Forecasting Indicators of the Region Intellectual Potential

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Abstract: This study established that in the conditions of Russian aggression, one of the most important factors for the recovery of Ukraine's economy is the effective use and multiplication of the existing intellectual potential of the regions. It was determined that the main structural elements of the intellectual potential of the region are educational, scientific and innovative potential. Fractal analysis and forecasting of key indicators of the intellectual potential of the region were carried out. Within the framework of the educational potential of the region, the following indicators were studied: the coverage of children in preschool education institutions, the number of graduate students, the number of students in general secondary education institutions, the number of teachers in general secondary education institutions, the number of students and trainees in vocational and vocational education institutions. As part of the scientific potential, the indicator of the number of employees involved in the performance of scientific research and development was considered. Within the framework of innovation potential - the specific weight of enterprises that introduced innovations and the number of implemented new technological processes. As a result of the conducted fractal analysis, it was established that all indicators belong to the anti-persistent type of time series. Therefore, the method of exponential smoothing and moving average was used as forecasting. A negative trend in the development of the component indicators of the intellectual potential of the region was revealed. This requires appropriate decisive actions on the part of the authorities in order to activate and grow the educational, scientific and innovative potential, which will lead to the improvement of the indicator of the intellectual potential of the region and its positive impact on the indicators of economic efficiency.

1 INTRODUCTION

The modern stage of society's development is characterized by the formation of an innovative economy, in which the role of knowledge and information is growing significantly. This leads to the need for continuous updating of knowledge, accelerated learning, transformation of intellectual resources into a key factor of the region's competitiveness. In this connection, the role of intellectual potential is increasing, and the creation of conditions for its reproduction is becoming a priority area of Ukrainian policy. Many different factors determine the economic growth of the developed countries of the world. One of the most important is the effective realization of the intellectual potential of each country, the recognition of intellectual potential as an indispensable element of social well-being. Therefore, the issue of forecasting the key indicators of the intellectual potential of the region in order to identify their development trends in the future is quite relevant.

2 LITERATURE REVIEW

A significant number of scientists devoted their research to the assessment and forecasting of intellectual potential and its components [1-8].

In work [1], a system of indices was created based on subject views of experts to assess regional scientific and technical innovation opportunities and collect empirical data for comparison of individual municipalities in Taiwan using the CFPR-VIKOR hybrid approach. This approach is a combined sequential fuzzy preference relationship (CFPR) and the VIKOR model aimed at prioritizing criteria and decision alternatives. The work [2, 3] predicts the innovative development of regions using correlation analysis, the Bartlett method, and the formation of an integral indicator.

The paper [4] develops a model based on genetic programming to solve the problem of forecasting the effectiveness of regional innovations.

The work [5] predicts the level of development of innovative potential of enterprises using factor analysis, K-means cluster analysis, taxonomy method, discriminant analysis.

The work [6] builds a model of the scenario of mixing in the conditions of innovative changes and market fluctuations and the evolutionary process of the development of the resort and recreation system.

The work [7] is evaluated of enterprise knowledge management system.

In the work [8], the indicators of the innovative attractiveness of the region were forecast.

3 METHODOLOGY

By the intellectual potential of the region, we will understand the possibility of realizing the educational, scientific and innovative potential of the region with the aim of transforming it into an intellectual basis of new quality for solving problems arising in the future.

Therefore, we will analyze the dynamics of indicators of educational, scientific and innovative potential using the example of Khmelnytskyi region in order to forecast them.

Reasoned choice of the forecasting method allows to reflect the existing trends of the process of intellectualization of the economy, identify problematic aspects and, accordingly, make management decisions that will improve the situation. A significant amount of research by scientists is devoted to the study of the issue of dynamic processes in the economy, finance, technology from the point of view of their fractal analysis.

In the general case, the time series can be viewed as a sum of various components: the system component of the trend function – average values over long averaging intervals; cyclic components with a certain repetition period; local features; anomalies of different order; higher-order fluctuations (noise) around all the listed components. The presence of trend and cyclical components requires the use of appropriate approaches to determine the self-similarity of the studied process. The most important concept, from which it is necessary to start the study of the fractal structure of a random process, is the verification of the hypothesis of the presence of self-similarity (long-term dependence) [9, 10].

We will use Hurst's method to perform a fractal analysis of indicators of intellectual potential according to the algorithm. Having determined the Hurst index for the investigated series of observations, it is possible to choose a method of forecasting the values of the indicator, taking into account the persistence (anti-persistence) of the series.

Algorithm for determining the Hurst indicator (fractal method based on R/S analysis or normalized swing method), which affects the choice of indicator forecasting method, consists of the following stages:

Stage 1. Determination of the accumulated deviation from the average value for the studied indicator:

$$X_{t,N} = \sum_{u=1}^{t} (e_u - M_N)$$

In this formula, *N* is the length of the period, which varies from 2 to <length of the time series>; *t* is a variable whose value ranges from 1 to *N*-1; M_N is the average of *N* elements; *e* is a specific element of the time series.

Stage 2. Obtaining *N*-1 values of *Xt,N* at each iteration:

$$R = Max(X_{t,N}) - Min(X_{t,N})$$

In this formula, *R* is the range of *X* deviations.

Stage 3. Normalization of the range by dividing by the standard deviation *S*, which is found by *N* values.

Stage 4. We logarithmize *R/S* and *N* and build a graph of the function of the dependence of the *R/S* value in a logarithmic scale on the period in a logarithmic scale based on the data obtained.

Stage 5. On the graph of the function Ln (*R/S*) from Ln(*t*), we find the slope by linear approximation. The tangent of the angle of this slope is Hurst's index.

The Hurst index can be in the range from 0 to 1. To characterize the subjects, it can be explained as follows:

1) ($0 \leq H < 0.5$) – anti-persistent or ergodic time series (“pink noise”), a countertrend is observed, the tendency of the economic system to constantly change the trend (growth is replaced by decline, and vice versa). The stability of such anti-persistent behavior depends on how close H is to zero. The closer its value is to zero, the more variable or volatile the series. This type of system is often called "reversion to the mean";

2) (H = 0.5) – the numerical series is completely random or stochastic ("white noise"), random behavior of the studied indicator is observed;
3) (0.5 < H ≤ 1) – persistent time series (“black noise”), a trend is observed.

Therefore, the deviation of the value of the H indicator from 0.5 indicates the fractal properties of the processes that cause the time series.

The following forecasting methods were also used: the moving average method and the exponential smoothing method.

The moving average model used is as follows:

$$SMA = \frac{\sum_{i=1}^{n} y_i}{n},$$

where *SMA* is the value of the moving average; *n* is the smoothing length; *yi* is the current value of the dynamics series.

The exponential smoothing model used is as follows:

$$S_t = \alpha \cdot y_t + (1 - \alpha) \cdot S_{t-1},$$

where *St* is the value of the exponential average at time *t*; *yt* is the current value of the dynamics series; S_{t-1} is the value of the exponential average at time *t*-1; α is the smoothing (damping) coefficient.

4 RESULT AND DISCUSSION

We will apply the Hurst index and the *R/S* method for selected indicators of the intellectual potential of the region. The following indicators of the educational potential of Khmelnytskyi region were chosen for the study: the coverage of children in preschool education institutions, percent to the number of children of the corresponding age (x_1); the number of graduate students (x_2); the number of students in general secondary education institutions, thousands of people (x_3); the number of teachers in general secondary education institutions, thousands of people (x_4); the number of students and trainees in vocational and vocational education institutions at the end of the year, thousands of people (x_5) (Table 1).

Figure 1 shows a graph of the function of the dependence of the value of *R/S* in a logarithmic scale on the period in a logarithmic scale for the indicator x_1.

According to Figure 1, it is obtained:

Ln(R/S)=0,2538 Ln(t)+0,3389.

Table 1: Indicators of the educational potential of Khmelnytskyi region, selected for research.

Year	x_1	x_2	x_3	x_4	x_5
1995	44	96	217,5	22,5	16,5
1996	44	131	217,8	21,7	15,7
1997	39	138	218,0	21,5	15,8
1998	39	163	216,3	21,4	15,9
1999	44	184	214,8	21,4	16,0
2000	43	201	212,0	22,0	16,1
2001	45	231	207,8	21,4	15,2
2002	50	258	201,5	21,1	14,7
2003	53	270	194,2	20,6	14,6
2004	55	274	185,9	20,1	14,8
2005	59	316	176,7	20,4	15,3
2006	60	368	168,4	20,8	15,2
2007	61	392	159,9	20,7	14,7
2008	61	436	151,7	20,5	15,0
2009	60	417	144,7	20,5	15,1
2010	61	416	137,7	20,1	15,4
2011	62	411	131,5	19,8	14,8
2012	62	412	128,9	19,8	14,3
2013	64	379	127,3	19,1	13,3
2014	64	367	127,9	18,6	12,6
2015	65	394	128,3	17,9	12,9
2016	66	390	129,2	17,3	10,9
2017	68	411	131,2	17,1	10,1
2018	71	412	134,3	16,8	9,5
2019	72	422	136,8	16,4	8,9
2020	72	393	138,7	16,3	9,1
2021	74	375	138,8	15,9	9,3
2022	68	568	140,3	15,6	9,5

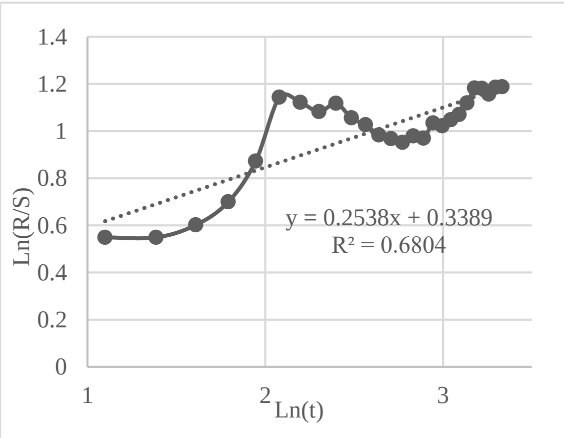

Figure 1: Graph of function Ln (*R/S*) from Ln(*t*) for x_1.

Therefore, *H*=0.2538. The investigated indicator x_1, according to the Hurst indicator (*H* < 0.5), belongs to anti-persistent time series.

According to the above algorithm, intermediate calculations in the *R/S* analysis are displayed (Table 2).

Table 2: Intermediate calculations in the *R/S* analysis for the indicator (x_1).

Year	x_1	t	Ln(t)	$x_{t,N}$	R	S	R/S	Ln(R/S)
1995	44	1	-	-14,0	-	-	-	-
1996	44	2	0,69	-14,0	0	0,00	0,00	-
1997	39	3	1,10	-19,0	5	2,89	1,73	0,55
1998	39	4	1,39	-19,0	5	2,89	1,73	0,55
1999	44	5	1,61	-14,0	5	2,74	1,83	0,60
2000	43	6	1,79	-15,0	5	2,48	2,01	0,70
2001	45	7	1,95	-13,0	6	2,51	2,39	0,87
2002	50	8	2,08	-8,0	11	3,51	3,14	1,14
2003	53	9	2,20	-5,0	14	4,56	3,07	1,12
2004	55	10	2,30	-3,0	16	5,42	2,95	1,08
2005	59	11	2,40	0,9	20	6,54	3,06	1,12
2006	60	12	2,48	1,9	21	7,30	2,87	1,06
2007	61	13	2,56	2,9	22	7,88	2,79	1,03
2008	61	14	2,64	2,9	22	8,23	2,67	0,98
2009	60	15	2,71	1,9	22	8,36	2,63	0,97
2010	61	16	2,77	2,9	22	8,49	2,59	0,95
2011	62	17	2,83	3,9	23	8,64	2,66	0,98
2012	62	18	2,89	3,9	23	8,72	2,64	0,97
2013	64	19	2,94	5,9	25	8,88	2,81	1,03
2014	64	20	3,00	5,9	25	8,99	2,78	1,02
2015	65	21	3,04	6,9	26	9,12	2,85	1,05
2016	66	22	3,09	7,93	27	9,26	2,92	1,07
2017	68	23	3,14	9,93	29	9,47	3,06	1,12
2018	71	24	3,18	12,93	32	9,81	3,26	1,18
2019	72	25	3,22	13,93	33	10,13	3,26	1,18
2020	72	26	3,26	13,93	33	10,38	3,18	1,16
2021	74	27	3,30	15,93	35	10,69	3,27	1,19
2022	68	28	3,33	9,93	35	10,67	3,28	1,19

In a similar way, it was established that the indicators x_2-x_5 belong to anti-persistent time series.

Consider the indicator of the number of employees involved in the implementation of scientific research and development - in total, persons with scientific potential as x_6 (Table 3).

Table 3: The number of employees involved in the performance of scientific research and development - total, persons (x_6).

Year	x_6
2010	950
2011	925
2012	460
2013	434
2014	439
2015	368
2016	321
2017	380
2018	348
2019	373
2020	233

The following indicators were selected for the study of innovation potential: the specific weight of enterprises that introduced innovations (x_7) and the number of implemented new technological processes (x_8), which are shown in the table 4.

Table 4: The specific weight of enterprises that introduced innovations (x_7) and the number of implemented new technological processes (x_8).

Year	x_7	x_8
2007	6,4	8
2008	3,9	16
2009	5,1	14
2010	16,0	42
2011	20,9	44
2012	22,2	32
2013	17,9	24
2014	9,9	11
2015	12,3	9
2017	5,7	7
2019	6,6	7

Figure 2 shows a graph of the function of the dependence of the value of *R/S* in a logarithmic scale on the period in a logarithmic scale for the indicator x_6, Figure 3 - for the indicator x_7, Figure 4 - for the indicator x_8.

According to Figure 2, it is obtained:

$$Ln(R/S)=0,2929\ Ln(t)+0,7227.$$

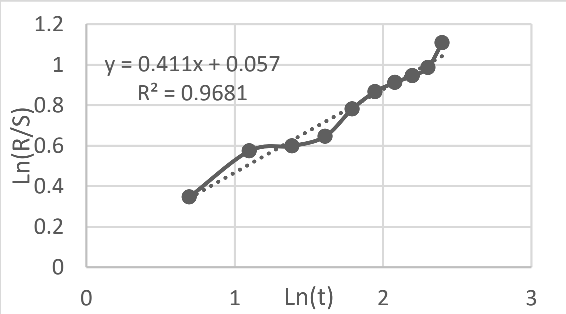

Figure 2: Graph of function Ln (*R/S*) from Ln(t) for x_6.

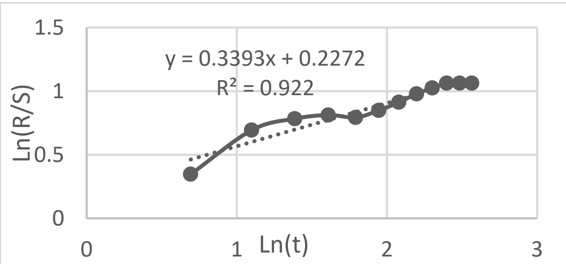

Figure 3: Graph of function Ln (*R/S*) from Ln(t) for x_7.

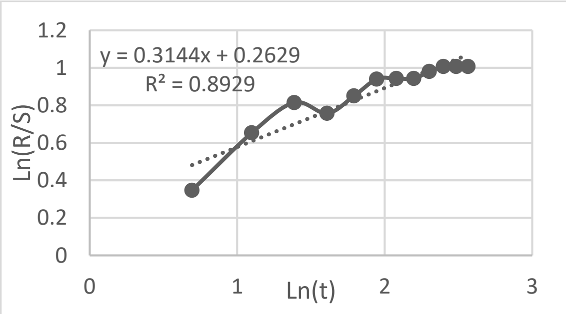

Figure 4: Graph of function Ln (*R/S*) from Ln(*t*) for x_8.

According to Figure 3, it is obtained:

$$Ln(R/S)=0,3393\ Ln(t)+0,2272.$$

According to Figure 3, it is obtained:

$$Ln(R/S)=0,3144\ Ln(t)+0,2629.$$

Let's summarize the results of the fractal analysis of indicators of intellectual potential (table 5). Therefore, all indicators refer to anti-persistent time series.

Table 4: Results of fractal analysis of indicators.

№	Indicator	*H*	Time series type
1	x_1	0,2538	anti-persistent
2	x_2	0,2204	anti-persistent
3	x_3	0,1125	anti-persistent
4	x_4	0,3129	anti-persistent
5	x_5	0,2929	anti-persistent
6	x_6	0,4110	anti-persistent
7	x_7	0,3393	anti-persistent
8	x_8	0,3144	anti-persistent

Since it was determined that the studied indicators belong to anti-persistent time series, this type of system is often called "reversion to the mean", so exponential smoothing and moving average should be chosen as forecasting methods.

Moving average models for 3, 4, 5, 6, 7, 8, 9, 10 periods and exponential smoothing models with α equal to 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9 were built for indicators x_1 - x_5.

Figure 5 presents real and model values (moving average models) for x_1.

Figure 6 presents real and model values (exponential smoothing models) for x_1.

For indicators x_6 - x_8, in connection with the published data for a smaller number of years, moving average models for 2, 3, 4, 5, 6, 7, 8 periods and exponential smoothing models with α equal to 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9 were built.

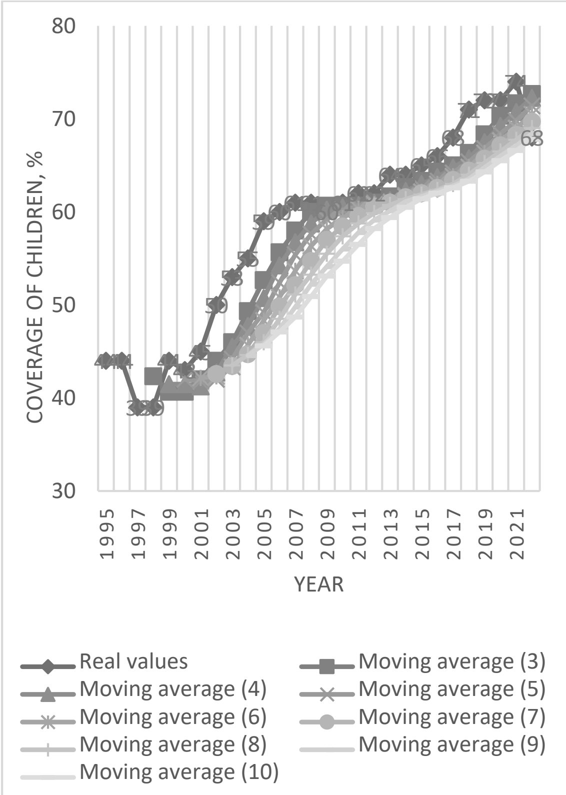

Figure 5: Real and model values (moving average models) for x_1.

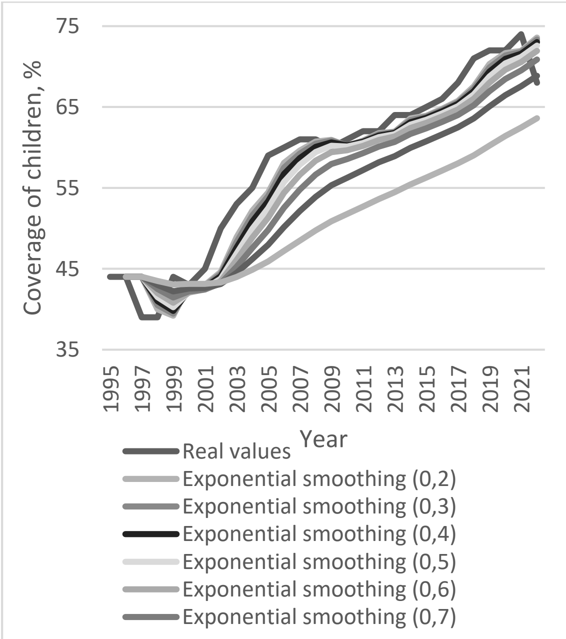

Figure 6: Real and model values (exponential smoothing models) for x_1.

Let's summarize the simulation results in table 5, which shows the R^2 indicator (coefficient of determination) for each of the constructed models (moving average (MA), exponential smoothing (ES). It is the criterion for choosing optimal models for forecasting.

Table 5: R^2 indicators of constructed models.

Model	Indicator							
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
MA(2)	-	-	-	-	-	0,43	0,22	0,30
MA(3)	0,92	0,80	0,95	0,95	0,90	0,44	0,01	0,11
MA(4)	0,92	0,75	0,92	0,94	0,87	0,41	0,00	0,12
MA(5)	0,88	0,68	0,88	0,93	0,85	0,08	0,00	0,17
MA(6)	0,87	0,59	0,84	0,93	0,82	0,04	0,00	0,15
MA(7)	0,85	0,49	0,79	0,92	0,80	0,35	0,01	0,36
MA(8)	0,82	0,40	0,16	0,07	0,24	0,56	0,52	0,33
MA(9)	0,78	0,25	0,65	0,91	0,77	-	-	-
MA(10)	0,76	0,11	0,54	0,92	0,78	-	-	-
ES(0,2)	0,94	0,86	0,98	0,97	0,94	0,60	0,41	0,42
ES(0,3)	0,94	0,86	0,97	0,96	0,93	0,60	0,36	0,96
ES(0,4)	0,93	0,86	0,96	0,96	0,93	0,59	0,29	0,88
ES(0,5)	0,92	0,85	0,95	0,96	0,92	0,58	0,21	0,76
ES(0,6)	0,91	0,85	0,93	0,96	0,91	0,56	0,12	0,70
ES(0,7)	0,89	0,83	0,90	0,95	0,90	0,54	0,04	0,70
ES(0,8)	0,86	0,80	0,84	0,95	0,88	0,60	0,00	0,71
ES(0,9)	0,81	0,74	0,74	0,95	0,88	0,60	0,01	0,74
Max R^2	0,94	0,86	0,98	0,97	0,94	0,60	0,52	0,96

According to Table 5, the optimal model for forecasting for x_1, x_3, x_4, x_5, x_6 is exponential smoothing (0.2); for x_2, x_8 - exponential smoothing (0.3); for the x_7 indicator, none of the proposed models is suitable for forecasting according to the low R^2 indicator.

Table 6 summarizes information about the selected models for forecasting the studied indicators, their real values of the last research period and forecast values for the next period, as well as the forecast trend of the indicator to increase or decrease is displayed.

Therefore, the indicator x_2 (number of graduate students, people) will decrease from 568 people in 2022 to 512 people in 2023. Indicator x_3 (number of students in general secondary education institutions - total, thousand people) will decrease from 140.3 thousand people in 2022 to 140.0 thousand people in 2023. Indicator x_4 (number of teachers in general secondary education institutions, thousand people) will increase slightly from 15.6 thousand people in 2022 to 15.7 thousand people in 2023. Indicator x_5 (number of students, students in professional (vocational and technical) education institutions at the end of the year, thousands of people) will remain the same in 2023 as in 2022 at the level of 9.5 thousand people. Indicator x_6 (the number of employees involved in scientific research and development - total, people) will increase from 233 people in 2020 to 266 people in 2021. The x_8 indicator (the number of introduced new technological processes, units) in 2020 will remain at the level of 2019 - 7 units.

Table 6: The results of forecasting the investigated indicators.

№	Indicator	Selected model	Real value	Predictive value	Trend
1	x_1	ES (0,2)	2022 y.	2023 y.	↑
			68	69,1	
2	x_2	ES (0,3)	2022 y.	2023 y.	↓
			568	512	
3	x_3	ES (0,2)	2022 y.	2023 y.	↓
			140,3	140,0	
4	x_4	ES (0,2)	2022 y.	2023 y.	↑
			15,6	15,7	
5	x_5	ES (0,2)	2022 y.	2023 y.	-
			9,5	9,5	
6	x_6	ES (0,2)	2020 y.	2021 y.	↑
			233	260	
7	x_7	-	2019 y.	-	not established
			6,6	-	
8	x_8	ES (0,3)	2019 y.	2020 y.	-
			7	7	

5 CONCLUSIONS

Development of intellectual potential is the result of successful management of economic, ecological, social and cultural life processes of territorial communities and society as a whole. Thus, for the continuous and successful development of the region, it is necessary to constantly increase its intellectual potential, which will contribute to increasing the competitiveness of the resource provision of communities and the country's economy as a whole.

Indicators of innovative potential of Ukraine as a component of intellectual potential were analyzed; the indicators of the scientific potential of Ukraine as a component of the intellectual potential were analyzed; indicators of the educational potential of the Khmelnytskyi region were analyzed. The conducted analysis shows negative trends in the processes of formation and utilization of intellectual potential and its components.

Fractal analysis and identification of trends in the development of indicators of the innovative potential of Ukraine and predicted indicators of the intellectual potential of the Khmelnytsky region were carried out.

As a result of the fractal analysis, it was established that the constituent indicators of the intellectual potential of the Khmelnytsky region are anti-persistent, and therefore it is advisable to use the method of moving average and exponential smoothing for their forecasting.

According to the selected model of exponential smoothing (2), the forecast value of the indicator x_1 of the coverage of children in preschool education institutions (percentage to the number of children of the appropriate age) for 2023 will be 69.1% compared to 2022, in which this indicator was 68%, so the situation is insignificant will improve indicator x_2 (number of graduate students, people) will decrease from 568 people in 2022 to 512 people in 2023. Indicator x_3 (number of students in general secondary education institutions - total, thousand people) will decrease from 140.3 thousand people in 2022 to 140.0 thousand people in 2023. Indicator x_4 (number of teachers in general secondary education institutions, thousand people) will increase slightly from 15.6 thousand people in 2022 to 15.7 thousand people in 2023. Indicator x_5 (number of students, students in professional (vocational and technical) education institutions at the end of the year, thousands of people) will remain the same in 2023 as in 2022 at the level of 9.5 thousand people. Indicator x_6 (the number of employees involved in scientific research and development - total, people) will increase from 233 people in 2020 to 266 people in 2021. The x_8 indicator (the number of introduced new technological processes, units) in 2020 will remain at the level of 2019 - 7 units.

It has been established that the forecast values demonstrate an insufficient level of development of innovative processes at industrial enterprises of Ukraine and the Khmelnytskyi region and a high probability of maintaining similar trends in the future, which will lead to a deterioration of the economic situation both in the region and in the country as a whole. It is possible to come to a conclusion regarding the disappointing trend of the constituent indicators of the intellectual potential of the Khmelnytskyi region, which requires appropriate decisive actions on the part of the authorities in order to activate and grow the educational, scientific and innovative potential, which will lead to the improvement of the indicator of the intellectual potential of the region and its positive impact on the indicators of economic efficiency.

Time to invest in human resources will reveal new priorities for the region. Any development requires investments - intellectual investments justify themselves with the quality of life and longevity of dividends in the form of inexhaustible qualities of intellectual potential.

The obtained research results can be used for: forecasting and improving indicators of the intellectual potential of the region. The models built in the work can be adapted to the operating conditions of any region.

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