The use of mathematical methods of analysis in the pharmaceutical area of Kazakhstan

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Abstract: Using the mathematical methods of analysis, the authors found out that the predicted value of the production of pharmaceutical medicines for 2013 year would be equal to 253,2 million U.S. dollars, and for the 2014 - 308,6 million U.S. dollars. It shows the dynamics growth in the pharmaceutical industry of the Republic of Kazakhstan, and has great promise for the future. Besides, with the use of mathematical modeling the authors counted that it was spent 31083,72 tg. (202,96 U.S. dollars) on the average for medicines of one patient in specialized medical institution and the factors influencing the volume of spent money were defined. Considering the dynamics of patients' number growth it was possible to predict the volume of necessary budgetary assignments for the treatment of concrete disease both in area scales, and for the whole republic.
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1. Introduction

The Kazakhstani pharmaceutical branch is one of the major elements of healthcare system and on the threshold of basic changes. In the maximum degree these changes have to be connected with the organization of innovative component, development of import substitution and labor productivity increase. In this regard the question of pharmaceutical branch's state regulation improvement becomes actually explored.

The external environment of the pharmaceutical organizations consists of market, consumers, and competitors. For the practical pharmacy it is important to form the concept of the research including objects, methods and means. It becomes easier using objects, methods and means to obtain necessary information about conditions of the external market environment with the purpose of further development of optimum management decisions for improvement in the sphere of medicine' provision and receiving the maximum profit [1, 2, 3].

The main directions of Kazakhstani pharmaceutical industry's development:

– providing a stable market sales of domestic pharmaceutical and medical products;
– providing pharmaceutical branch with the qualified personnel;
– improvement of standard and legal base;
– trade policy;
– project measures on implementation of the Program of Kazakhstani pharmaceutical industry's development [4].

For further reforming of health care system the Government invented the State development program of the Republic of Kazakhstan (RK) "Salamatty Kazakhstan" for 2011-2015. It is planned to allocate 215,9 billion tg. in total from the republican budget (in 2011 – 71,6 billion tg., in 2012 – 74,9 billion tg., in 2013 – 69,4 billion tg.) [5].

Statistical data for 2002-2012 years shows that the pharmaceutical market is fast-growing sector of Kazakhstan's economy. According to the Agency of Statistics of the RK the consumption of medicines in Kazakhstan in 2012 was 1493,6 million US dollars, comparing to 2011 it had increased by 12,5% (Table 1).

The pharmaceutical market has been dynamically developing since 2002. The average growth of consumption of medicines in Kazakhstan was 25,6% a year nominally in US dollars. The production of pharmaceutical medicines increased by 85% (8,47) in cost terms (USD) in 2012 comparing with the data of 2002. The volume of export was considerable. If in 2012 this figure was equal to 23,9 million US dollars, in 2002 it constituted only 1,4 million US dollars. Generally the wholesale market importers of medicines own. The price for medicines increased for 18,9% in 2009 and for 11,7% in 2010. The main reasons of cost increase in 2009 were tenge

devaluation concerning currencies of the countries and growth of the world prices.

Table 1. The indicators in dynamics of pharmaceutical branch of RK for 2002-2012 years.

Year	Production, mln $	Fixed assets, %	Price level,	Export, mln $	Consuption, mln $	Wholesale turnover, %	Retail turnover, %	Salary, ths tg	Package, $	Investment, bln tg	Population, %	Doctors, ths
	Y	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11
2002	23,2	122	105,3	1,4	196,4	100	100	22,6	0,8	1100	100	53,7
2003	25,9	117	101,5	1,7	233,3	140	102	29	0,8	1327	100,6	54,6
2004	33,1	116	101,2	3,6	330,2	180	108	35,2	1	1703	100,8	54,8
2005	46,2	127	102,1	5,3	439	207	162	37,1	1	2420	101	55,5
2006	62,4	136	102	12,2	517,9	294	158	44	1,2	2824	101,2	57,5
2007	80,3	122	104,8	16,7	645,8	350	193	59,4	1,4	3392	101,1	59,4
2008	84,8	126	109,6	18	763,8	410	205	61,2	1,7	4211	102,6	58,9
2009	84,2	127	120,7	17,1	876,6	400	286	74	1,8	4585	101,4	60,7
2010	131,3	106	160,1	19,3	1152,9	465	337	82,1	2	4654	101,5	63,9
2011	180,4	113	148,8	22,6	1307,6	487	407	90,1	2,3	5010	101,5	65,2
2012	196,5	120	154,2	23,9	1493,6	503	424	101,1	2,5	5455	101,4	65,8
2012 to 2002	8,47	0,98	1,46	17,07	7,60	5,03	4,24	4,47	3,13	4,96	1,01	1,23

Source: compiled by authors on the data of the Agency of Statistics of the RK.

2. Materials and methods

The main direction of marketing researches in pharmaceutical branch is studying of consumers, research and formation of assortment policy, forecasting of medicines' requirement, and also the analysis and forecasting of the pharmaceutical market. Nowadays the forecasting of the market is calculated with mathematical methods [6, 7, 8].

3. Results

The authors studied the dependence of production of pharmaceutical medicines (Y) from 11 factors during 2002-2012 years: fixed assets, % (X1); price level on pharmaceutical production 2001=100, % (X2); export of pharmaceutical production, mln. US dollars (X3); consumption of pharmaceutical production, mln. US dollars (X4); volume of wholesale turnover 2002=100, % (X5); volume of retail turnover 2002=100, % (X6); average monthly nominal salary of the worker, thousand tenge (X7); average price of medicines' package, US dollar (X8); investments into fixed capital, billion tenge (X9); population 2001=100, % (X10); number of doctors, thousand people (X11).

According to statistical data of factors for the period 2002-2012 years the pair coefficients of correlation presented in the form of a correlation matrix pay off. The authors would like to note that the first correlation table showed close connection between these factors, as relationship of factors more than 0,9. This table showed false correlation relationship because there were no economic relationships between some factors according to the contents, in this regard chain growth rates of these factors had been calculated (in %) for the period of 2003-2012 in the second correlation table. By the results of the second correlation table it was revealed that there had been a good correlation relationship between production of pharmaceutical production (Y) and factors of consumption of pharmaceutical production (r_{yx4}=0,51) and number of doctors (r_{yx11}=0,54). These factors directly affected the production of medicines. It could be argued that the statistics showed an increase in the number of patients each year, and thus, there was a demand for drugs, and the state increased the number of doctors.

For making the regression analysis, the authors chose the rate of growth of these factors: the consumption of pharmaceutical production, mln. US dollars (x4) and the number of doctors, thousand people (x11). If the authors considered the sign of a productive relationship with all the factors in this task, it should be noted that among the factors x4 and x11 there was a good correlation, as the multiple correlation coefficient R = 0,75. The coefficient of determination showed that 56% of the variation in production of pharmaceutical products could be explained by changes in the consumption of pharmaceutical products and the number of doctors (coefficient of determination R^2 = 0,56). The resulting equation could be used to predict the pharmaceutical industry's development of the Republic of Kazakhstan, as the null hypothesis had been rejected according to the random nature, statistical significance and reliability of the regression model had been recognized:
(F_{table}=4,26<F_{fact}=4,5; t_{table}=2,2 < t_{b4} =2,27; t_{table} =2,2 < t_{b11} =2,38).

Multivariable regression equation in terms of growth has such form as:
$Y=a+b_4x_4+b_{11}x_{11}=-555,9926+0,9742x_4+5,4998x_{11}$.

Predictive value of Y was calculated for 12 and 13 periods separately, using a polynomial function of factors x4 and x11.

According to the source data for 2002-2012 years (11 periods) authors constituted the dynamic range for factor of the consumption of pharmaceutical production, mln. US dollars (x4), the polynomial function of the form was obtained:
$X4 =8,4212t^2+29,604t+158,38$; $R^2 = 0,99$, (t=0,1, …, 11).

In this case, the authors found that the predictive value of x4 in 2013, when t = 12 was equal to 1726,3 million dollars, the predictive value for 2014 at t = 13 was 1966,4 million dollars.

Followed by the initial data for 2002-2012 years (11 periods) the authors constituted dynamic range for factor of the number of doctors, thousand people (x11), the polynomial function of the form was obtained:
$X11 = 0,0627t^2+0,5385t+52,976$; $R^2 = 0,98$, (t=0,1, …, 11)

According to factor a polynomial function of the number of doctors (x11), predictive value x11 for 2013 at t = 12 was equal to 68,5 thousand people, and the predictive value for x11 for 2014 at t = 13 was equal to 70,6 thousand people.

Due to the fact that the second phase of the work, the authors changed the original data in growth rates and used them throughout the solutions, in the final part of the work the authors needed to find the predicted values of Y in terms of growth, their percentages, and found that Y (%) according to the regression equation $Y = a+b_4x_4 +b_{11}x_{11}=-555,9926+0,9742x_4+5,4998x_{11}$, the predictive value for 2013 at t = 12 would be equal to 128,9% in 2014 and at t = 13 - 121,9%.

It should be noted that the predicted value of Y for the 12th time (2013) the average is equal to 253,2 million U.S. dollars, and the 13th period (2014) the average is equal to 308,6 million U.S. dollars.

Besides, mathematical methods of the analysis are used for the optimum calculation of budgetary assignments' volume of medicines for specialized medical institutions. The second research aim was the development of mathematical model for optimum calculation of budgetary assignments' volume for medicines for specialized medical institutions.

The objects of research were 200 clinical records of therapy N1, therapy N2, therapy N3 and therapy N4 offices of the regional tubercular clinic of South Kazakhstan. In the analysis of clinical records it was established that patients' accompanying disease had joined the main disease that often lead to increase in number of patients' bed days (unit of time stay account in a hospital). The average value of bed days was 89 days a year.

During research it was defined: how much money was planned for treatment of one patient and how many percents were allocated from the planned volume. On the basis of the carried-out analysis the authors established that the volume of medicines was influenced by following factors. There were such as:

– The duration of bed days in the hospital;

– The age of the patient;

– The existence of accompanying diseases.

In this regard the authors carried out the factor analysis and created the polynominal model determining the predicted volume of budgetary assignments. The assessment of the above-stated factors' influence on pharmacotherapy cost in quantitative calculation was made by means of mathematical modeling methods [9, 10].

The following formula was used for this purpose:

$$Y=b_0+\sum_{i=j}^{k} b_i x_i+\sum_{i\rangle j} b_{ij} x_i x_j ;$$

where: b_0 - free number showing the range of factors' change -1<x<+1, it means x=0;

when b_i - the speed of average exit change of dy/dx in the range of -1<x<1;

b_{ij} - effect of interaction considering dialectic contrast in difficult technical and economic system.

On the basis of the executed calculations the volume of cash expenditures on medicines for patients in specialized medical institution was presented in the following three-factorial (Table 2).

Table 2. The volume of cash expenditures on medicines for patients, tg.

Number of bed days in hospital in a year (average)	Information on accompanying diseases of patients			
	No		Yes	
	Till 31 years	Over 31 years	Till 31 years	Over 31 years
Till 89	26 105,24	29 702,58	23 631,89	30 310,42
Over 89	44 045,65	17 109,31	39 001,37	38 763,33

Level of factors change was presented in Table 3.

Table 3. The level of factor change.

№	Factors	Transition level	
		-1	+1
1	Number of days	Till 89	Over 89
2	Age of patient	Till 31 years	Over 31 years
3	Accompanying diseases	No	Yes

The above indicators of tables 2, 3 were the basis for creation of polynominal model.

Table 4. The matrix of calculation and comparison $\overline{Y}_u$ и Y_u

Expense of monetary volume on medicines for the patient (Y_u)	The matrix of calculation							Results	
	X_0	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	$\overline{Y}_u$	fault, %
26105,24	+1	-1	-1	-1	+1	+1	+1	24832,77	5,1%
23631,89	+1	-1	-1	+1	+1	-1	-1	16455,11	43,6 %
29702,58	+1	-1	+1	-1	-1	+1	-1	30975,07	4,1%
30310,42	+1	-1	+1	+1	-1	-1	+1	37487,17	19,1 %
44045,65	+1	+1	-1	-1	-1	-1	+1	36868,89	19,5 %
39001,37	+1	+1	-1	+1	-1	+1	-1	37728,87	3,4%
17109,31	+1	+1	+1	-1	+1	-1	-1	24286,07	29,5 %
38763,33	+1	+1	+1	+1	+1	+1	+1	40035,81	3,2%
Total	0Y 248669,79	1Y 29169,53	2Y 16898,51	3Y 14744,23	12Y - 37450,25	13Y 18475,25	23Y 29779,49		

Inserting the previous values into this model, the authors calculated the following:

X_0Y=26105,24+23631,89+29702,58+30310,42+44045,65+39001,37+17109,31+
+38763,33=248669,79;

X_1Y=-26105,24-23631,89-29702,58-30310,42+44045,65+39001,37+17109,31++38763,33 =29169,53;
X_2Y=-26105,24-23631,89+29702,58+30310,42-44045,65-39001,37+17109,31++38763,33=16898,51;
X_3Y=-26105,24+23631,89-29702,58+30310,42-44045,65+39001,37-17109,31++38763,33=14744,23;
X_1X_2Y=12Y=26105,24+23631,89-29702,58-30310,42-44045,65-39001,37++17109,31+38763,33=-37450,25;
X_1X_3Y=13Y=26105,24-23631,89+29702,58-30310,42-44045,65+39001,37-17109,31+38763,33=18475,25;
X_2X_3Y=23Y=26105,24-23631,89-29702,58+30310,42+44045,65-39001,37-17109,31+38763,33=29779,49;

Now with the use of formula the authors determined the coefficients of mathematical model.

$b_0=\frac{X_0Y}{n}=\frac{248669,79}{8}$ =31083,72;

$b_1=\frac{X_1Y}{n}=\frac{29169,53}{8}$ =3646,19;

$b_2=\frac{X_2Y}{n}=\frac{16898,51}{8}$ =2112,31;

$b_3=\frac{X_3Y}{n}=\frac{14744,23}{8}$ =1843,02;

$b_4=\frac{X_1X_2Y}{n}=\frac{12Y}{8}=\frac{-37450,25}{8}$ =-4681,28;

$b_5=\frac{X_1X_3Y}{n}=\frac{13Y}{8}=\frac{18475,25}{8}$ =2309,41;

$b_6=\frac{X_2X_3Y}{n}=\frac{23Y}{8}=\frac{29779,49}{8}$ =3722,44.

The next step the authors made the mathematical model by which defined the amount of money had spent for medicines acquisition in terms of one specific patient.

$\overline{Y}$ =31083,72+3646,19·X_1+2112,31·X_2+1843,02·X_3-4681,28·X_1X_2+2309,41·X_1X_3+3722,44·X_2X_3 (model);

$\overline{Y}_1$ =31083,72+3646,19·(-1)+2112,31·(-1)+1843,02·(-1)-4681,28·(-1)·(-1)+2309,41·(-1)·(-1)+3722,44·(-1)·(-1)=31083,72-3646,19-2112,31-1843,02-4681,28+2309,41+3722,44=24832,77; $\overline{Y}_2$ =31083,72+3646,19·(-1)+2112,31·(-1)+1843,02·(+1)-4681,28·(-1)·(-1)+2309,41·(-1)·(+1)+ 3722,44·(-1)·(+1)=31083,72-3646,19-2112,31+1843,02-4681,28-2309,41-3722,44=16455,11;

$\overline{Y}_3$ =31083,72+3646,19·(-1)+2112,31·(+1)+1843,02·(-1)-4681,28·(-1)·(+1)+2309,41·(-1)·(-1)+3722,44·(+1)·(-1)=31083,72-3646,19+2112,31-1843,02+4681,28+2309,41-3722,44=30975,07;

$\overline{Y}_4$ =31083,72+3646,19·(-1)+2112,31·(+1)+1843,02·(+1)-4681,28·(-1)·(+1)+2309,41·(-1)·(+1)+3722,44·(+1)·(+1)=31083,72-3646,19+2112,31+1843,02+4681,28-2309,41+3722,44=37487,17;

$\overline{Y}_5$ =31083,72+3646,19·(+1)+2112,31·(-1)+1843,02·(-1)-4681,28·(+1)·(-1)+2309,41·(+1)·(-1)+3722,44·(-1)·(-1)=31083,72+3646,19-2112,31-1843,02+4681,28-2309,41+3722,44=36868,89;

$\overline{Y}_6$ =31083,72+3646,19·(+1)+2112,31·(-1)+1843,02·(+1)-4681,28·(+1)·(-1)+2309,41·(+1)·(+1)+3722,44·(-1)·(+1)=31083,72+3646,19-2112,31+1843,02+4681,28+2309,41-3722,44=37728,87

$\overline{Y}_7$ =31083,72+3646,19·(+1)+2112,31·(+1)+1843,02·(-1)-4681,28·(+1)·(+1)+2309,41·(+1)·(-1)+3722,44·(+1)·(-1)=31083,72+3646,19+2112,31-1843,02-4681,28-2309,41-3722,44=24286,07; $\overline{Y}_8$ =31083,72+3646,19·(+1)+2112,31·(+1)+1843,02·(+1)-4681,28·(+1)·(+1)+2309,41·(+1)·(+1)+3722,44·(+1)·(+1)=31083,72+3646,19+2112,31+1843,02-681,28+2309,41+3722,44=40035,81.

Then the authors calculated value of comparative fault.

$\delta_1=\frac{(24832,77-26105,24)}{24832,77}\cdot 100\%=5,1\%$;

$\delta_2=\frac{(16455,11-23631,89)}{16455,11}\cdot 100\%=43,6\%$;

$\delta_3=\frac{(30975,07-29702,58)}{30975,07}\cdot 100\%=4,1\%$;

$\delta_4=\frac{(37487,17-30310,42)}{37487,17}\cdot 100\%=19,1\%$;

$\delta_5=\frac{(36868,89-44045,65)}{36868,89}\cdot 100\%=19,5\%$;

$\delta_6=\frac{(37728,87-39001,37)}{37728,87}\cdot 100\%=3,4\%$;

$$\delta_7=\frac{(24286,07-17109,31)}{24286,07}\cdot 100\%=29,5\%;$$

$$\delta_8=\frac{(40035,81-38763,33)}{40035,81}\cdot 100\%=3,2\%.$$

The model that was made by the authors of the article confirmed that the comparative faults specified in Table 3 had completely proved the determination of average cost of medicines' necessary volume for the treatment of one patient.

Table 5, The comparative price and the faults which were for one patient's medicines

Specifically spent means, tg.	Settlement indicators, tg.	Comparative faults, %
26105,24	24832,77	5,1%
23631,89	16455,11	43,6%
29702,58	30975,07	4,1%
30310,42	37487,17	19,1%
44045,65	36868,89	19,5%
39001,37	37728,87	3,4%
17109,31	24286,07	29,5%
38763,33	40035,81	3,2%

Thus, with the use of mathematical modeling it was established that it had been spent 31083,72 tg (202,96 U.S. dollars) for medicines of one patient in specialized medical institution and also the factors influencing volume of spent money had been defined.

4. Discussions

Thus, with the use of mathematical methods of analysis, we pointed that the predicted value of the production of pharmaceutical medicines for the 12th time (2013) the average was equal to 253,2 million U.S. dollars, and the 13th period (2014) the average was equal to 308,6 million U.S. dollars. It was clear that the dynamics showed the growth in the pharmaceutical industry of the Republic of Kazakhstan, and had great promise for the future. Besides, with the use of mathematical modeling the authors of the article found out that it had been spent 31083,72 tg. (202,96 U.S. dollars) for medicines of one patient in specialized medical institution and also the factors influencing volume of spent money had been defined. It was determined that considering the dynamics of patients' number growth, it was possible to predict the volume of necessary budgetary assignments for the treatment of concrete disease both in area scales, and for the whole republic.

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