamic Model of Retail Trade Market of Computer Equipment in Ukraine

Mykola Dyvak[1],Vasyl Brych[2], Iryna Spivak[3], Lyudmyla Honchar[4], Nataliya Melnyk[5]

1. Department of Computer Science, Ternopil National Economic University, UKRAINE, Ternopil, 8 Chekhova str., email: mdy@tneu.edu.ua

2. Department of International Tourism and Hotel Business, Ternopil National Economic University, UKRAINE, Ternopil, 11 Lvivska str., email: v.brych@tneu.edu.ua

3. Department of Computer Science, Ternopil National Economic University, UKRAINE, Ternopil, 8 Chekhova str., email: i.spivak@tneu.edu.ua

4. Department of Computer Science, Ternopil National Economic University, UKRAINE, Ternopil, 8 Chekhova str., email: l.honchar@tneu.edu.ua

5. Faculty of Economics, Ivan Franko National University of Lviv, UKRAINE, Lviv, email: talya_m@ukr.net

Abstract: **In this article the discrete dynamic model of the retail computer market functioning in Ukraine is considered. The existing distribution models are analyzed between the main entities in the market. A new model is proposed and an example of the IT market dynamics is shown.**

Keywords: ***retail computer market; discrete dynamic model; correction function; predicted indicators.***

I. Introduction

Mathematical modeling is one of the most important tools for researching economic processes. The constant demand for new IT generates new types of computer equipment (CE), as well as new IT services. These proposals are aimed not only at meeting the needs of business structures, but also at an average household information consumer. The last circumstance stimulates the rapid development of CE retail market, on which the main buyer is the individual consumer of the information product. To predict the development of this market, it is necessary to build its dynamics model. Such models are described in the works [1, 2], where the problems of their structural and parametric identification on the basis of data analysis are considered. Such models are called discrete dynamic or differential operators [1].

To construct a model of market dynamics, let's consider the important moments of the subject modeling area. At the domestic CE retail market we distinguish four sellers categories: consumer electronics, specialized computer stores, mobile communication stores and B2B-sector enterprises [3]. A narrow range of sellers in the domestic market of CE is conditioned by the monopoly in this area. Those structures, which operate on the domestic market, play the role of a distributive link, which does not define strategic directions of IT development and applies to advance achievements in this field. Without having their own product and struggling for a part of the market share they are forced to behave extremely responsibly in their own business, paying attention to a number of factors, on which they have no influence [3].

The need of planning strategies and tactics of doing business, challenges the participants with complex problems of mathematical modeling of processes in the retail market of CE, which are happening in this market. The modeling results can be taken into consideration during development and implementing business policies in specific circumstances. Predicted by discrete dynamic mathematical models, the indicators of business development make it possible to adequately assess their own investment opportunities and to attract investments from the side. Mathematical models are used to track trends in the market. This allows you to correctly emphasize the position of advertising companies in order to timely implement effective marketing activities. Consequently, the skillful use of the market's subject methods of mathematical modeling in the final result gives you a number of advantages in the competition [3].

Rapid changes in the IT-industry trends put high demands to the possibility of mathematical models. For example, a model that adequately reproduces sales of storage devices, will not necessarily work in the case of a rapid and massive transition from the use of optical disks to electronic media. This can be explained by the fact that entities in the common market react differently to these changes. Some of them, which are oriented to the sale of goods in large batches, are not able to quickly abandon the devices, which action is based on "outdated" technologies, since there are a large number of such devices in the warehouses. Obviously, the advertising and marketing policies of such structures will be aimed at reducing their stocks as quickly as possible. Other market players, who are more mobile in the process of transitioning to new technologies, are pursuing a policy aimed at promoting the latest devices. Therefore they are receiving competitive advantages that are not taken into account in conventional foreseen models [6].

It is also possible that new sellers will enter the market, who bet on the latest IT technology, or some vendors will be replaced by others. Individual sellers can change their priorities and refuse to commerce certain types of CE. Apparently, such vendor substitutions also require correction of existing linear dynamic models [3], for example, by introducing a nonlinear part that reflects switching processes.

The purpose of this study is to develop a new model of the retail market of CE based on the rapid changes that take place

CEUR-WS.org/Vol-2300/Paper13.pdf

in IT. To achieve the goal, you need to solve these problems: analysis of existing models of distribution of the retail market of CE between sellers by major segments; to construct a discrete dynamic model with a "switch" for describing the CE market, which is subjected to change of circumstances of its functioning; check the model for adequacy.

II. Task Defining

Work [3] proposes a model that reflects the distribution of the retail CE market dynamics between the four large suppliers (entities) by separate segments of the market. Each segment corresponds to a certain type of CE. In the example given in [3], four segments are considered, namely: personal computer segment (PC), laptops segment, a segment of displays and a segment of multifunctional devices (MFD).

To simulate the dynamics, the mathematical model is selected as a linear discrete equation (differential operator) in the form [3,6]:

$$\begin{cases} \vec{x}^{(k+1)} = F \cdot \vec{x}^{(k)} + G \cdot \vec{v}^{(k)} \\ \vec{y}^{(k+1)} = C \cdot \vec{x}^{(k+1)}, k = 0,1,2,... \end{cases} \quad (1)$$

where $\vec{x}^{(k)}$ – vector of state variables, which characterize the change in the formal state of the market; $\vec{v}^{(k)}$ – vector of input variables, which reflect the effect of factors on the market; $\vec{y}^{(k)}$ – vector of output variables, which reflect the characteristics of the distribution of the market among its subjects; k – time sequence number, in which the value of the components of the corresponding vectors is determined; F,G,C – valid matrices of the corresponding measurements.

Parameters of this model (matrix elements F,G,C) are obtained in the form of parametric identification according to the well-known Ho-Calman algorithm [4-6]. The reason of parametric identification is the Henkel block matrix. Each block of this matrix in the case [3] is formed from the data on the market share, which is occupied by the j-th element ($j = \overline{1,4}$) in the i-th ($i = \overline{1,4}$) market segment by the results of k-th year ($k = \overline{1,4}$).

In the work [3] an assumption was made, that conditions of functioning of the retail market CE were unchanged. Model built in this way, allowed to get a rough estimate of the distribution of the market for $k+1$ period among the main categories of vendors for each segment of the market.

III. Improved Discrete Dynamic Model

As shown in [3], even with the preservation of previous trends in the functioning of the retail market of CE, the full adequacy of the basic model could not be achieved. Only use of optimization procedures allowed to get adequate values for predicted indicators. Obviously, when market trends fluctuate, the proposed model becomes inadequate. Therefore, it is necessary to complicate the structure of the model, taking into account changes in the market. Such a complication can be done using the methods of structural identification [2]. However, in our case, the dynamics model is deterministic and its structure can be obtained based on a detailed analysis of the subject area. In order to take into account the changes in trends changes is offered to modify the proposed model by introducing switching functions that simulate a sharp change in market conditions.

Let's consider the case when at a certain point in time t_{out} on the market in a particular segment changes the number of subjects, namely, one of the subjects leaves the specified segment. This means that the number of non-zero vector components $\vec{y}^{(k)}$ in (1) decreases. To represent this possible change we introduce into the equations of the output variables of model (1) an additional diagonal matrix T, which has such a general view:

$$T = \begin{pmatrix} f(t_1) & 0 & \cdots & 0 \\ 0 & f(t_2) & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & f(t_n) \end{pmatrix}, \quad (2)$$

where is the switch function $f(t_s) = \begin{cases} 1, & t_s < t_{out} \\ 0, & t_s \geq t_{out} \end{cases}$, $s = \overline{1,n}$, n - number of vector components $\vec{y}^{(k)}$ in the model (1). Then we will get:

$$\begin{cases} \vec{x}^{(k+1)} = F \cdot \vec{x}^{(k)} + G \cdot \vec{v}^{(k)} \\ \vec{y}^{(k+1)} = T \cdot C \cdot \vec{x}^{(k+1)}, k = 0,1,2,... \end{cases} \quad (3)$$

Based on these tasks in [3], we will analyze the obtained model structure. At the same time, we assume that sellers belonging to a certain category, namely: mobile communication stores, refused to sell monitors. In fact, this situation was observed in 2015. In model (3) this year corresponds to the order number of the time point $k = 5$. And the serial number of the monitor – $s = 3$. So with $k = 5$ we get $t_3 = t_{out}$ and accordingly the switching function $f(t_3) = 0$, and the corresponding matrix T will have the form:

$$T = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \quad (4)$$

According to model (3), foreseen indicators reflecting the the distribution of CE market in the segment of monitors between entities, which are left in this segment are: consumer electronics– 38,5%; specialized stores – 23,7%; B2B sector – 36,2%.

Obviously, that the market share, which according to forecasts should have mobile exhibition halls (which is 1,6%), were distributed among the remaining enterprises in the segment of monitors. Assuming that this division took place in proportion to that part, that each subject has in this segment, then each of them received an additional share in the amount respectively 0,62%, 0,38% i 0,6%. Consequently, the final forecast for the distribution of the retail market of monitors is as follows: consumer electronics – 39,12%; specialized stores – 24,08%; B2B - sector – 36,8%.

If we apply the optimization procedure for the initial distribution (38,5%; 23,7%; 36,2%) and under conditions, that the goal function as the sum of the shares of all sellers remaining in the segment is equal 100%, and the deviation of each particle does not exceed 1,6%, then we obtain the following final values: consumer electronics – 36,9%; specialized stores – 25,3%; B2B - sector – 37,8%.

The difference between the two methods of estimating the forecasted values of market distribution lies within the limits [2,22%; -1%]. Obviously, taking into account such clear limitations in forecasting, the entity of the retail market CE has the opportunity to more precisely define its own business development strategy.

To reproduce changes in the retail market of CE, which are connected with elimination or gradual abandonment of this market by separate subjects, into the model (1) it is appropriate to enter correction functions into the vector of input variables $\vec{v}^{(k)}$. Let's look at an example where subject 3 (mobile stores) dramatically reduces its presence on the market in all its segments. Instead, its market share is individually trying to be captured the subject 2 (specialized stores).

According to the Ho-Calman algorithm [4-6] model (3) reproduces indicators of a particular subject, on the basis of which it was built, on the condition, that at the starting moment of time ($k=1$) the corresponding input variable is equal to 1, and all others - equal to zero. So for the second and third subject, the vectors of the input variables are respectively:

$$\vec{v}^{(1)} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \text{ i } \vec{v}^{(1)} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}. \qquad (5)$$

For all other moments of time ($k=2,3,...$) all components of the input vector must be zero.

Reduction of the share in all segments in the market of an individual entity simulating by replacing the value of the corresponding component in the vector $\vec{v}^{(1)}$, namely: the value 1 is replaced by the value α ($0<\alpha<1$). The smaller the value α, the faster is the process of leaving this subject of the CE market.

Vice versa, capturing part of the share market by specific subject, which previously belonged to another entity, are described by replacing the value of the corresponding component in the vector $\vec{v}^{(1)}$ on β ($\beta>1$).

For a general case let's write a vector $\vec{v}^{(1)}$ with the correction function $g(\xi_1,\xi_0)$, where ξ_0 i ξ_1 – respectively market shares, which the subject takes before and after changing certain condition. Finally vector $\vec{v}^{(1)}$ will have the following generalized form:

$$\vec{v}^{(1)} = \begin{pmatrix} 0 \\ 0 \\ \vdots \\ g(\xi_1,\xi_0) \\ \vdots \\ 0 \end{pmatrix}, \qquad (6)$$

where $g(\xi_1,\xi_0) = \begin{cases} 1, & \xi_1 = \xi_0 \\ \alpha, & \xi_1 < \xi_0 \\ \beta, & \xi_1 > \xi_0 \end{cases}$.

Therefore, we'll assume, that subject 3 has rapidly reduced its presence in the CE retail market. Let this be decreased 70%. This means that in this case, the correction function $g(\xi_1,\xi_0)$ has value $\alpha=0{,}3$. By introducing such a value into the main model (1) we obtaining foreseen market shares in different segments for this subject, namely: PC segment – - 0,4%, laptop segment – 3,2%, displays segment – 0,4%, MFD segment – 1,6%.

If entity 2 can individually capture that market share, which entity 3 has left, so this means, that the correction function for it considering his total share for all segments will have value $\beta=1{,}15$. As a result of foreseeing, we obtain the following values for different segments of the market: PC segment – 9,4%, laptop segment – 24,2%, displays segment – 27,3%, MFD segment – 24,4%.

For such values α and β, segments modeling error are within the range limits [0,6%;4,3%].

In terms of practice, it is unlikely, that entity 2 alone captures all market shares, which entity 3 has left. Most likely, this circumstance will be used by other entities. In our case, this is the subject 1 (consumer electronics) and subject 4 (the enterprise B2B sector). If we assume, that released market share by subject 3 is divided between subjects 1, 2 i 4 in proportions 5:2:3, so the corresponding values of the correction functions will be: $\beta_1=1{,}35$, $\beta_1=1{,}14$, $\beta_1=1{,}21$. For such correction function values, after optimization procedures use by the method [7-11] with restriction, which are within [0,4%;4,5%], we get a forecast of market distribution by segments.

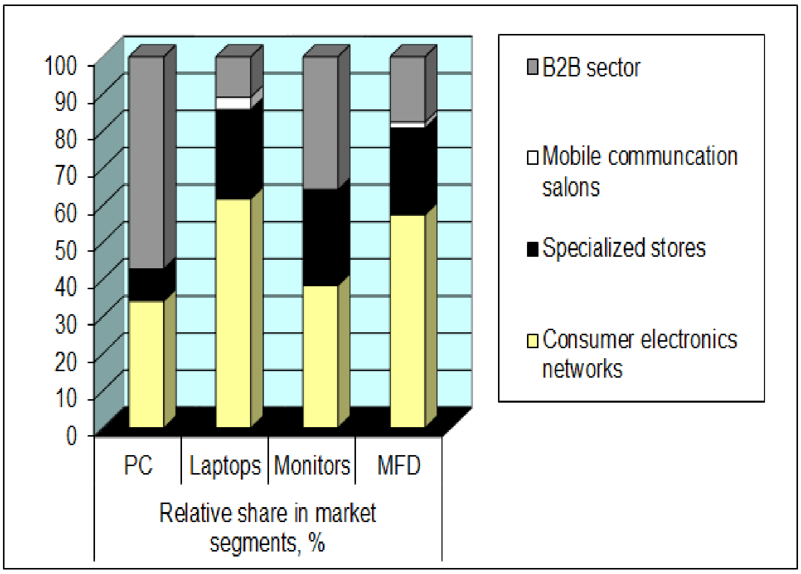

Fig. 1. Estimated distribution of the CE retail market.

Consequently, the introduction into the model (1) the correction function allows to adequately describe the processes in the retail market of CE in case of trends changes.

IV. Conclusion

The instability of the situation on the retail market of CE due to various factors, in particular the rapid development of IT. This complicates the simulation of those processes, which are happening on it, since existing models do not count technological changes in IT industry, and corresponding changes in the structure of the market. Therefore, these models should be modified by introducing correction functions to them.

The correctional functions proposed in this research, make it possible to predict the distribution of the retail CE market for y segments between entities in the case of abrupt changes in the tendencies of its functioning. Namely: in the case of a certain subject's refusal to trade in a particular type of CE, and in the case of a rapid decrease in the presence of the entity in all segments of the market.

In the future studies non-linearity of segmental redistribution of the market between entities should be taken into account. To do this, you need to switch to a more complex form of the main model, for example, bilinear. However, such approach is suitable not for all cases. Therefore, in further researches, the structure identification methods based on inductive approach will be used to choose the model [12]. Also, it is advisable to take into account the uncertainty of given data, scilicet, their variety on different intervals.

References

[1] I. Voytyuk, M. Dyvak, V. Spilchuk, “Research of quality characteristics of models structure in kind of interval difference operator”, Proceedings of International Conference CADSM’2011, Polyana-Svalyava, 2011, pp. 87.

[2] N. Porplytsya, M. Dyvak, I. Spivak, I. Voytyuk, “Mathematical and algorithmic foundations for implementation of the method for structure identification of interval difference operator based on functioning of bee colony”, Proceedings of International Conference CADSM’2015, Lviv, Ukraine, 2015, pp. 196-199.

[3] N. Melnyk, M. Dyvak, “Modeling of the dynamics distribution model by retail computer market segments”, Lviv national university herald. Economical series, Lviv, 2016, Edition 53, pp. 150-157.

[4] R.E. Kalman, P.L. Falb, M.A. Arbib, Topics in mathematical system theory. McGraw Hill Book Co, 1969.

[5] Bowden, R.: The theory of parametric identification. Econometrica 41, 1069–1074 (1973).

[6] Graupe, D.: Identification of systems. Technology & Engineering (1976).

[7] P.H. Stakhiv, Y.Y. Kozak, O.P. Hoholyuk, “Discrete macromodeling in electrical engineering and related fields”, monograph: Lviv Polytechnic Publishing House, 2014. – 260 p.

[8] E. Rosolowski, P. Stakhiv, O. Hoholyuk, "Prospects of discrete macromodels usage for calculation of electric power systems modes", Modern Problems of Radio Engineering, Telecommunications and Computer Science, Proceedings of the 13th International Conference on TCSET’ 2016, Lviv-Slavsko, p.55-57.

[9] Rastrigin, L.A.: A random search. Znanie, Moscow (1979). (in Russian)

[10] Rastrigin L.A.: Adaptation of complex systems. Zinatne, Riga (1981). (in Russian)

[11] I. Calishchuc, M. Dyvak, P. Stakchiv, "Identyfikacja dynamicznego modelu obwodu elektrycznego na podstawie danych interwałowych", Przegląd Elektro-techniczny, Nr. 2/2005, pp. 60-62.

[12] Ivakhnenko A.G., “The inductive method for self-organization of models of complex systems” Naukova Dumka, 1981, 296pp. (in Russian).