MATHEMATICAL SIMULATION FOR ASSESSMENT OF THE SMALL BUSINESS EFFICIENCY: REGIONAL ASPECTS

Oleksandr Zamkovyy
+380501643344
sash411@ukr.net
National Mining University
Department of Economic Analysis and Finance
Finance and credit

Mathematical simulation of economic systems and processes are considered. The description of macroeconomic models for assets formation, consumer behaviour, production activity of an enterprise, and market balance is given. The line balance model of diversified economic system is examined.

Key words: mathematical simulation, market balance, neural network, parameters, algorithm

Introduction

One of the main problems of the economic development of the state comprises underdevelopment, uncertainty and imperfection of the financial system. Current financial and economic situation in Ukraine is complicated and ambiguous. Particularly, this concerns small and medium enterprises as an important link in managing the state; for them the issue of choosing the ways of stabilization, promotion of competitiveness, solvability, financial persistence and profitability is still urgent.

Under current conditions of the development of management concepts and formation of efficient technologies of financial management and financial analysis of enterprises, new approaches to the improvement of their organization forms, management systems and information instruments are of great interest. Every event which reflects inadequate changes of the external environment and does not coincide with the goals of an enterprise's development, poses a threat for it and can turn into a management problem in some cases.

Nowadays, most business process automation systems (OLAP-systems) allow obtaining certain analysis reports [9]. However, all of them feature one disadvantage: a report type is fixed and, as a rule, requires involving computer programmers and automation department employees to change it.

Answers to the problems defined have been obtained partly in works on mathematical economics [1;2]. However, the approaches regarded are not complex and do not consider all the variety of market problems within one complex model. This has resulted in the fact that research in the economics faces a certain crisis [3;4]. To find a way out of the crisis, it is worth developing general mathematical models of the modern market economy and their computer simulation [5;6]. Renowned models of Leontiev and von Neumann considerably simplify the current reality where tasks of balanced economic growth are mainly solved for fixed technologies [10]. The number of market participants is limited and functions of its participants such as banks and the state definitely are not determined.

Models of Valras [5] do not determine apparently strategy-preserving utility functions which are to be defined for each consumer. The volume of useful information for market participants regarding their developing efficient managerial decision is limited. Some modern research studies use optimal control models or game theory to simulate the market economy, but their numerical implementation for the virtual amount of problem space is problematic. All this requires the development of new mathematical market models which would correspond to the current reality to a greater extent.

Research analysis

Section 1 Dynamic model of the market economy with all market participants

Mathematical simulation is one of the main instruments of managing economic systems which involves developing methods of solving optimization problems and studying the results obtained.

To consider this issue under conditions of today's challenges in more detail, it is worth introducing a dynamic model of the market economy with all market participants: raw material suppliers, manufacturers, consumers, banks and the state. As opposed to classic models, consumers are characterized by a market niche according to a product rather than by the strategy-preserving utility function [8].

The input data for the mathematical model are as follows: a market participant's initial capital, an initial price, a market niche according to a product, technological matrix, interest rate on credits, deposits and securities, budget distribution proportion. The mathematical model describes an interaction of all the market participants within a specified amount of real time and appears as follows. It is necessary to maximize manufacturers' returns:

$$max\{\sum_{i=1}^{n}\sum_{j=1}^{m}\left(p_i y_{ij} - s_i x_{ij}\right) + A_1(m) - B_1(m) - G_1(m) + H_1(m) + V(m) - W(m) - Q(m)\} \quad (1)$$

under restrictions (suppliers' income is non-deductible):

$$\sum_{i=1}^{N}\sum_{j=1}^{k} s_i^0 u_{ij} \le Q_0 + \sum_{i=1}^{N}\sum_{j=1}^{k-1} p_i^0 z_{ij} + A_0(k) - B_0(k-1) - G_0(k) + H_0(k-1) - Q_0(k) \quad (2)$$

manufacturers income is non-deductible

$$\sum_{i=1}^{n}\sum_{j=1}^{k} s_i x_{ij} \le \sum_{i=1}^{n}\sum_{j=1}^{k-1} \delta p_i y_{ij} + A_1(k) - B_1(k-1) + V(k) - W(k-1) - G_1(k) + H_1(k-1) - Q_1(k) \quad (3)$$

consumers' income is non-deductible

$$\sum_{i=1}^{n}\sum_{j=1}^{k-1} p_i y_{ik} \le P + \sum_{i=1}^{n}\sum_{j=1}^{k} o s_i x_{ij} - A_2(k) - B_2(k-1) - G_2(k) + H_2(k-1) + u(1+\sigma)Q(k) \quad (4)$$

banks' income is non-deductible

$$K + (1-\beta)(-A(k) + B(k-1) + G(k) - H(k-1) + \sum_{i=1}^{n}\sum_{j=1}^{k} \gamma s_i x_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{k-1} \gamma p_i y_{ij} - M(k) + O(k-1)) \ge 0 \quad (5)$$

budget income is non-deductible

$$V(k) - W(k-1) - M(k) + O(k-1) \le R + v(1+\sigma)Q(k) \quad (6)$$

throughout k = 1,..., m.

The parameters of the model are:

n is the number of types of merchandise,

m is the number of manufacturing cycles,

$Q0$ is raw material suppliers' initial capital,

Q is manufacturers' initial capital,

P is consumers' initial capital,

K is banks' initial capital,

R is the initial capital of the budget,

xij is the volume of i goods manufactured over a j period,

yij is the volume of i goods realized over a j period,

$si0$ stands for expenditures on the production of i goods by suppliers,

$pi0$ is the price of suppliers' i goods,

si stands for expenditures on the production of i goods,

pi is the price of i goods,

Ri is a market niche for i goods,

$A0(k)$ stands for loans obtained by suppliers from commercial banks over k periods,

$A1(k)$ stands for loans obtained by manufacturers from commercial banks over k periods,

$A2(k)$ stands for loans obtained by consumers from commercial banks over k periods,

$B0(k)$ stands for suppliers' reimbursed loans including the interest over k periods,

$B1(k)$ stands for manufacturers' reimbursed loans including the interest over k periods,

$B2(k)$ stands for consumers' reimbursed loans including the interest over k periods,

$V(k)$ the central bank loans obtained by manufacturers over k periods,

$W(k)$ stands for manufacturers' reimbursed loans including the interest over k periods,

$G0(k)$ stands for deposits delivered to banks by suppliers over k periods,

$G1(k)$ stands for deposits delivered to banks by manufacturers over k periods,

$G2(k)$ stands for deposits delivered to banks by consumers over k periods,

$H0(k)$ stands for deposits returned to suppliers including interest earned over k periods (the interest is charged at the end of every period),

$H1(k)$ stands for deposits returned to manufacturers including interest earned over k periods (the interest is charged at the end of every period),

$H2(k)$ stands for deposits returned to consumers including interest earned over k periods (the interest is charged at the end of every period),

$Q0(k)$ stands for supplier taxes over k periods,

$Q1(k)$ stands for business taxes over k periods,

$M(k)$ stands for securities sold by the central bank to commercial banks over k periods,

$O(k)$ stands for returned securities including interest earned over k periods (the interest is charged at the end of every period),

α is a part of manufacturers' expenses which return to the market as salaries and wages,

β is a part of commercial banks' assets which make expenses and reserves,

γ is a part of commercial banks' deductions from account activities,

δ is a part of business profits intended for investment,

σ is a part of the budget made of non-taxable income,

u is the expenditure (social) budget,

v is a part of the budget intended as investment.

The market niche according to a product cannot be overfull during the planning period

$$\sum_{i=1}^{m} y_{ij} \leq R_i, \quad i = 1,2, \ldots . n \qquad (7)$$

The market economy operates during a series of m production intervals. The volume of goods manufactured regarding each from n goods is defined through a technological matrix A of an n×N order with the formula x= Az (or x= (I– A)z) [12].

The output parameters of the model considered within every production interval are: uij – volumes of raw products of i form over a j period, zij – product supply to manufacturers, production and disposal of goods (xij, $y\ ij$), volumes of loans, deposits, securities, budget income and expenditure.

Section 2 Equilibrium in the system with limited resources

Up to now we have considered the behaviour of two subjects of the economy, the consumer and the manufacturer, being isolated. Now it is worth analysing their interaction within a larger structure, namely, the market. The interaction of subjects leads to the concept of balance. To a wide extent, the equilibrium, when subjects with diverging interests interact, is the condition of the system (in politics or economics) which suits all its participants in the absence of better conditions. For particular cases, more specific definitions of equilibrium notion are given.

Let us assume that the system has a few participants with diverging interests. The implementation of each participant's objectives depends on both their activities and those of other participants. Moreover, the participants operate regardless of one another and do not exchange the information on predictable actions. As a result, each participant should assume that other participants of the process operate properly regarding themselves. In this case, the system state is balanced when deviation of any participant from the system with permanent behaviour of the others deteriorates their own state. This is the definition of equilibrium by Nash. A particular case of equilibrium for two participants with divergent interests according to Nash is saddle-node equilibrium. This concept is widely used in the game theory, which is within a range of interests of one of economic and mathematical disciplines, which is operations research [8].

If the participants of the process, whose interests do not coincide, can exchange the information on predictable actions, the equilibrium can emerge as a result of the following situation: one participant's information on their predictable actions, which do harm to other participants, meets corresponding information on predictable counteracting and this makes the participant refrain from any actions. Such equilibrium often occurs in politics.

Regarding market models, equilibrium means equation of product demand D and supply S at a certain price p*. The corresponding price is called an equilibrium price. The mathematical expression of equilibrium is

$$D(p^*) = S(p^*) \tag{8}$$

The graphic illustration of this definition (providing goods are regular) is given in Fig.1.

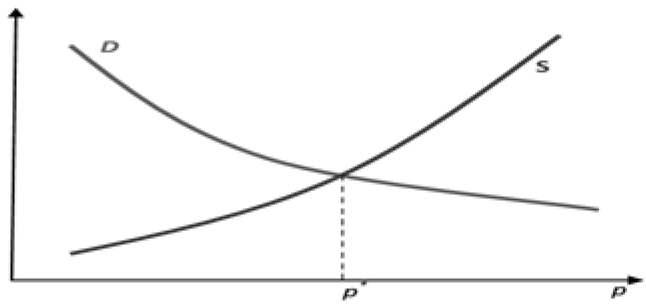

Fig.1. Equation of demand and supply

The equilibrium price p* is defined influenced by factors of production and consumption. On the part of the manufacturer, it is influenced by considerable production expenditures; on the part of the consumer, it is influenced by the consumer's income and comparative utility of goods. To the widest extent possible, equilibrium is any condition when excess demand E = D – S is not positive:

$$D - S \leq 0. \quad (9)$$

The problem considered describes a process of manufacturing goods through the use of the supply functions upon which considerable constraints are imposed. To consider a more complex economic structure which takes limited resources of production into account, it is necessary to become acquainted with a new class of mathematical optimization problems. Let us consider a problem of convex programming. Its description is as follows.

It is necessary to maximize a concave function of *N* variables

$$f(x_1, x_2, \dots, x_j, \dots, x_N) \rightarrow max \quad (10)$$

Under the following conditions:

1) all variables $xj \geq 0$;

2) inequality gi(x1, x2, …, xN) ≥0, (i = 1, 2,…, M) is fulfilled;

3) all the functions gi are concave.

Let us remind that a function is concave if the second derivative is strictly negative almost everywhere (for functions with several variables, second derivatives are negative throughout all the arguments).

Essential and sufficient conditions of solving this problem are defined by Kuhn-Tucker theorem:

To make the point (vector) x* = (x1*, x2*, …, xN*) the solution of the problem of convex programming, it is necessary and sufficient to have such a point (vector) u* = (u1*, u2*, …, ui, …, uM), that a couple of points x*, u* can create a nonnegative saddle point of the Lagrange function

$$L(x, u) = f(x) + \sum_{i=1}^{M} u_i g_i(x) \quad (11)$$

This means that provided deviation of any constituent of the vector x from the given point, the function *L(x, u)* decreases, while the deviation of any constituent of the vector x from the same given point increases:

$$L(x, u^*) \leq L(x^*, u^*) \leq L(x^*, u) \quad (12)$$

To find a saddle point of the Lagrange function, various iteration algorithms are applied (algorithms of progressive approximation). The economic model applies the algorithm (model) of Arrow-Gurvits. The procedure is conducted through steps and at every (1+1)-step the values of unknown variables xj and parameters ui are defined through the previous values of these variables (at 1-step) through the formulas:

$$(x_j)_{i=1} = max\left\{0; (x_j)_i + \alpha_j\left[(\frac{\partial f}{\partial x_j})_l + \sum_{i=1}^{M}(u_i)_l(\frac{\partial g_i}{\partial x_j})\right]\right\} \quad (13)$$

$$(u_i)_{l+1} = max\{0;\ (u_i)_l - \beta_i g_i(x_l)\} \quad (14)$$

The positive parameters αj and βi are called adaptation parameters and should be selected as relatively small; otherwise the search process will lose its stability. The end of search occurs when the difference of the determined values of variables xj and parameters ui from the previous ones becomes sufficiently small. The main variants of the finishing condition are:

$$\sum_{j=1}^{N}\left[(x_j)_{l+1} - (x_j)_l\right]^2 < \varepsilon \quad (15)$$

or

$$max_j\left|(x_j)_{l+1} - (x_j)_l\right| < \varepsilon \quad (16)$$

where ε is a small quantity selected in advance.

The vector x obtained in the course of evaluation determines the solution to the problem, while the vector components characterize relative importance of the problem restriction.

It is worth mentioning that regarding the problem under analysis, the algorithm of Arrow-Gurvits is an algorithm of "trying" the optimal resolution [11].

Let us consider a complicated economic system consisting of a consumer sector, a producing sector and a resource sector.

We assume that N of goods (amenities) are traded on the market. The set of these goods x = (x1, x2, …, xj, …, xN) is described with a single strategy-preserving utility function

$$U(x_1, x_2, \dots x_j, \dots, x_N) \quad (17)$$

The structure of the producing sector is as follows. Goods are produced by a certain manufacturer to the number of yj (j= 1, 2, …, N). The level of production is defined with the production function

$$y_j = f_j(r_{j1}, r_{j2}, \dots, r_{jk}, \dots, r_{jK}), \quad (j = 1,2, \dots, N) \quad (18)$$

where rjk stands for k-input requirements (k = 1,2, …, K) for manufacturing j-products (goods).

The structure of the resource sector is described with volumes of Rk resources intended to be used in the producing sector. Obvious restrictions are imposed on the resource usage

$$\sum_{j=1}^{N} r_{jk} \le R_k, \quad (\text{for all } k) \quad (19)$$

The equilibrium position (to a wide extent) is defined as the following proportion between demand x and supply y simultaneously for every product:

$$x_j \le y_j\,, \quad (j = 1,2, \dots, N) \quad (20)$$

It is necessary to find such values of consumption xj with which the single strategy-preserving utility function $U(x)$ will be highest and both conditions of limited resources and equilibrium conditions (19) will be fulfilled. Considering (17) we get the following mathematical notation of the problem

$$U(x_1, x_2, \dots, x_N) \to max \quad (21)$$

under the condition

$$f_j(r_j) - x_j \ge 0, j = 1,2, \dots, N,$$

$$R_k - \sum_{j=1}^{N} r_{jk} \ge 0,\ k = 1,2, \dots, K$$

$$x_j \ge 0, \quad r_{jk} \ge 0 \quad (22)$$

It is easy to see that the given problem is a particular case of convex programming problem. The strategy-preserving utility function U acts as the target function f in this case, while the constraint function gi can be expressed as follows

$$\overline{g_j} = f_j(r_j) - x_j \quad (23)$$

and

$$\overline{\overline{g_k}} = R_k - \sum_{j=1}^{N} r_{jk} \quad (24)$$

Then the Lagrange function for this problem looks as follows

$$L(x,p,w) = U(x) + \sum_{j=1}^{N} p_j\left[f_j(r_j) - x_j\right] + \sum_{k=1}^{K} w_k\left(R_k - \sum_{j=1}^{N} r_{jk}\right) \quad (25)$$

This function contains two vectors of the Lagrange multipliers. The components of the vector p = (p1, p2, …, pj, …, pN) have a meaning of optimum prices for different products. The components of the vector w = (w1, w2, …, wk, …, wK) correspond to the evaluation of the resources used in the production, namely, material, or raw material, resources (then wk is the price on a raw material item), labour, or human, resources (then wk is the rate of remuneration), financial (then the corresponding argument assigns evaluation of the cost of capital services – bank interest rate) etc. The rjk values – k-resource expenses for output of j-products – make an extra group of the auxiliary unknown.

The iterative formulas for search of the optimal market parameters in this case look as follows

$$(x_j)_{l+1} = max\left\{0;\ (x_j)_l + \alpha_j\left[\left(\frac{\partial U}{\partial x_j}\right)_l - (p_j)_l\right]\right\} \quad (26)$$

$$(r_{jk})_{l+1} = max\left\{0; (r_{jk})_l + \beta_{jk}\left[(p_j)_l\left(\frac{\partial f_j}{\partial r_{jk}}\right)_l - (w_i)_l\right]\right\} \quad (27)$$

$$(p_j)_{l+1} = max\{0;\ (p_i)_l - \gamma_j\left[(f_j(r_j))_l - (x_j)_l\right]\} \quad (28)$$

$$(w_k)_{l+1} = max\{0;\ (w_k)_l - \delta_k\left[R_k - \sum_{j=1}^{N}(r_{jk})_l\right]\} \quad (29)$$

This iterative process quite precisely simulates the market mechanism of achieving the equilibrium by varying volumes of demand for goods (amenities) and resources as well as the values of corresponding prices. Certain steps of the iterative process correspond to selling days.

Section 3. Neural networks – intensification of managing the process of decision making

According to the foreign and domestic experts in the field of simulating financial markets, there are over 100 methods of forecasting the indicators of dynamics of the processes which occur in the financial market.

The number of the basic prognostics methods which can be found in one form or another in other methods is much smaller. Many of these "methods" refer rather to particular techniques or procedures of forecasting, others present a set of particular techniques which differ from the basic ones or one from another in the number of special techniques and subsequence of their usage.

The neural networks are mathematical models as well as their software implementation built on the principle of organization and functioning of biological neural networks – the networks of neuronal cells of a living organism. This concept appeared when the processes occurring in the brain were studied and an attempt was made to simulate these processes. The neural networks of McCulloch and Pitts became the first attempt of the kind [7;10]. Later after the development of learning algorithms, the models were used for practical purposes: in forecasting problems, pattern identification, in management problems, etc. Most concepts which refer to neural networks methods are best explained in terms of particular neural network software. Thus, it is worth considering the STATISTICA Neural Networks package (abbreviated, ST Neural Networks, a neural-network pack of StatSoft company), which is realization of all the range of neural-network methods of data analysis. The recent years have witnessed burst of interest in neural networks which are successfully implemented in various spheres including business, medicine, engineering, geology, physics, etc. The neural networks have come into practice almost everywhere where problems of forecasting, classifying or managing are to be solved. Such tremendous success is defined by a number of reasons:

- neural networks are an exceptionally powerful method of modelling which allows simulating extremely complicated dependencies. In particular, neural networks are nonlinear in their nature (this concept is explained in detail further in the section). Linear modelling is one of the main simulation methods in most areas, since procedures of optimisation have been well developed for it. In tasks where linear approximation is unsatisfactory (there are quite a lot of them), linear models work badly.
- neural networks are studied via examples. A neural network user puts representative data together and then runs the learning algorithm which recognises the data structure automatically. At the same time a user is supposed to have certain heuristic knowledge of how to select and then prepare data, to choose required architecture in the networks and interpret the results; however, knowledge level required for successful implementation of neural networks can be lower than that required for the use of conventional statistical techniques.
- neural networks are attractive a tentative point of view, since they are based on the primitive biological model of nervous systems. In the future, the development of such neural biological models can result in creation of virtually thinking computers. Meanwhile, “simple” neural networks, which the ST Neural Networks system develops, are powerful tools for an expert in applied statistics [7]. Apart from this, the network may have even more intermediate (hidden) neurons which fulfil internal functions. Input, hidden and output neurons are to be interconnected. The key question here concerns inverse relationship.

The simplest network has a structure of direct signal transmission: signals come from the inputs through the hidden elements and finally come to the output elements. This structure features stable behaviour. If the network is recurrent (i.e. it has connections that allow conveying information to the farthest neurons), it can be unstable and have complicated dynamics of behaviour [15]. The recurrent networks are of great interest for researchers in the field of neural networks; yet while solving practical problems, at least up to now, the structures of direct transmission have appeared to be the most useful and this particular kind of neural network is simulated in the ST Neural Networks package.

The networks in which neurons are connected only with the neurons of the previous level could also be considered. However, the networks with a complete system of connections are better for most applications; thus, the ST Neural Networks package implements these networks.

When the network is operating (being used), values of input variables are sent to the input elements and then, consequentially, the neurons of the intermediate and output levels work out. Each of them calculates its activation value taking the weighted sum of outputs of the elements of the previous level and subtracting the threshold value from it. Then, the activation values are converted by the activation function and, as a result, a neuron output occurs. After the whole network works off, the output values of the output level elements are assumed to be the output of the whole network.

There is another important condition of implementing the neural networks: it is essential to know (or at least have a strong suspicion) that there is a certain connection between acquainted input values and unknown outputs.

This connection can become noisy (hardly anyone can expect an absolutely accurate forecast to be developed based on data examples of stock price forecasting, since the price can be influenced by other factors not presented in the input data set; moreover, the problem has an element of randomness), but it is to be available.

As a rule, the neural network is applied when the precise connection between inputs and outputs is unknown; if it was known, the connection could be simulated directly. Another essential peculiarity of the neural networks is the dependence between the input and output in the process of training networks. To train the neural networks two types of algorithms are used (different networks use different types of training): supervised learning ("learning with a teacher") and unsupervised learning ("without a teacher"). Learning with a teacher is used more frequently [12;14].

To apply to the supervised learning, a user should prepare a set of learning data. These data are examples of input data and corresponding outputs. The network trains to establish connections between them. As a rule, the learning data are taken from historical intelligence. Then the neural network is learnt through a particular algorithm of the supervised learning (the back propagation technique is the most well-known algorithm) when available data are used to correct demerits and threshold values of the network to minimize forecast errors.

If the network is trained well, it gains an ability to simulate a (unknown) function which connects values of input and output variables and later this network can be applied for forecasting in situations when output values are unknown.

If a problem is to be solved with a neural network, it is necessary to collect data for training. The training data set is a set of observations for which values of input and output variables are denoted. The first issue to be solved is which variables are to be used and how many (and which) observations to collect.

The selection of variables (at least the initial one) is done intuitively. The relevant experience in this field helps to decide which variables are important. Working with the ST Neural Networks package, it is possible to select variables arbitrarily and deselect them. Moreover, the ST Neural Networks system itself is able to select useful variables by test. To begin with, it is worth including all the variables which, in an analyst's point of view, can affect the result.

The neural networks can work with numeric data which are within a certain limited range. This causes problems when the data are of non-standard scale, when they have missing values and when the data are non-numeric. The ST Neural Networks package has arrangements which allow coping with all these difficulties. The numeric date are scaled within the relevant range, and missing values can be replaced by average values (or by other statistics) of this variable according to all the instructional samples available.

The issue concerning the number of observations required to train the network often appears to be a difficult one. A distinguished set of heuristic rules which connect the number of the observations needed with network sizes (the simplest one testifies that the number of observations should be ten times as great as the number of links in a network). In fact, this number also depends on (unknown in advance) the degree of complexity of denotation of an item which the network is trying to simulate. With quite a small (for instance, fifty) number of variables, an abundance of observations may be needed.

For most real-world problems a few hundreds or thousands of observations provide a sufficient number. For especially difficult tasks, even a larger number can be required whereas tasks for which fewer than a hundred observations can be sufficient hardly ever occur (even trivial ones). If there are fewer data, there is not enough information to train the network, and the best thing that can be done is to adjust a certain linear model to the data. The ST Neural Networks package actualizes methods of adjusting linear models.

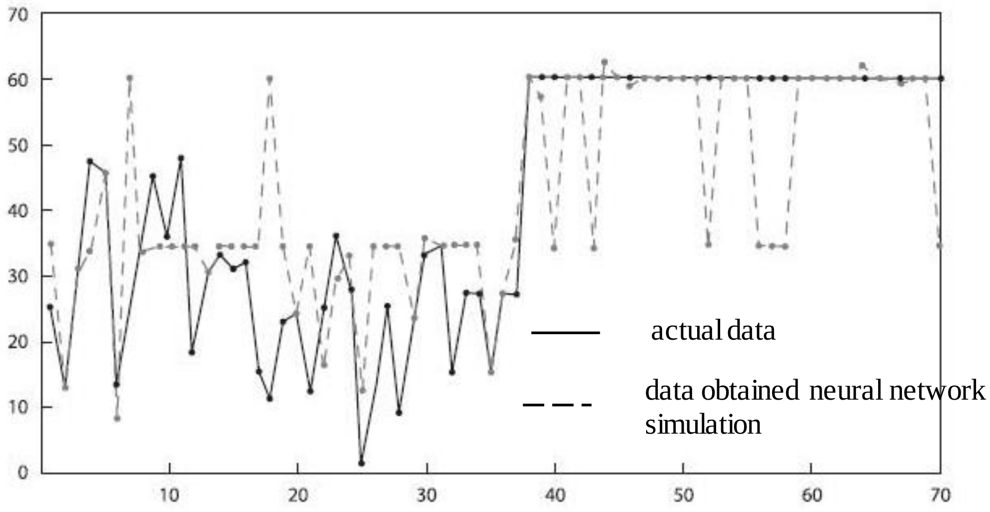

Fig.2. Time forecast in months till market equilibrium advent

In most real-world problems one has to deal with data which is not entirely indubitable. Values of certain variables can become noisy or partially missing. The ST Neural Networks have special methods of working with missing values (as it has been mentioned above, they can be replaced by average values of this variable or by its other statistics). If there are not so many data, cases with missing values can be taken into consideration. Apart from this, neural networks are usually resistant to noise. However, the resistance is limited [13].

For example, drops, i.e. values which are far from the area of ordinary values of a certain variable, can misrepresent training results. In such situations it is necessary to find out and remove these drops (either by removing relevant observations or converting drops into missing values). If it is difficult to find out drops, one can use the means available in the ST Neural Networks package to make the training process resistant to drops; however, such training which is resistant to drops is, as a rule, less efficient than ordinary training.

Conclusions

The article suggests a conception of a complex of mathematical simulations to evaluate instruments of regulating the development of small business and making management decisions regarding the issues of small business development.

The functioning practice of small and medium-size businesses requires an efficient mechanism which will contribute to solving complicated business problems. That is why implementation of conceptual issues of the developed methods and recommended advanced information technologies which can assist in solving current issues is essential.

The approach suggested regards simulation of functioning and development of small enterprises under conditions of uncertainty caused by factors of different nature. It is based on a system paradigm and considers rational and adaptive mechanisms of formation of enterprises' expectations regarding future factors of market conditions and the process of making management decisions on the basis of system characteristics.

The article substantiates practicability of applying a combination of fuzzy and stochastic measures of uncertainty in simulating the dynamics of key indicators of a small enterprise's functioning under conditions of uncertainty which has a complicated structure. It will allow obtaining economic effect both at the regional and nationwide levels.

References

1. Ekonomiko-matematicheskoe modelirovanie: uchebnoe posobie / I. V. Levandovskaya, I. S. Dmitrenko, O.N. Kuznetsova, N.S. Grudkina. – Kramatorsk: DGMA, 2008. – 48 s

2. Ekonomiko-matematicheskie modeli: uchebnoe posobie / E.Yu. Liskina; Ryaz. gos. un-t im. S.A. Esenina. – Ryazan, 2009. – 110 s.

3. Nakonechniy S.I., Savina S.S. Matematichne programuvannya: Navch. posib. — K.: KNEU, 2003. — 452 s.

4. Hristianovskiy V.V. Ekonomiko-matematicheskie metody i modeli: teoriya i praktika: ucheb. posob. / V.V. Hristianovskiy, V.P. Scherbina. – Donetsk: DonNU, 2010. – 335 s.

5.Semenova E.G., Smirnova M.S. Osnovyi ekonometricheskogo analiza: ucheb. posobie / E.G. Semenova, M.S. Smirnova; GUAP. – SPb., 2006. – 72 s.: il

6.Modeli i metodi sotsialno-ekonomichnogo prognozuvannya: pidruchnik dlya stud. visch. navch. zakl. / V.M. Geets, T.S. Klebanova, O.I. Chernyak ta in.; Harkivskiy nats. ekon. un-t. – 2-ge vid. – Harkiv: Inzhek, 2008. – 394 s.

7.Lyisenko Yu.G. Neyronnyie seti i geneticheskie algoritmyi: ucheb. posob. dlya studentov ekon. spetsialnostey vuzov/ Yu.G. Lyisenko, N.N. Ivanov, A.Yu. Mints. – Donetsk: Yugo-Vostok, 2003. – 230 s.

8.Kosolap A.I. Vstup do matematichnoyi ekonomiki. Navchalniy posib. / A.I. Kosolap.- Dn-sk: DNU, 2002. -96 s.

9.Kremer N.Sh. Matematika dlya ekonomistov: ot Arifmetiki do Ekonometriki: uchebno-spravochnoe posobie: dlya studentov vyissh. Uchebnyih zavedeniy, obuchayuschihsya po ekonomicheskim spetsialnostyam/ N.Sh. Kremer, B.A. Putko, I.M Trishin; pod red. N.Sh. Kremera. – M.: Vyisshee obrazovanie, 2009. – 646 s.

10.L.Fogel, A.Odens, M. Uolt. Shtuchniy Intelekt ta evolyutsiyne modelyuvannya. — M.: Mir,1969. — S. 166.

11. Vitlinskiy V.V. Modelyuvannya ekonomiki / V.V. Vitlinskiy. – K.: KNEU, 2003. – 408s.

12. Ekonomichna teoria: makro- ta mikroekonomika. Navch. posibnik / Za red. Z. Vatamanyuka ta S. Panchishina. – K.: Alternativi, 2001. – 608 s.

13. Kostina N.I. FInansove prognozuvannya: metodi ta modeli / N.I.Kostina, A.A.AlEekseev, O.D. Vasilik –K.: «Znannya», 1997. – 184 s.

14. Klebanova T. S., Raevneva E. V. Strizhichenko K. A., Guryanova L. S., Dubrovina N. A. Matematicheskie modeli transformatsionnoy ekonomiki: Uchebnoe posobie. — H.: ID «INZhEK», 2004. — 280 s.

15. Hachatryan S.R., Pinegina M.V., Buyanov V.P. Metodyi i modeli resheniya ekonomicheskih zadach: Uchebnoe posobie. — M.: Ekzamen, 2005. — 384 s.

16. Perkins R., Brabazon A. Predicting Credit Ratings with a GA-MLP Hybrid // Artificial Neural Networks in Real-Life Applications / Rabunal J. R., Dorrado J. (Eds.). – Hershey – London – Melbourne – Singapore: Idea Group Publishing, 2006. – P. 220–237.