Formation of Multivariate Models of Macroeconomic Indicators of Society Development

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Abstract

The work carried out the development of a generalized algorithm for the comparative analysis of indicators of the results of socio-economic development based on multivariate models of macroeconomic indicators of the development of society.
The study of the 16-factor complex of global indices, which includes five indicators of results, made it possible to identify its systemic characteristics and main interrelationships. It is shown that the Human Development Index and Social Progress Index have a dominant influence on various performance indicators. In addition to the high level of influence on other indicators of results (0.3–0.7 total influence), they have a cooperative effect on other indicators within the framework of complex predictors. The GDP per capita indicator is interconnected within the framework of complex predictors, mainly with the World Happiness Index.

Keywords: Human Capital, Happiness Index, Social Progress Index, Human Development Index, GDP per capita, forecasting, optimization, regression analysis

Introduction

For a long time, the main indicator of the state of the economy was considered the Gross Domestic Product - GDP, proposed in the 30s of the 20th century by the American economist Simon Kuznets. The ratio of the GDP to the population (GDP per capita) is interpreted as an indicator of the well-being of the population. In 1954, purchasing power parity exchange rates - PPP - were first published. This approach became widespread after 1978, when a worldwide database of PPP exchange rates was created.

In connection with the growth of the well-being of the population, material prosperity ceased to correspond to the role of the ideal of social development. This has led to increased criticism of GDP as a universal measure of country performance. At the same time, the developers of the 2011 system of national accounts noted that "the GDP indicator was never intended to measure well-being" (Peter van de Ven, 2014).

In 1990, a group of economists led by Pakistani Mahbub ul-Haq developed the Human Development Index (UNDP, 2018), which is published annually by the United Nations Development Program (UNDP). An essential advantage of the Human Development Index (HDI) is that it is based on two indicators of a natural type (life expectancy and the number of years of education), and the third ensures the inheritance of the relationship with GDP per capita at PPP. Its simplicity is, however, both an advantage and a disadvantage, since it takes limited account of the characteristics of the socio-economic development of countries.

The concept of the economy of happiness has been proposed as a fundamentally different approach to assessing the results of social development (Easterlin, 1974; Veenhoven, 1991; Argyle, 2003; Layard,

2011). This concept received support at the 65th UN session in 2011. At the same time, the resolution "Happiness: A Holistic Approach to Development" was approved. One such approach is implemented as the World Happiness Index (Helliwell at al., 2019). Among the disadvantages of this index, it can be noted that highly intangible indicators such as the feeling of positive or negative emotions make a significant contribution to it. It is characteristic that the dependence of the World Happiness Index (WHI) on a number of predictors is bimodal, and at a certain stage of the development of society, a decrease in the level of happiness may occur with an increase in well-being. This led to a lengthy debate among economists about the Easterlin paradox, which is that GDP growth only within certain limits leads to an increase in the level of happiness (Easterlin, 1974; Diener, 2013).

Since the share of human capital (Schultz, 1962; Becker, 1962) in the national wealth of countries began to grow rapidly since the end of the 20th century, and, according to some estimates, it reaches 80% in developed and large developing countries (Koritsky, 2013; Korchagin, 2005; Suvorov et al; 2014), then human capital (HC) actually also begins to play the role of an indicator of social development (Prichina, 2019). The difficulty lies in the fact that different methods for assessing human capital do not give fully consistent results. For example, the two human capital indices developed by the World Economic Forum (WEF, 2019) and the World Bank Group (World Bank Group, 2019) are based on significantly different indicators.

Finally, under the leadership of M. Porter, the Social Progress Index was developed in 2013 (Porter, 2015; Stern, 2018), the first version of which was released in 2014. The index is formed on the basis of 54 indicators, structured in three areas: basic needs of people, the basics of well-being and opportunities, and for each area 4 groups of indicators were formed, 3-5 in a group. It is fundamentally important that among the indicators used there are no those that characterize the economy and business, which makes it possible to establish the relationship between the economy and the social characteristics of society.

The presence of a wide range of indicators of the development of society, the active improvement of their design, makes the question of the relationship between these indicators urgent.

The aim of the work is to develop a method for comparative analysis of indicators of the results of socio-economic development based on multivariate models of macroeconomic indicators of the development of society.

To solve this problem, in this work, a statistical analysis of the dependence of various indicators on a complex of 15 global indices, including those that can also serve as the resulting indicators, is carried out.

Research methodology

The methodological foundations of this work are systematic and statistical analysis. As indicators of the results of the socio-economic development of countries, the indices presented in Table 1 are used.

Table 1: indicators of the results of socio-economic development

i	Abbre-viation	Full name	Indicators
1.	GDP/C	GDP per capita at PPP	Gross domestic product at purchasing power parity в долл. США 2018 года, по данным World Bank
2.	HDI	Human Developmen Index	Life expectancy, length of study, log GNI at PPP (UNDP, 2018)
3.	IHC	Index of Human Capital	A comprehensive indicator of human capital, formed from indices: Global Human Capital and Human Capital Index
4.	WHI	World	Life expectancy forecast, freedom to choose a life path,

		Happiness Index	support from other people and social, low corruption, positive or negative emotions, people (Helliwell, 2019)
5.	SPI	The Social Progress Index	- food and low mortality from disease, sanitation and water, housing and electricity, personal safety; - coverage by secondary education, communication and access to information, healthy life and ecology; - rights and freedoms, tolerance for minorities, access to higher education (Porter, 2015; Stern, 2018)

The research program is as follows. Using five indicators of countries' development results, on the basis of a statistical analysis of the database on global indices (factors) shown in Table 2, form a series of complex predictors that provide the minimum regression error with the corresponding performance indicators. The weights of the indices in these predictors presumably reflect the level of influence of these indices on the corresponding development results. Comparison of these indices and their coefficients in various predictors will be used to identify the systemic characteristics of mutual influence, both performance indicators and the complex of global indices used.

Table 2: indices used as factors

i	Abbre-viation	Full name
1.	IEF	Index of Economic Freedom (Miller, 2019)
2.	EDB	Ease of Doing Business Ranking, (Doing Business, 2020)
3.	WGI	Worldwide Governance Indicators (Kaufmann, 2010)
4.	GCI	Global Competitiveness Index, (Schwab, 2019)
5.	MYS	Mean Years of Schooling (UNDP, 2018)
6.	GHC	Global Human Capital (WEF, 2019)
7.	HCI	Human Capital Index (World Bank Group, 2019)
8.	RDE	R&D Expenditure (Knoema, 2017)
9.	LPI	The Legatum Prosperity Index (Legatum, 2019)
10.	CPI	Corruption Perception Index (Transparency, 2020)
11.	LEI	Life Expectancy Index (UNDP, 2018)
12.	KIG	KOF Index of Globalization (Savina, 2019)

It should be noted that the indicators presented in Table 1 were also used as factors on which other indicators of results depend. In addition, the number of indices shown in Table 2 includes those that are not formally global indices, for example, Mean Years of Schooling, but are important from the point of view of the completeness of this system of indices. For ease of comparison with other arguments, the MYS index is normalized to the average duration of tertiary education (16 years). The value of R&D Expenditure is given in terms of GDP, Life Expectancy Index in years.

The work used data for 72 countries, for which data were available for all indices. A number of fuel producing countries (Qatar, Kuwait, Saudi Arabia) that deviate significantly from the general trends in GDP / C were not included in the sample under study. All countries were ranked according to the value of GDP at PPP and the largest samples were formed, differing in the number of countries: G72, G48, G24, G12, G6. For each of these samples, regression dependencies, coefficients of determination (R^2), and regression error ($\Delta R^2 = 1 - R^2$) were determined. In addition, the mean value of the regression error ($\Delta R^2_m = 1 - R^2_m$) was determined for five samples (G6 – G72). Optimization of predictors was carried out by minimizing ΔR^2_m.

To track the regular nature of the interdependence of performance indicators on a multidimensional complex of factors, at the first stage of the study, for each performance indicator, the dependence of the indicator on single and optimal paired predictors was studied. Paired predictors were formed by a linear composition of indices according to formula (1).

$$P_2 = k\ In_1 + (1 - k)In_2 \quad (1)$$

Here In_1 and In_2 are the values of two indices for a particular country, k is the contribution coefficient of the first index (1> k> 0), P_2 is the value of the paired index. Complex predictors were formed similarly to paired ones, which included the maximum appropriate number of indices, according to formula (2), where Σki = 1.

$$P_C = \Sigma k_i\ In_i \quad (2)$$

The search for the coefficients ki when optimizing complex predictors was carried out by varying them, defining a regression model and estimating the value of ΔR^2_m . Further, the optimal values of ki were determined by the gradient descent method with cyclic change of variables.

Optimizing predictors for GDP / C

First of all, the dependence of GDP per capita at PPP on various global indices was investigated. At the first stage, the values of the regression error ΔR^2_m of the dependence of GDP / C on the single indices presented in Table 1 were calculated. The lowest regression error was demonstrated by the Human Development Index, for which ΔR^2_m = 5.5% with a trend as a power of number. The dependence of GDP / C on the Human Developmen Index for the G24 is shown in Fig. 1. Trends in the form of a power of a number and an exponent (dotted line) are close to each other in the considered range of the argument.

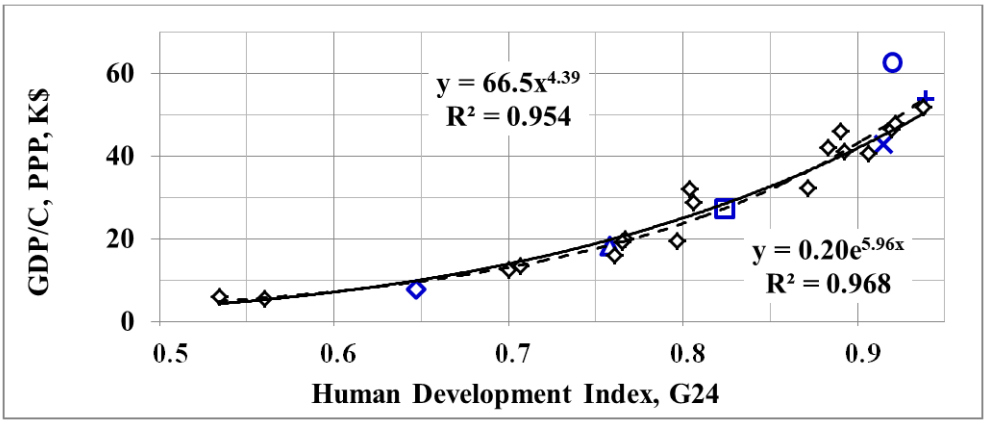

Fig. 1. Dependencies of GDP / C on Human Development Index, G24

It should be noted that the Human Development Index, as one of the three main components, includes gross national income (GNI), which is quite close in size to GDP. Therefore, the correctness of including HDI in the GDP / C predictor complex is somewhat questionable. In this regard, special attention was paid to GDP / C predictors that do not include HDI. Those that provide the smallest ΔR^2_m are shown in Table 3.

Table 3: indexes-predictors of GDP / C with the smallest ΔR^2_m,%.

	G6	G12	G24	G48	G72	mid
LPI	18.2	15.9	16.6	19.5	17.3	17.5
HCI	16.6	11.5	8.9	28.3	22.0	17.4
MYS	8.5	11.7	13.6	29.2	23.4	17.3
SPI	12.4	13.3	9.1	22.8	19.1	15.3
HDI	2.2	2.2	4.6	11.4	7.0	**5.5**

Next, we considered paired predictors formed according to formula (1). HDI and SPI were used as the first of the pairs of indices, which showed the best individual results. The optimal paired predictors of GDP / C are presented in Table 4. The left half of the table shows the values of ΔR^2 for various samples and ΔR^2_m (column - mid), and the right - the values of the coefficients ki of the contribution of the indices to the predictors.

Table 4: regression error of paired GDP / C predictors,%

	G6	G12	G24	G48	G72	mid	IEF	EDB	MYS	GHC	HCI	WHI	SPI	HDI
HDI +IEF	1.7	2.8	3.1	8.5	5.3	4.3	0.20							0.80
HDI +EDB	1.4	2.3	4.3	9.8	6.4	4.8		0.20						0.80
HDI +WHI	1.5	2.8	3.6	10.0	6.2	4.8						0.15		0.85
MYS+SPI	6.7	5.8	6.6	18.2	13.1	10.1			0.40				0.60	
GHC+SPI	4.5	4.1	7.4	19.1	14.9	10.0				0.42			0.58	
HCI+SPI	7.5	6.2	6.4	16.9	13.7	10.1					0.35		0.65	

It can be seen that the predictors that include HDI are characterized by approximately half the values of ΔR^2_m than those with SPI, and the smallest ΔR^2_m = 4.3% is provided by the predictor P = 0.8HDI + 0.2IEF. Among paired predictors that do not contain HDI, the minimum ΔR^2_m = 10% for the predictor P = 0.42GCI + 0.58SPI. Note that the optimal paired predictors, including SPI, contain as the second index those that individually provide low ΔR^2_m. The predictors containing IHD, as the second component, include indices with low individual ΔR^2_m.

At the third stage of the study, complex predictors were identified, which include three indices and an arbitrary number of them, and this was done, both with the inclusion of the Human Development Index, and without it. The found optimal predictors are presented in Table 4 (ERD and CPI indices with a weight of ~ 0.01 are not shown in Table 5).

Table 5: error of regression of complex predictors of GDP / C,%

	G6	G12	G24	G48	G72	mid	IEF	EDB	GCI	MYS	GHC	HCI	WHI	LPI	SPI	KIG	HDI
Pc_1	1.3	2.6	2.9	8.4	5.2	4.1	0.15						0.1				0.75
Pc_2	1.0	2.1	3.1	8.1	5.2	3.9	0.1	0.1					0.1				0.7
Pc_3	4.3	7.1	7.9	16.0	11.3	9.3				0.2			0.25		0.55		
Pc_4	2.4	2.6	5.8	13.1	9.6	6.7	0.03	0.06	0.2	0.12	0.08	0.15	0.15	0.04	0.26	0.07	

Complex predictors including HDI, as in the case of simpler predictors, are characterized by approximately half the regression error, about 4%. Since HDI individually has a very low regression error (ΔR^2_m = 5.5%), adding other indices to it does not contribute to a significant decrease in ΔR^2_m.

Therefore, the optimal complex predictor Pc_2, including HDI, contains only 4 components and is marginally superior (ΔR^2_m = 3.9%) compared to the predictor of three Pc_1 indices.

Predictors that include SPI benefit significantly from adding other indexes. The optimal complex predictor Pc_4 includes 12 components and has ΔR^2_m = 6.7%. The SPI index (ki = 0.26) makes the largest contribution to this predictor, which is consistent with the results of studies of ΔR^2_m for individual and paired predictors. Also, the contributions of HCI (ki = 0.15) and GHC (ki = 0.08) are quite high. Overall, the group of human capital indexes (HCI, GHC, MYS) contributes the most to the composite optimal predictor of GDP / C - 0.35. The contribution of the World Happiness Index is also quite large (0.15). The dependence of GDP / C on the Pc_2 predictor for the G24 sample is shown in Fig. 2.

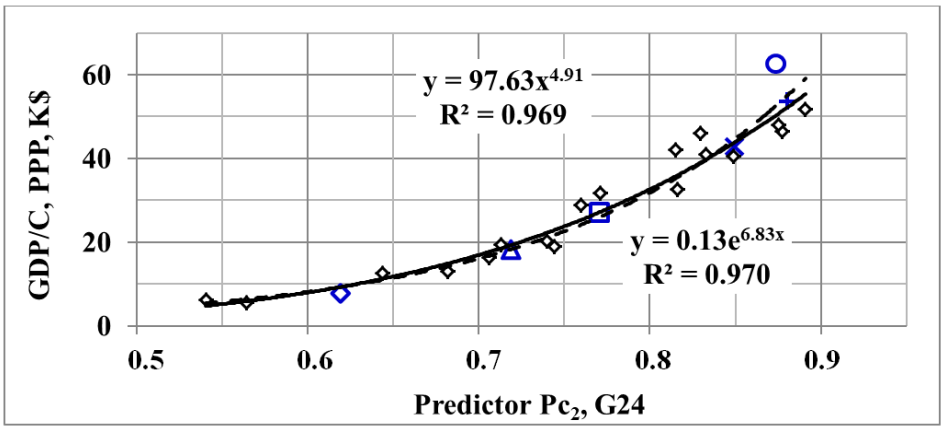

Fig. 2. Dependences of GDP / C on the predictor Pc_2, G24

In Fig. 1, 2 sample points G6 are marked with special symbols from left to right: India, China, Russia, Japan, USA, Germany. It can be seen that all points except for the USA (circle) lie very close to the trend. This means that there is a natural relationship between GDP / C and the found optimal predictor, and the countries under consideration, including Russia, have GDP / C close to this relationship.

Optimization of predictors for Human Development Index

Let us consider the possibilities of forecasting the Human Development Index using the global indices presented in Table 2. Table 6 shows the indices, when used as predictors for HDI, the minimum regression error ΔR^2_m is provided for various samples with a trend in the form of a second degree polynomial.

Table 6: indexes-predictors of HDI with small ΔR^2_m,%

	G6	G12	G24	G48	G72	mid
LPI	12.8	12.7	16	13.2	11.7	13.3
MYS	6.5	9.9	10.7	18.7	16.0	12.4
HCI	10.3	8.8	4.8	14.1	12.8	10.2
SPI	0.6	9.0	5.6	12.5	11.1	7.8
GDP/C	0.2	1.7	5.0	10.3	9.8	5.4

It can be seen that the best individual predictor in this sense is GDP / C with ΔR^2_m = 5.4%, and this value is close to the GDP / C regression error depending on HDI. Some of the difference is due to the

fact that these two relationships have different trends. Social Progress Index ranks second in terms of ΔR^2_m = 7.8%. Table 7 presents paired, triple, and complex predictors that provide low regression biases for HDI.

Table 7: complex HDI predictors with small ΔR^2_m,%

	G6	G12	G24	G48	G72	mid	MYS	HCI	SPI	LEI	GDP/C
MYS+SPI	1.28	2.41	3.69	7.31	6.19	4.18	0.4		0.6		
MYS+GDP/C	1.50	2.31	4.21	5.85	5.30	3.83	0.35				0.65
HCI+SPI	2.53	2.56	2.43	4.45	5.58	3.51		0.45	0.55		
HCI+GDP/C	1.51	2.14	2.41	5.27	5.22	3.31		0.4			0.6
SPI+GDP/C	0.31	1.74	2.49	6.52	5.44	3.30			0.4		0.6
MYS+SPI+GDP/C	1.63	1.65	2.77	4.74	4.01	2.96	0.35		0.35		0.3
MYS+LEI+GDP/C	0.95	1.36	1.45	2.81	2.80	1.87	0.33			0.33	0.34
HCI+SPI+GDP/C	0.39	0.82	1.45	2.28	3.43	1.67		0.35	0.4		0.25
Pc_5	0.20	0.55	1.13	1.87	2.32	1.21	0.2	0.2	0.3	0.1	0.2

The first column of the table contains abbreviations of the indexes that make up the predictor, and the last five columns show the proportion of these indexes in complex predictors. Among paired predictors, the smallest average regression error ΔR^2_m = 3.3% is provided by the combination SPI + GDP / C with an SPI share of 0.4, which is consistent with the low individual values of ΔR^2_m for these indices.

Adding the third index to the predictor (HCI + SPI + GDP / C) allows to reduce the regression error by half, to 1.67%. An even more complex predictor Pc3, which includes five indices (MYS + HCI + SPI + LEI + GDP / C), provides a very low level of regression error – 1.2%.

It is interesting that among the paired predictors there are those that do not contain GDP / C and MYS and have a fairly low regression error of ~ 3.5%. This allows HDI to be predicted without having these values included in the HDI definition.

The dependence of the Human Development Index on the optimal complex predictor Pc_3 for the G48 sample is shown in Fig. 3. It can be seen that all points, including G6, are very close to the trend line (polynomial of the second degree - P2).

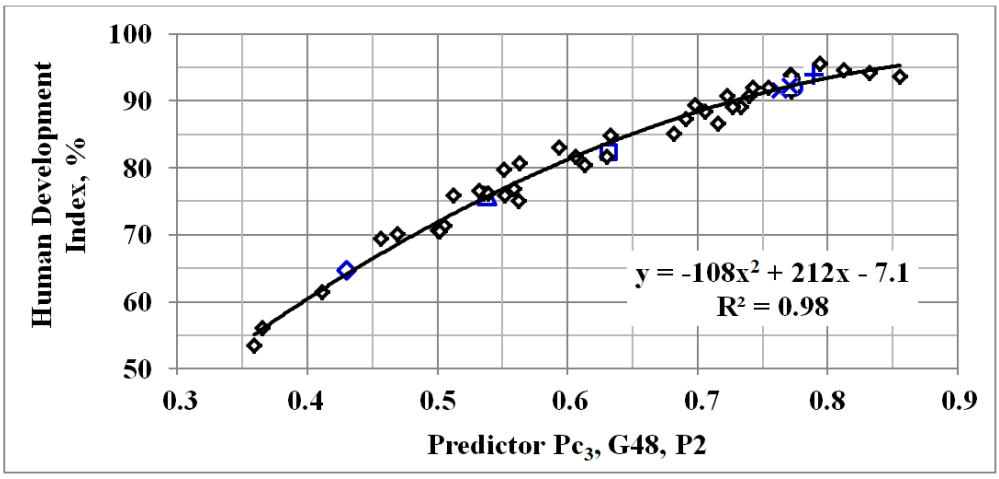

Fig. 3. Dependencies of HDI on the optimal complex predictor

Optimization of predictors for the World Happiness Index

Similarly to the previous indicators, we will consider the multi-factor models of the World Happiness Index. Table 8 shows the indices, when used as predictors for WHI, the minimum regression error ΔR^2_m is provided for various samples. In this case, we used a trend in the form of a polynomial of the fifth degree (for G6 – the third).

Table 8: indexes-predictors of WHI with minimum ΔR^2_m,%

	G6	G12	G24	G48	G72	mid
MYS	4.2	27.3	41.1	39.2	47.5	31.8
HDI	7.4	22.6	34.6	27.5	30.7	24.5
GDP/C	4.8	18.9	35.5	29.5	28.4	23.4
LPI	13.5	26.8	25.3	22.5	25.3	22.7
SPI	12.0	14.7	20.3	26.1	32.3	21.1

It can be seen that the regression error for the WHI is much larger than for the GDP / C and Human Development Index. Comparison of tables 4, 6 and 8 shows that the indices providing the minimum ΔR^2_m for the three indicators of the results of society development are represented by the same group of indices: GDP / C, HDI, SPI, MYS, HCI, LPI.

Table 9: regression error of optimal predictors WHI, %

	G6	G12	G24	G48	G72	mid	IEF	WGI	GDP/C	LPI	SPI	LEI	KIG
IEF+SPI	12.1	19.5	15.6	21.1	28.6	19.4	0.15				0.85		
WGI+SPI	11.4	13.5	15.3	22.1	29.2	18.3		0.15			0.85		
WGI+ GDP/C	3.24	7.88	17.9	27.1	28.4	16.9		0.4	0.6				
LPI+ SPI	12.3	8.7	15.6	21	26.7	16.9				0.45	0.55		
SPI+ GDP/C	0.67	10.6	17.7	20.2	28.1	15.5			0.35		0.65		
IEF+SPI+ GDP/C	0.84	11.7	15	18.1	27.1	14.6	0.15		0.3		0.55		
WGI+SPI+ GDP/C	0.08	5.09	12.7	19.5	28	13.1		0.15	0.37		0.48		
Pc_6	0.29	6.45	11.4	17.3	26.6	12.4	0.14	0.13	0.25		0.45	0.01	0.02

Table 9 shows paired, triple, and more complex optimal complex WHI predictors. The Social Progress Index makes the largest contribution to all types of World Happiness Index complex predictors, with its contribution to the complex predictor Pc_6 being 0.45 compared to 0.26 for the complex Pc_4 predictor for GDP / C and 0.3 for the HDI predictor (Pc_5). This is a consequence of the proximity of these indices in terms of characteristics of the results of socio-economic development. GDP / C has the second largest share (0.23), which indicates that material well-being makes a relatively small contribution to the happiness of the population.

The indices characterizing human capital, as well as the Human Development Index, in the WHI predictors that provide the minimum regression error are not presented. This is a very important phenomenon, which indicates that an increase in educational level and an improvement in health does not make the population happier, at least in the considered World Happiness Index model. At the same time, human capital has a very significant impact on the GDP / C value. Instead of HC factors, the WHI is significantly influenced by the Index of Economic Freedom (0.14) and Worldwide Governance Indicators (0.13).

Characteristically, the trend for WHI is bimodal, as can be seen from Fig. 4, which shows the dependence of the World Happiness Index on the optimal complex predictor Pc_6 and the trend in the form of a polynomial of the 5th degree (P5).

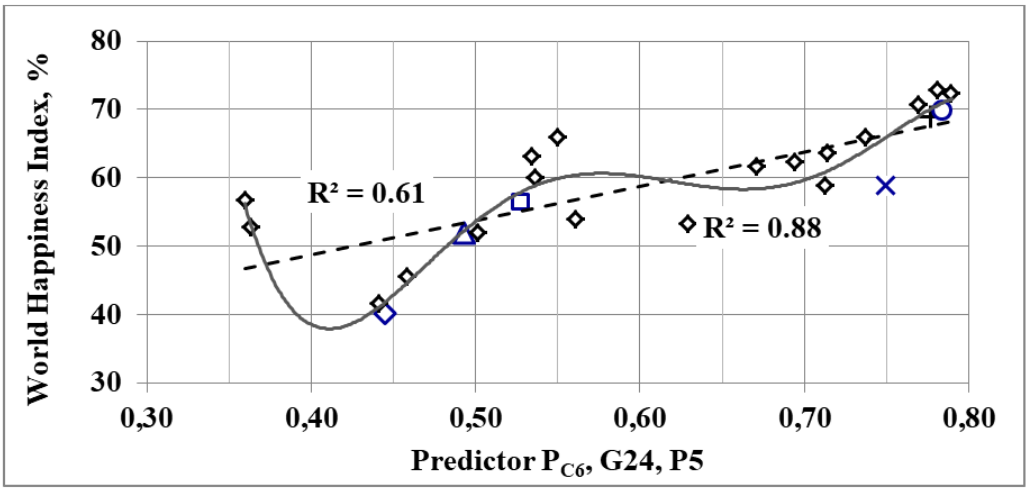

Fig. 4. Dependence of WHI on the optimal predictor P_{C6}, G24

In Fig. 4 large icons represent the countries in the G6 sample from left to right: India, China, Russia, Japan, Germany, and the United States. It can be seen that most of the corresponding points are close to the trend line, which corresponds to a low regression error $\Delta R^2 = 0.3$ for the G6 sample. Also, they are all in uptrend parts.

Discussion

This paper continues a series of studies that examine the multifactorial system of global indices and their relationship with the results of socio-economic activity. In these works, the number of involved indices was constantly increasing and it happened more than once that the new index had a very significant impact on the system of interconnections. Among the latter of such indices are the Social Progress Index and Human Developmen Index and, as it turned out, they are the most important in this system. At the same time, the Human Developmen Index was taken into account from the very beginning, since it includes an analogue of GDP per Capita and therefore its use for forecasting GDP / C is not entirely correct. However, in connection with the involvement in the study of other indicators of development results, the Human Developmen Index was introduced into the system of the studied indices and it turned out that it is key. This forces us to pay attention to the possibility of the presence of other global indices that can play a significant role in this predictive system.

Among such indicators, an important role can be played by the indicator of natural resources; however, at present, such a correctly formed index is not known to the authors. The existing private components of such an index are rather controversial. For example, the most valuable natural resource in Russia is considered to be forest resources, the value of which is estimated at $ 29 trillion. However, in reality, these resources cannot be used, in particular, due to the lack of appropriate transport opportunities. The cost of arable land in different countries differs tenfold, and these prices are very unstable, as well as the prices for energy carriers. Nevertheless, the relevance of the development of a natural resource value index is very significant from the point of view of the development of investment forecasts.

Conclusion

The studies carried out allow us to draw the following conclusions:

1. A method of statistical analysis of indicators of the results of socio-economic development of countries has been developed and successfully tested, which makes it possible to identify the system characteristics of a complex of 16 global indices, including five indicators of the results of socio-economic development (GDP / C, HDI, WHI, IHC, SPI).

2. Comparison of the interdependencies of the system shows that the Human Developmen Index and Social Progress Index have the greatest impact on the performance indicators. Their influence on other indicators of results is the greatest and amounts to 0.3–0.7 of the total influence and have a cooperative effect on other indicators within the framework of complex predictors. In third place in terms of influence is GDP per Capita.

3. The developed complex optimal predictors for various performance indicators provide a low level of average regression error, which is: for GDP per Capita - 3.9%, Human Developmen Index - 1.2%, World Happiness Index - 12.4%, Index of Human Capital - 5%, Social Progress Index - 5.2% (for the average of five samples, including 6, 12, 24, 48 and 72 countries, ranked by GDP). For a sample of 24 largest economies, the corresponding values of the regression error are: 3.1%, 1.1%, 6.5%, 2.3%, 3.2%, which is significantly less than for the predictors from individual indices.

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