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PREDICTIVE EQUILIBRIUM SOLUTIONS OF THE SYSTEM OF EQUATIONS OF DEMAND AND SUPPLY OF PRODUCTS IN POORLY FORMALIZED PROCESSES

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ABSTRACT

Changes in the market prices of monopolists and other economic entities must be sufficiently justified, i.e. specific reasons for the increase in prices should be indicated, on what basis the increase in prices is expected. In the article a list of tasks to be solved jointly with the marketing service of the company - forecasting the equilibrium price of products, goods and services is proposed with fuzzy initial information.

Keywords: membership functions, soft computing, forecast, equilibrium solutions, demand, supply, marketing, algorithm, farmer's market, labor mark.

INTRODUCTION

Changes in the market prices of monopolists and other economic entities must be sufficiently justified, i.e. specific reasons for the increase in prices should be indicated, on what basis and by what percentage the increase in prices is expected. One of the basic market economic laws is the universal law of supply and demand, which is the basis of marketing. And the practical solution of the marketing problem is the algorithms for the equilibrium solution of the system of supply and demand equations [1].

Due to the limited capabilities of traditional methods of mathematical modeling, when solving poorly formalized problems, data mining technologies are used. They are based on methods of artificial intelligence and, especially, methods of soft computing (Soft Calculation, Soft Computing) and emerging on this theoretical and methodological basis of the direction of

Computational Intelligence - intelligent computing technologies. The main components of these areas are the theory of fuzzy sets, fuzzy inference, genetic algorithms, artificial neural networks and neural network computing. The Computational Intelligence technology makes it possible to obtain solutions with an accuracy acceptable for practice, by learning from available initial data, available in a limited, incomplete volume, and also presented in a qualitative form [4, 5].

The method of forming fuzzy concepts based on the work of Zadeh [3] implies the rejection of the basic confirmation of classical set theory about whether an element belongs to a set or not. In this case, a special characteristic function of the set is introduced, that is, the membership function (MF), which takes values in the range [0,1].

The formation of fuzzy concepts in this way makes it possible to approximate the movement of non-deterministic systems that are difficult to solve using mathematical analysis, classical methods of mathematical modeling. In some cases this will be the only possibility that can be expressed [8-12].

Formulation of the problem

It is proposed, together with the marketing service of the company (JSC, enterprise), to calculate scientifically based predictive equilibrium prices P_n^* and P_i^* of products, goods and services between demand D (consumers, buyers) and supply S (manufacturers, sellers) according to the algorithms developed [1]:

- determination of the contractual price P_n^* between companies when D=S;
- Calculation of the predicted equilibrium price P_n^* between demand D and supply S for purchase and sale by both legal entities and individuals;
- substantiation of prices P_n^* and P_i^* of monopolists and other economic entities, when D=S;
- predictive assessment for price fluctuations P_i^* on commodity and stock exchanges, on farmer's and clothing markets, when D=S;
- predictive estimate for monthly (quarterly) increases or decreases in prices P_i^*, when D=S.

The marketing service of the company (JSC, enterprise) will need to determine:

- general formulation or statement of the problem;
- the initial (initial) price P of products (goods, services) and give what it was formed from, its decoding;
- reasons for the price increase;
- expected inflation I;
- the price forecast P and the volume of goods Q of consumer D and producer S (it is enough to give one P and Q for D and for S).

From these marketing data, it is also possible to make practical calculations of reliably justified forecast equilibrium prices of P_n^* and P_i^* products, goods and services using algorithms [1].

The algorithm for solving the above problem is used for a balanced and sustainable development of the economy, maintaining a balance between demand D and supply S, matching the interests of the consumer (buyer) and producer (seller), increasing trade turnover, observing the Law of supply and demand, when D=S, $p^D=p^S$, $q^D=q^S$, and monetary circulation mV=pQ by regions and the country in the interests of the individual [2].

As an example, consider the application of the Law of Supply and Demand in the labor market. In a market economy, labor power is a commodity. Based on this, demand D is the representation on the labor market of the need for labor, and supply S is the labor force that is on the labor market or can be delivered to it.

Application soft computing to the problem.

A whole section of the theory of fuzzy sets - soft calculations (fuzzy arithmetic) - introduces a set of operations on fuzzy numbers.

The main difficulty when working with fuzzy values lies in the fact that even in the case of the simplest membership functions, as a result of elementary actions performed on them, membership functions of a complex form are formed that require a large number of numerical parameters. Therefore, in many works [6, 7] it is required to approximate the results of the current membership functions and the actions performed on them through the functions of triangles, exponential, trapezoidal of a certain class, which depend on certain numerical parameters. In this case, it is possible to construct a relatively simple basic operation that does not exclude the chosen class of functions from its boundaries.

Bounds of fuzzy number. If the following relation holds for the number a

From these marketing data, one can also make practical calculations of reliably justified predictive equilibrium prices and products, goods and services using algorithms [1].

$$\forall \delta \mu_A = 0; \mu(a-\delta) \neq 0, \mu(a+\delta) \neq 0, \tag{1}$$

then it is called the boundaries of the membership function. If it takes into account that there are two such boundaries: upper(b) and lower (a), then the fuzzy number can be written as follows:

$$A = \int_a^{\bar{a}} (x-a)/x + \int_{\bar{a}}^{b} (b-x)/x. \tag{2}$$

Using (2), it is possible to get the following:

$$A*B = \left(\int_a^{\bar{a}} \mu_A(x)/x + \int_{\bar{a}}^{b} \mu_A(x)/x. \right) ** \left(\int_{a'}^{\bar{a}} \mu_B(x)/x + \int_{\bar{a}}^{b'} \mu_B(x)/x. \right) == \int_{a''}^{\bar{a}*\bar{b}} \mu_{A*B}(x)/x + \int_{\bar{a}*\bar{b}}^{b''} \mu_{A*B}(x)/x. \tag{3}$$

Here a'', b'' are obtained from a, b, and a'', b' are obtained by a certain operation, determined by the operation $\mu_{A*B}(x)$ and normalization μ.

A+B is calculated as following:

$$A+B = \left(\int_a^{\bar{a}} \mu_A(x)/x + \int_{\bar{a}}^{b} \mu_A(x)/x. \right) ++ \left(\int_{a'}^{\bar{a}} \mu_B(x)/x + \int_{\bar{a}}^{b'} \mu_B(x)/x. \right) == \int_{a''}^{\bar{c}} \mu_C(x)/x + \int_{\bar{c}}^{b''} \mu_C(x)/x = C, \tag{4}$$

here

$$\bar{c} = \bar{a} + \bar{b},\ a'' = a + a',\ b'' = b + b'.$$

μ_C is defined as $\mu_C = k_1 x + k_2$. Based on normalization, we can write (4) with respect to $a'' \leq x \leq \bar{c}$ as follows:

$$A+B=\int_{a''}^{\bar{c}} \frac{x-a''}{\bar{c}-a''}\Big/ x+\int_{\bar{c}}^{b''} \frac{b''-x}{b''-\bar{c}}\Big/ x=C. \quad (5)$$

For other fuzzy arithmetic operations, the following can be obtained in a similar way [5]:

$$A-B=\int_{a''}^{\bar{c}} \frac{x-a''}{\bar{c}-a''}\Big/ x+\int_{\bar{c}}^{b''} \frac{b''-x}{b''-\bar{c}}\Big/ x=C, \quad (6)$$

here

$$a''=a-b',\ b''=b-a',\ \bar{c}=\bar{a}-\bar{b}.$$

Taking the membership function in the form $\mu_C=k_1\sqrt{x}+k_2$, the following is obtained:

$$A*B=\int_{a''}^{\bar{c}} \frac{\sqrt{x}-\sqrt{a''}}{\sqrt{\bar{c}}-\sqrt{a''}}\Big/ x+\int_{\bar{c}}^{b''} \frac{\sqrt{b''}-\sqrt{x}}{\sqrt{b''}-\sqrt{\bar{c}}}\Big/ x=C. \quad (7)$$

Here

$$a''=a*a',\ b''=b*b',\ \bar{c}=\bar{a}*\bar{b}.$$

Taking the membership function μ_C as $\mu_C=\frac{k_1}{x}+k_2$,

the following is obtained:

$$A:B=\int_{a''}^{\bar{c}} \frac{(x-a'')\bar{c}}{(\bar{c}-a'')x}\Big/ x+\int_{\bar{c}}^{b''} \frac{(b''-x)\bar{c}}{(b''-\bar{c})x}\Big/ x=C. \quad (8)$$

Here

$$a''=a':a,\ b''=b':b,\ \bar{c}=\bar{b}:\bar{a}.$$

Example. Find the predicted equilibrium amount of labor at the end of the year, if the labor market expects an annual increase in the demand for labor from about 5% to about 7%, and an increase in supply from about 10% to about 30%, with an initial labor force of q_0 = about 1.00 and p_0 = about 1.00 or 100%.

According to the condition of the task, the predicted amount of labor

q_1 = approximately 1.05=[1.05] and q_2 = approximately 1.07=[1.07],

q_3 = approximately 1.10=[1.10] and q_4 = approximately 1.30 =[1.30].

Let's find the forecast labor prices by the formula p=q*tgφ, φ is the polar angle. With a decrease in the price on demand: p_1 =approximately 1.2516=[1.2516], p_2 = =approximately 1.10852=[1.10852] and with an increase in the price on offer: p_3 =approximately 1.06227=[1.06227], p_4 = approximately 1.09083=[1.09083].

Let's make a system of equations of any direct lines of demand and supply of labor:

$$\left.\begin{aligned} p^D &= k_1 q^D + b_1, \\ p^S &= k_2 q^S + b_2 \end{aligned}\right\} \quad (9)$$

where $k_1=\frac{p_2-p_1}{q_2-q_1}$ and $b_1=\frac{p_1 q_2-q_1 p_2}{q_2-q_1}$

$k_2 = \frac{p_4 - p_3}{q_4 - q_3}$ and $b_2 = \frac{p_3 q_4 - q_3 p_4}{q_4 - q_3}$

Using (1) – (8) we find the angular coefficients of the lines of demand k_1 and supply k_2, and the segments cut off by the lines of demand b_1 and offers b_2 on the axis OP:

$$k_1 = \frac{[1{,}10852] - [1{,}2516]}{[1{,}07] - [1{,}05]} = [-7{,}154].$$

1) $[1{,}10852] - [1{,}2516] = [-0{,}14308];$

2) $[1{,}07] - [1{,}05] = [0{,}02];$

3) $[0{,}14308] : [0{,}02] = [-7{,}154].$

(β_1=[-820], directed clockwise, β_1=arctgk1),

$$k_2 = \frac{[1{,}09083] - [1{,}06227]}{[1{,}30] - [1{,}10]} = [0{,}14308].$$

1) $[1{,}09083] - [1{,}06227] = [0{,}02856];$

2) $[1{,}30] - [1{,}10] = [0{,}2];$

3) $[0{,}02856] : [0{,}2] = [0{,}1428].$

(β_2=[80], directed clockwise, β_2=arctgk2),

$$b_1 = \frac{[1{,}2516] * [1{,}07] - [1{,}05] * [1{,}10852]}{[1{,}07] - [1{,}05]} = [9{,}305].$$

1) $[1{,}2516] * [1{,}07] = [1{,}34];$

2) $[1{,}05] * [1{,}10852] = 1{,}1539];$

3) $[1{,}34] - [1{,}1539] = [0{,}1861];$

4) $[1{,}07] - [1{,}05] = [0{,}02];$

5) $[0{,}1861] : [0{,}02] = [9{,}305].$

$$b_2 = \frac{[1{,}06227] * [1{,}30] - [1{,}10] * [1{,}09083]}{[1{,}30] - [1{,}10]} = [0{,}95525]$$

1) $[1{,}06227] * [1{,}30] = [1{,}38095];$

2) $[1{,}10] * [1{,}09083] = [1{,}1999];$

3) $[1{,}38095] - [1{,}1999] = [0{,}19105];$

4) $[1{,}30] - [1{,}10] = [0{,}2];$

5) $[0{,}19105] : [0{,}2] = [0{,}95525].$

Substitute the obtained values k_1, b_1, k_2 and b_2 for the system of equations (9):

$$\left. \begin{aligned} p^D &= [-7{,}154] q^D + [9{,}305], \\ p^S &= [0{,}1428] q^S + [0{,}95525]. \end{aligned} \right\} \quad (10)$$

According to the Law of supply and demand $p^D = p^S$; we rewrite the system of equations (10) in the form:

$$[-7{,}154] q^D + [9{,}305] = [0{,}1428] q^S + [0{,}95525],$$

also, assuming $q^D = q^S = q$, we get

$$q = \frac{[9{,}305] - [0{,}95525]}{[0{,}1428] + [7{,}154]} = [1{,}1443].$$

1) $[9{,}305]-[0{,}95525]=[8{,}34975];$
2) $[9{,}305]-[0{,}95525]=[7{,}2968];$
3) $[8{,}34975]:[7{,}2968]=[1{,}1443]\ or\ [114{,}4]\%.$

So, the predicted equilibrium amount of labor at the end of the year will be [114.4] % with an initial labor force of 100%.

We would get the same thing by solving a system of general equations

$$\left.\begin{aligned} k_1 q - 1 * p + b_1 &= 0, \\ k_2 q - 1 * p + b_2 &= 0 \end{aligned}\right\} \text{ in a matrix way}$$

$$Q = \begin{vmatrix} -1 & b_1 \\ -1 & b_2 \end{vmatrix} : \begin{vmatrix} k_1 & -1 \\ k_2 & -1 \end{vmatrix} = \frac{b_1 - b_2}{k_2 - k_1}.$$

CONCLUSION

The use of the Law of supply and demand in the labor market once again proves the universality of this Law, which is one of the main market economic laws and is the basis of marketing. The algorithm for solving the problem is a practical marketing solution for finding the equilibrium market price, as well as the equilibrium amount of labor in the labor market. Thus, in the article the task of determining the predicted equilibrium number of the workforce at the end of the year with fuzzy information was determined by the method of soft calculations.

The formation of fuzzy concepts in this way makes it possible to approximate the movement of non-deterministic systems that are difficult to solve using mathematical analysis, classical methods of mathematical modeling. In some cases this will be the only possibility that can be expressed. In the end, we note that there is a direct proportionality between the growth rate of gross domestic product and the growth of the predicted equilibrium amount of labor.

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