Development of the Indicative System for Assessing GDP Per Capita Using Cumulative Indices, Including Human Capital

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Abstract--- The goal of the study is to develop the indicative system for assessing GDP per capita (result), depending on changes in the indices describing both human capital and a wide range of alternative institutional development factors at the international level (potential reasons) using an exploratory forecast. A generalized correlation formula of combining ten global indices into the optimal predictor CP_1 has been developed based on regression modeling, which provides a GDP per capita (GDP/C) forecast with a low coefficient of determination equal to 3 % for 12 largest economies and an average of 8 % for five samples from the largest countries by GDP (6, 12, 24, 48, and 72). The generalized correlation formula for the regression dependence, which allows finding the value of GDP/C from the predictor CP_1, is as follows: $GDP/C = 139 \cdot CP_1^{\mathbf{3.75}}$. The degree of influence of the indices included in the predictor CP_1 and determining the value of GDP/C has been revealed. The main influence is exerted by the indices describing the development of human capital: Human Capital Index and Mean Years of Schooling (44 %), as well as the World Happiness Index (24 %) and Legatum Prosperity Index (19 %). The use of regression modeling has allowed to identify potential causes that were not taken into account by the existing global indices, but had significant impact on the GDP/C value. The result of the study is an optimized system of indices, which predicts GDP/C with a high coefficient of determination.

Keywords--- Human Capital, GDP Per Capita, Economic Dynamics, Education, Modeling, Forecasting, Indicative Diagnostics, Regression Analysis, Correlation, Global Index, R&D.

I. Introduction

The problem of economic forecasting of the states (prospects) of an object is a connecting link between the theoretical and practical activities in micro- and macroeconomics (Barro and Sala-i-Martin, 2004). Its complexity is explained by the fact that the connection between the forecast and the analyzed phenomenon is probabilistic. The method of cross-country comparison can be used to study the exploratory model of the influence of these factors on the dynamics of development, but this requires to conduct measuring in a single system and with due consideration of the influence of hundreds statistical information parameters (Hawksworth *et al*., 2017; Ageev *et al*., 2007).

The dependence of the influence of such variable as the education of workers, taking into account the influence of the share of various education levels (potential cause), on another variable – GDP of the 14 largest world economies (result) – was analyzed in the work (Orekhov *et al*., 2019) in order to simplify the solution of this problem.

The study revealed that the forecast error for most of these economies was generally satisfactory, but the conversion of educational capital to GDP significantly deviated from the average for some countries. In particular, this deviation was very large for Russia – minus 49 %. This is a fundamentally important result that poses the following dilemma:

- Either it is necessary to take a wider range of factors into account for the proper indicative diagnostics,
- Or Russia has some specifics that impede the effective conversion of educational human capital into GDP.

This study was conducted in order to resolve the dilemma; ten of the most representative global indices and indicators were used as predictors in it (Aderikho, 2010; Drovyannikov, 2017; Economic development, 2019). This approach was chosen because the world economy was developing as a single system with a single capital of explicit knowledge and technologies (Kapitsa, 2012), therefore it was of fundamental importance to rely on information

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
Received: 17 Mar 2020/Accepted: 18 Apr 2020

about this system, which takes into account both the parameters of individual countries and the integral vision of the entire world economy, when developing the prognostic models.

Several dozen such indices have already been developed: Index of Economic Freedom (Miller *et al*., 2019), Worldwide Governance Indicators (Kaufmann et al., 2010), The Legatum Prosperity Index (The Legatum Prosperity, 2019), and others. Typically, the indicators in the above indices are mainly aimed at diagnosing the level of various kinds of freedoms (Gurvich, 2012) and do not cover a significant part of the important areas of the socioeconomic system. The Global Competitiveness Index (Schwab, 2019a) provides more comprehensive diagnostics of the production and economic activities, paying attention to various aspects of business competitiveness, market activities, and human capital factors (Kataeva *et al*., 2015; Kryukova *et al*., 2016; Fomicheva *et al*., 2017; Yudina *et al*., 2018; Fomicheva *et al*., 2018; Shcherbakov *et al*., 2019; Kataeva *et al*., 2018; Kryukova *et al*., 2019; Nakhratova *et al*., 2018; Shpilina *et al*., 2017).

The share of human capital (Schultz, 1962; Becker, 1962) in the national wealth of most developed and large developing countries has grown sharply recently and now reaches 80 % (Koritsky, 2013; Korchagin, 2005; Suvorov *et al*., 2014). Therefore, some indices have been developed to aggregate the information on the human capital across countries, such as Global Human Capital (Schwab, 2019b) and Human Capital Index (The Changing Nature of Work, 2019), which use fundamentally different models of human capital.

Another important direction in the development of global indices is aimed at the formation of alternative GDP/C (van de Ven, 2014) – an indicator of the effectiveness of the economic policy. The World Happiness Index (Helliwellatal *et al*., 2019) and others (Easterlin, 1974; Veenhoven, 2015; Argyle, 2003; Layard, 2011; Shmatova and Morev, 2015; Economic development, 2019; McConnell and Bru, 2006) were developed to serve as such indicators. An increase in the level of people's happiness can contribute to the growth of human capital in the transition from a postindustrial to an intellectual society, and the corresponding index can correlate with indicators of human capital. Therefore, it is important to understand how the indicators of human capital and the Happiness Index interact in a set of indicators of indicative diagnostics.

The goal of this article is to develop the model of indicative diagnostics of the GDP/C value, depending on the indices describing both human capital and a wide range of alternative factors.

The main methodological idea was to form a predictor on the basis of these indices through their linear combination, which would best correlate with the GDP/C value. The weighting coefficients of the components of the complex predictor are optimized using the regression analysis, and the maximization of the determination coefficient (R^2), which describes the dependence of GDP/C on the complex predictor, is used as an optimization criterion. It is believed that the weights of the indices in such an optimized predictor reflect their influence on the GDP/C value. The contribution of human capital to the growth of GDP/C can be determined in this way. The mathematical model for the dependence of GDP/C on the optimized complex predictor developed in this way allows to determine the extent to which Russia and some other countries deviate from the averaged model.

The solution to this problem is also an important step towards understanding the set of factors (predictors) that influence the economic dynamics, since the progress of countries along the path of global index growth, in a quasistationary approximation, is supposedly equivalent to an increase in GDP/C accurate to nonstationary and cyclical effects.

II. Methods

The regression and correlation analyses were used as a methodological basis in the study. GDP/C was used as the main indicator (attribute) of the effectiveness of economic activities. GDP at purchasing power parity (PPP) expressed in USD for 2018 according to the World Bank data was used.

The dependence of the performance indicators of the economy on the predictors (arguments and factors) represented by global indices (ratings), which collectively describe the specifics of the economic, legal, and social structure of countries, was reviewed in the study. Although they are conventionally considered as factor attributes, it is clear that all parameters are interdependent in such a complex system. The most well-known indices were mainly used as such factors, the list of which is presented in Table 1, and three of them are among those describing human capital (GHC, HCI, and MYS).

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X

Received: 17 Mar 2020/Accepted: 18 Apr 2020

Table 1: Indices Reviewed as Factors

#	Abbreviation	Full name	Indicators
1.	IEF	Index of Economic Freedom	Freedom of business, trade, money, investment, finance, labor relations, taxes – from corruption, from the government, and protection of property rights (Miller *et al*, 2019)
2.	WGI	Worldwide Governance Indicators	Freedom of speech and accountability of the authorities, lack of violence and stability, efficiency of the authorities, quality and rule of law, and control of corruption (Kaufmann *et al*., 2010)
3.	EDB	Ease of Doing Business Ranking, World Bank	Ease of starting a business, construction, access to electricity, registering real estate, applying for a loan, protecting investment, taxing, international trade, managing contracts, and ending a business (Doing Business, 2020)
4.	GCI	Global Competitiveness Index, WEF	Macroeconomics, infrastructure, institutions, health, education; markets for goods, services, finance, and labor; innovative potential, technological development, and business competitiveness (Schwab, 2019a)
5.	MYS,	Mean Years of Schooling, UNDP	Mean duration of schooling for the working-age population (Human Development, 2018)
6.	GHC	Global Human Capital, WEF	Productivity (level of employees' education), implementation (accumulation of skills), development (education and qualifications), and know-how (skills used at work) (Schwab, 2019b)
7.	HCI	Human Capital Index, World Bank Group	Probability of a child surviving until turning five, the expected number of years of schooling until turning 18, taking the quality of education into account, the survival rate of adults under 60, and the proportion of children without arrested development (The Changing Nature of Work, 2019)
8.	RDE	R&D Expenditure	Research and development (R&D) expenditure. R&D covers basic research, applied research, and experimental development (R&D Expenditure, 2017)
9.	WHI	World Happiness Index	Healthy life expectancy, social support, freedom of life choice, support from other people, low corruption, and feeling positive or negative emotions (Helliwell *et al*., 2019)
10	LPI	The Legatum Prosperity Index, Legatum Institute	Economics, management, entrepreneurship, education, healthcare, personal freedoms, social capital, security, and environmental protection (The Legatum Prosperity, 2019)

In addition to the widely known global indexes, mean years of schooling (MYS) was also added to this group. This indicator is a subindex of the global index – the Human Development Index (Human Development, 2018) formed by the United Nations Development Program (UNDP). For the convenience of comparing this indicator with other indices, the MYS value is presented in relative units due to the reference to the conditional duration of tertiary education, which is assumed to be 16 years.

The Human Development Index is not fully used because it includes GDP/C and largely serves as a resultant indicator of the socioeconomic development of countries, rather than as an argument (Shmatova and Morev, 2015). In addition, the R&D Expenditure (in shares of GDP) is also used as an indicator, which describes the presence of human capital associated with the R&D activities. All indices are presented in the study in fractions of a unit.

Due to the significant difference among the countries in terms of population and GDP, the issue of comparing them and identifying statistical dependencies is ambiguous and requires either the introduction of weighting coefficients or limiting the diversity of the correlation field. It is significant that small countries are easily exposed to external or natural influences, therefore, the scatter of points corresponding to them may be more random. Therefore, the samples including larger countries in terms of GDP at PPP were used in the study, in the first place. These samples are presented in Table 2.

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X

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Table 2: Main Country Samples

Value	G6	G12	G24	G48	G72
Number of countries in the sample	6	12	24	48	72
Share in the world GDP, %	52	65	78	89	92
Minimum value of GDP at PPP, USD bln.	4.0	2.5	1.0	0.4	0.1

The oil producing countries, for which the dependence of GDP/C on various indices significantly deviates from general patterns, were not included in the samples: Qatar, Kuwait, and Saudi Arabia. The economies for which there were no data in a number of indices, were not included in the samples either: Azerbaijan, Belarus, Iraq, Lebanon, Libya, Oman, Puerto Rico, Sudan, Taiwan, Turkmenistan, and Uzbekistan. Instead, these samples included the countries with the largest GDP at PPP.

For visual analysis, the G6 countries were indicated on the charts by the following icons (△ for China, ○ for the US, ◇ for India, ✕ for Japan, + for Germany, and □ for Russia).

As GDP of different countries varies greatly, it was not advisable to find a single regression dependence for them. Therefore, regression dependencies and the approximation reliability (coefficients of determination – R^2) were determined for all samples from Table 2. The optimal complex index was found using the indicator of the maximum arithmetic average (mid) value of the coefficient of determination – R_m^2 for five samples. The error parameter of the regression model was also determined – $\Delta R_m^2 = 1 – R_m^2$. The target value was $\Delta R_m^2 = 0.1$.

In addition to the main Indices (predictors) presented in Table 1, some complex predictors were also studied, which represented a linear combination of the main indices according to formula (1), where K_i was positive coefficients, the sum of which was unity:

$$\mathbf{CP = k_1 \cdot IEF + k_2 \cdot EDB + k_3 \cdot WGI + k_4 \cdot GCI + k_5 \cdot MYS + k_6 \cdot GCI + k_7 \cdot HCI + k_8 \cdot RDE + k_9 \cdot WHI + k_{10} \cdot LPI.} \quad (1)$$

The GDP/C regression model from CP was determined, and R^2 values were found for five samples in the process of optimizing the complex predictor CP for various k_i. Next, the optimal values of k_i were found, at which the highest value of R_m^2 was reached.

III. Results

3.1. Correlation between GDP/C and Global Indices

For orientation in the level of pair correlation between GDP/C and each of the indices provided in Table 1, the values of the coefficients of determination were determined for them, using the samples presented in Table 2. The corresponding results are presented in Figure 1 for an exponential trend (there is no power trend for some samples, which complicates the comparison), where the average values of the determination coefficients R_m^2 are also provided for samples G6 – G72.

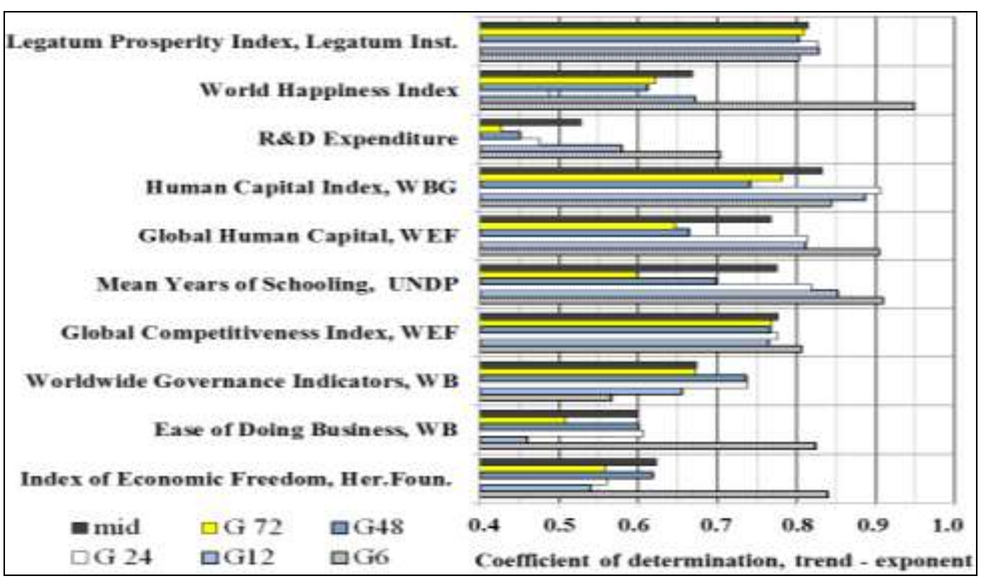

Figure 1: R^2 Values for the Dependence of GDP/C on Global Indices

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
Received: 17 Mar 2020/Accepted: 18 Apr 2020

It can be seen that the highest average value of $R_m^2 = 0.832$ is ensured by the Human Capital Index (World Bank Group), where $R^2 = 0.906$ with the exponential trend for the G24 sample, and $R^2 = 0.911$ with the power trend. The regression dependences of GDP/C on HCI for the G24 sample for exponential and power (dashed) trends are provided in Figure 2.

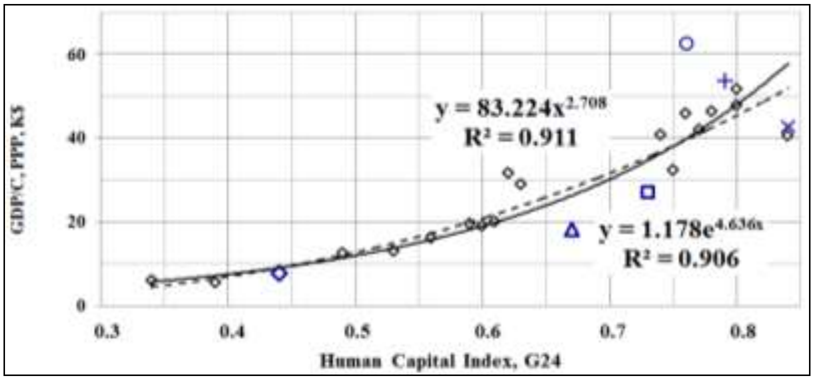

Figure 2: Regression Dependences of GDP/C on Human Capital Index

The charts of the power and exponential trends are quite close, and that for the power trend R_m^2 is slightly larger (~ 0.005). All indices describing human capital (HCI, GHC, and MYS) are among those with a high average value of R^2_m. The Legatum Prosperity Index is described by a rather high value of $R_m^2 = 0.814$, and $R^2 = 0.823$ for the G24 sample. The smallest values of the average coefficient of determination describe the R&D Expenditure ($R_m^2 = 0.53$), the Ease of Doing Business (0.60), and the Index of Economic Freedom (0.62).

A visual analysis of the field reveals that although the correlation is strong for the G24 sample points ($R^2 = 0.903$), the G6 sample points are much more dispersed – the value is $R^2 = 0.84$ for them. For example, the value of the Human Capital Index for Russia is HCI = 73 %, which is slightly less than for the US (HCI = 76 %). However, the GDP/C value is below the trend for Russia and much higher for the USA. As a result, the GDP/C in these countries differs more than twice, which negatively describes the predictive capabilities of this regression model.

The average value for the GHC, MYS, and GCI is $R^2_m \approx 0.79$ for exponential and power trends. R^2_m is lower for other trends. The coefficient of determination tends to increase when the sample size decrease, but this pattern may be violated for the G6 sample. The dependence of GDP/C on the MYS for the G24 sample is provided in Figure 3.

Although the determination coefficient for G24 is lower than that for the HCI ($R^2 = 0.82 – 0.86$) for the MYS, and the spread of points is greater, respectively, the value is $R^2 \approx 0.91$ for the G6 sample, and the points of this sample are mainly closer to the trend line. However, the point corresponding to Russia is quite far from the trend line for the MYS. This is probably due to the fact that the high educational level of Russian specialists is not effectively converted to GDP/C.

For the WGI, EDB, and IEF indices that are not related to human capital, and even for the ERD and WHI indices partially related to human capital, the average coefficient of determination is far from the target value of $R^2 \sim 0.9$ and lies mainly in the range of 0.6 – 0.67. A record low value of $R^2 \sim 0.53$ is characteristic of the R&D Expenditure due to very low values for the G24 – G72 samples, for which $R^2 \sim 0.45$. A very high correlation ($R^2 \sim 0.95$) is characteristic of the World Happiness Index for the G6 sample.

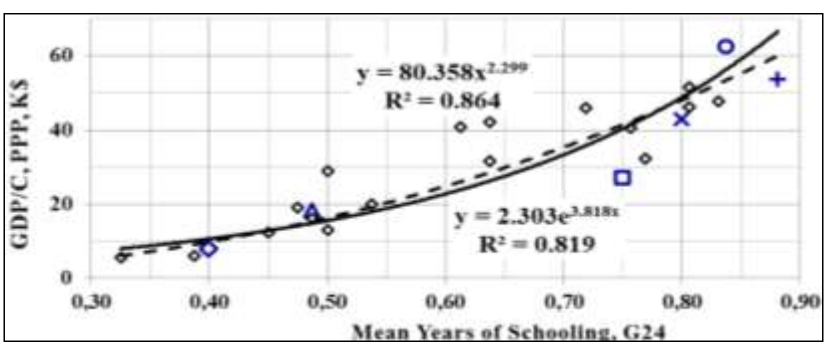

Figure 3: Dependence of GDP/C on the MYS for the G24 Sample

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X

Received: 17 Mar 2020/Accepted: 18 Apr 2020

3.2. Dependence of GDP/C on the Paired Complex Predictors

Let us study compositions of type (1), consisting of two global indices, in order to form complex predictors providing a better approximation of GDP/C (high R_m^2). The HCI, which individually provides the highest R_m^2 value, is based as a reference index. Since the coefficients of determination are close to unity in this case, the regression error $\Delta R_m^2 = 1 - R_m^2$ for the arithmetic mean of the G6 – G72 samples is used as an indicator of matching the correlation field with the trend. Let us determine their values at which the lowest ΔR_m^2 is ensured for a given pair of global indices through varying the coefficients. The corresponding values of ΔR_m^2 and k_i are provided in Table 3.

Table 3: Regression Error for the Optimal Paired Complex Predictors

	IEF	EDB	WGI	GCI	MYS	GHC	HCI	ERD	WHI	LPI	ΔR^2, %. Trend - polynomial					
	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	k_9	k_{10}	G6	G12	G24	G48	G72	mid
IEF	0.4						0.6				6.1	9.1	7.5	20.5	18.1	12.3
EDB		0.2					0.8				14.7	11.5	9.0	25.2	21.7	16.4
WGI			0.2				0.8				**8.0**	5.5	**7.0**	19.4	17.7	**11.5**
GCI				0.5			0.5				10.4	9.7	10.2	20.0	15.8	13.2
MYS					0.3		0.7				9.1	7.4	6.6	22.9	23.2	13.8
GHC						0.5	0.5				13.4	10.1	8.7	26.4	22.2	16.2
HCI							**1.0**				**16.6**	11.4	**8.9**	28.3	22	**17.4**
ERD							0.8	0.2			15.1	11.2	9.4	25.9	21.3	16.6
WHI							0.6		0.4		7.8	8.0	10.2	21.0	16.7	12.7
LPI							0.5			0.5	**6.9**	5.3	**7.8**	19.0	15.5	**10.9**

It can be seen that the smallest ΔR_m^2 is ensured by the predictor, in which the LPI is the second. The optimum is achieved at $k_{10} = 0.5$. In this case, ΔR_m^2 decreases by more than 1.5 times in comparison with the individual HCI predictor. ΔR^2 approximately halves for the G6 and G12 samples, reaching a level of 5 – 7 %. A good complementarity of these indices indicates that they reflect important complementary characteristics of the socioeconomic situation in the respective countries.

A significant decrease in ΔR_m^2, as well as ΔR^2 for the G6 – G24 samples, is also ensured by the paired complex WGI and IEF predictors. They had low ΔR_m^2 characteristics individually. It is interesting that these indicators ensure an optimal reduction in the regression error with a low contribution of $k_i = 0.2$.

The lowest decrease in ΔR_m^2 in the composition of the paired complex predictor is ensured by the EDB, GHC, and ERD indices. Moreover, the EDB and ERD generally weakly correlate with GDP/C, while the GHC is described by a sufficiently high ΔR_m^2, but it is significantly similar to the HCI and does not add new predictive information to the complex predictor.

The dependence of GDP/C on the best paired complex predictor for the G24 sample is provided in Figure 4 for exponential and power (dashed) trends. It can be seen that the coordination of points with the trend is better than for the HCI (Figure 2). Only the USA deviates significantly from the trend for the G6 sample.

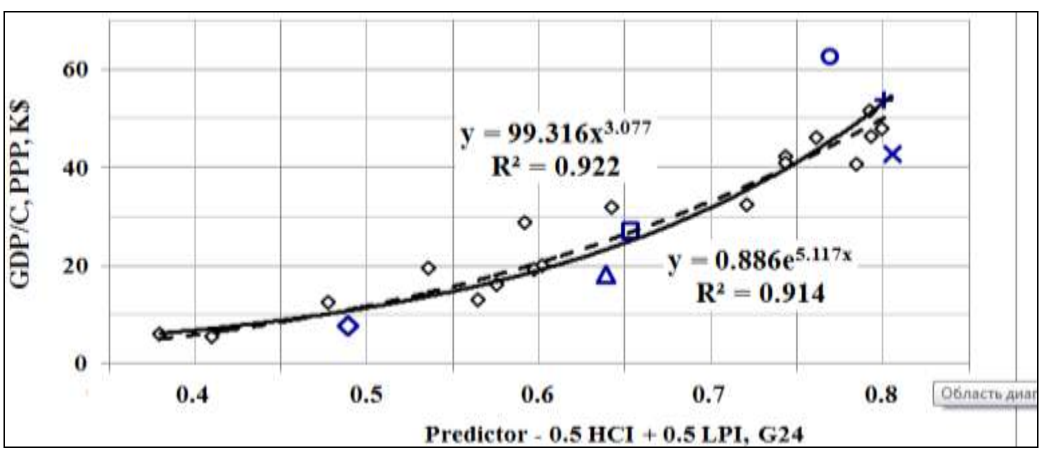

Figure 4: Dependence of GDP/C on the Best Paired Complex Predictor

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
Received: 17 Mar 2020/Accepted: 18 Apr 2020

3.3. Dependence of GDP/C on Multi-index Complex Predictors

The studies on the formation of optimal complex predictors that best correlate with GDP/C were conducted next. The choice was made by optimizing the function of many variables (indices) – R^2_m by the method of coordinate descent with a cyclic change of variables. The optimization was stopped if the changes in the function ΔR^2_m did not exceed 0.02 %. The regression error of the optimal complex predictor and its coefficients k_i are provided in Table 4. The characteristics of the HCI and paired complex predictor ($k_7 = 0.5$, $k_{10} = 0.5$) with the best regression errors in terms of GDP/C are also provided for comparison.

Table 4: Regression Error of the Best Complex GDP/C Predictors

	ΔR , %. Trend - polynomial						IEF	EDB	WGI	GCI	MYS	GHC	HCI	ERD	WHI	LPI
	G6	G12	G 24	G48	G 72	mid	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
HCI	16.6	11.4	8.9	28.3	22.0	17.44							1			
HCI+LPI	6.9	5.3	7.8	19.0	15.5	10.90							0.5			0.5
CI	2.1	2.8	7.8	14.8	12.8	8.06		0	0	0.1	0.2	0	0.3	0	0.2	0.2

It can be seen that the optimal complex predictor CP_1 has the value of R^2_m by one third lower compared to the paired complex predictor and more than twice compared to the HCI. It is also important that the regression error reaches record low values for the G6 and G12 samples (65 % of the world GDP at PPP): 2.1 – 2.8 %.

Another important result of studies on the optimization of complex indices is that the indices describing human capital (HCI, GHC, MYS) constitute the core of the optimal complex indices and their contribution is approximately 0.44.

The WHI makes the second largest contribution ($k_9 = 0.24$) to the complex predictor. The LPI ranks third by the contribution ($k_{10} = 0.19$) to the predictor CP_1. The IEF, GHC, and ERD indices are not in demand as part of the complex predictor (the GHC and ERD are not in demand as part of the paired complex predictors either). The results obtained indirectly indicate the weight of various global indices in the growth of GDP/C. However, the same set of indices has mutual influence.

A similar set of factors that influence the growth of GDP/C in the composition of the indices under study (Table 1) was reviewed by the authors earlier (Prichina *et al*., 2018) using cognitive modeling of a complex weakly structured system (Kosko, 1986; Saaty, 2008; Avdeeva, 2006; Kulinich, 2010). An alpha section of the mutual influence of concepts, which is represented in Figure 5, was built at a cutoff level of 75 %, as a result of processing the cognitive matrix of the system under study on the IGLA electronic platform for decision support (Podvesovsky, 2009; Podvesovsky, 2018). The dashed line outlines the negative influence, and the concepts associated with the negative influences are in italics.

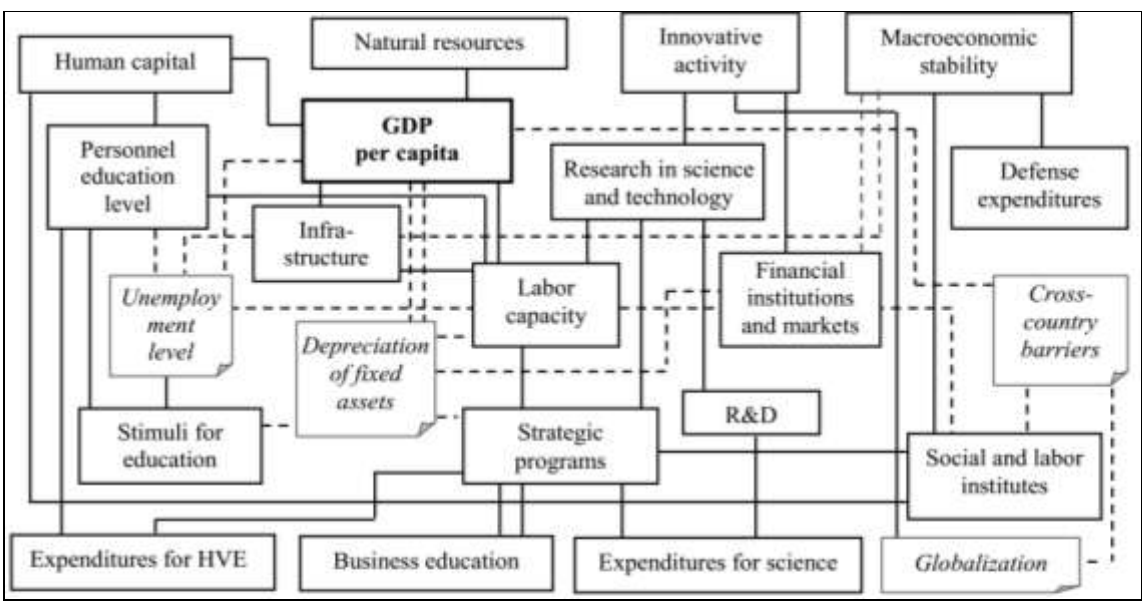

Figure 5: Flowchart of the Mutual Influence of the System of Concepts Determining the Growth of GDP/C

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X

Received: 17 Mar 2020/Accepted: 18 Apr 2020

There are both common and distinctive aspects in the system of factors considered above and in the one presented in Figure 5. In particular, human capital represented by the HCI and GHC, as well as the level of personnel education (MYS) also hold key places. Macroeconomics, infrastructure, financial institutions, innovative potential, and technological development are represented by the GCI, and research expenses are represented by the R&D Expenditure.

However, there are no explicit "Natural resources", "Depreciation of fixed assets", "Strategic programs", "Cross-country barriers", and "Defense expenditures" among the indicators used (Table 1). They largely represent “nonproductive” factors related to various freedoms, effectiveness of authorities, control of corruption, healthcare, and the “happiness of people”. However, it is important that Figure 5 actually represents the same system of interconnections of various concepts, but from a different standpoint. Moreover, this study allows to assess the level of mutual influence of a number of concepts through aggregated indices.

3.4. Regression Dependence of GDP/C on the Multi-index Predictor

The dependence of GDP/C on the complex predictor CP_1 for the G24 sample is presented in Figure 6. It can be seen that the dispersion of points is approximately the same as for the best paired predictor. The advantages of the predictor CP_1 are manifested in the G6 and G12 samples to a greater extent (Table 4). In particular, the point corresponding to Russia (square) is situated close to the trend line. In a polynomial trend, the regression equation for the optimal Predictor CP_1 (0; 0.03; 0.04; 0.06; 0.16; 0; 0.28; 0; 0.24; 0.19) is expressed by equation (2):

$$GDP/C = A \cdot CP_1^B \qquad (2)$$

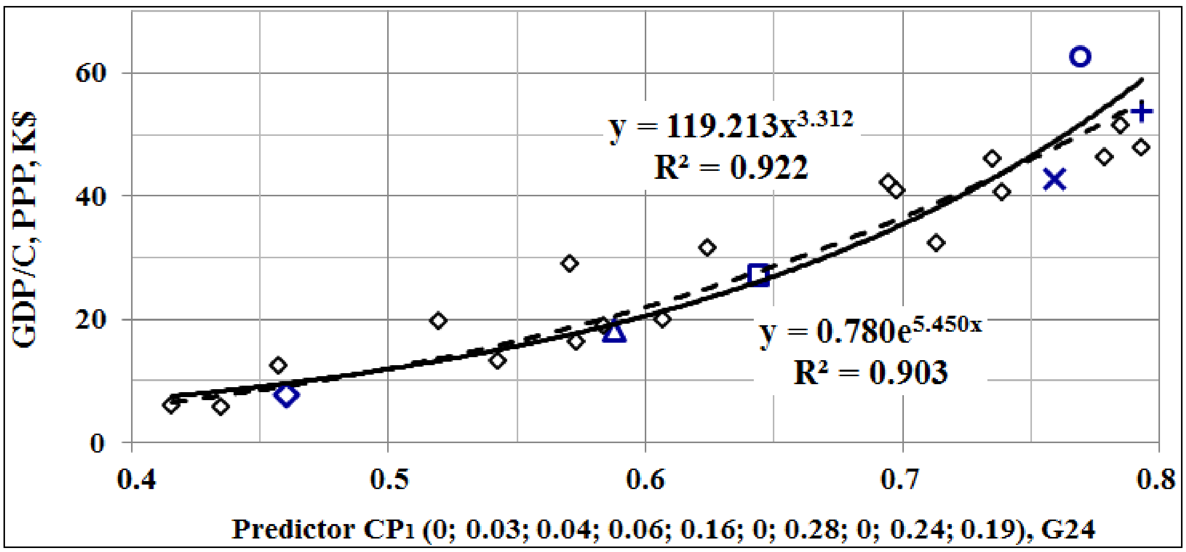

Figure 6: Dependence of GDP/C on the Optimal Multi-index Predictor CP_1

The coefficients *A* and *B* have different values, presented in Table 5, for different samples.

Table 5: Coefficients of the Regression Equations for the Predictor CP_1

	G6	G12	G24	G48	G72	mid
A – coefficient	135.4	137.5	119.2	144.9	158.2	139.0
B – power	3.701	3.761	3.312	3.818	4.139	3.746
R^2 – coefficient of determination	0.979	0.972	0.922	0.852	0.872	0.919

Accordingly, the regression lines are slightly different (Figure 7). The dependence for the G24 sample deviates most of all from others; moreover, it is higher than average values for small values of CP_1 and lower than average values for $CP_1 > 0.7$. Accordingly, it is preferable to use the average values of the coefficients *A* and *B* (mid). In this case, the regression equation is as follows (3), where GDP/C is expressed in thousands of USD.

$$GDP/C = 139 \cdot CP_1^{3.75} \qquad (3)$$

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
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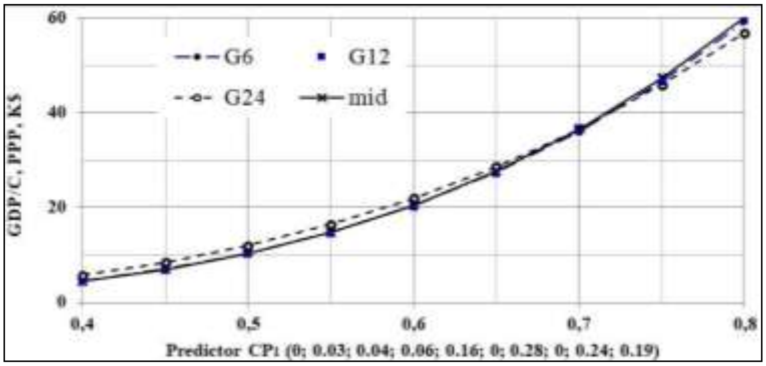

Figure 7: GDP/C Regression Lines Depending on CP_1 for different Samples

It can be estimated how different countries deviate from the average predictive dependence, using the regression equation (3). For this purpose, the values of CP_1 and forecast of GDP/C, in accordance with formula (3), as well as the relative deviation – Δ of real GDP/C from the forecast value in % – are provided in Table 6.

Table 6: GDP/C Forecast and Deviation – Δ of Real GDP/C from the Forecast, %

#	Country	CP1	GDP/C, K$	Δ, %	#	Country	CP1	GDP/C, K$	Δ, %
1	China	0.59	18.9	-4	37	Romania	0.63	24.5	-1
2	US	0.77	51.9	21	38	Sweden	0.79	58.6	-9
3	India	0.46	7.6	2	39	Kazakhstan	0.65	28.1	-1
4	Japan	0.76	49.4	-13	40	Austria	0.78	55.8	1
5	Germany	0.79	58.2	-8	41	Chile	0.67	31.5	-20
6	Russia	0.64	26.7	2	42	Peru	0.58	18.6	-23
7	Indonesia	0.54	14.0	-7	43	Czech Republic	0.75	46.2	-13
8	Brazil	0.57	17.2	-7	44	Ireland	0.78	54.1	55
9	France	0.73	43.7	5	45	Ukraine	0.57	16.7	-45
10	UK	0.78	54.5	-15	46	Israel	0.75	46.2	-12
11	Italy	0.69	35.5	19	47	Norway	0.79	58.3	9
12	Mexico	0.61	21.3	-6	48	Portugal	0.68	33.4	2
13	Turkey	0.57	17.0	70	49	Denmark	0.80	59.1	-5
14	South Korea	0.74	44.6	-9	50	Greece	0.63	25.2	19
15	Spain	0.70	36.1	13	51	Morocco	0.50	10.1	-15
16	Canada	0.79	58.2	-18	52	Hungary	0.67	30.5	2
17	Iran	0.52	11.9	63	53	Sri Lanka	0.55	15.2	-11
18	Thailand	0.58	18.5	3	54	Finland	0.81	61.7	-21
19	Australia	0.78	56.0	-8	55	Ethiopia	0.38	3.5	-43
20	Egypt	0.46	7.4	67	56	New Zealand	0.78	55.2	-24
21	Poland	0.71	39.2	-17	57	Ecuador	0.57	17.0	-31
22	Pakistan	0.44	6.1	-10	58	Dominic Republic	0.52	12.2	-13
23	Nigeria	0.42	5.2	16	59	Slovakia	0.70	35.6	-4
24	Malaysia	0.62	23.8	33	60	Kenya	0.49	9.3	-63
25	Netherlands	0.79	58.1	-2	61	Tanzania	0.41	4.8	-33
26	Philippines	0.56	15.5	-42	62	Bulgaria	0.63	25.1	-13
27	Argentina	0.60	20.3	1	63	Guatemala	0.45	6.9	23
28	South Africa	0.52	11.8	16	64	Tunisia	0.50	10.2	23
29	Colombia	0.58	18.1	-17	65	Ghana	0.49	9.3	-49
30	UAE	0.69	34.8	115	66	Serbia	0.65	28.3	-39
31	Vietnam	0.57	17.3	-57	67	Croatia	0.65	28.4	-3
32	Bangladesh	0.44	6.5	-32	68	Panama	0.50	10.3	147
33	Algeria	0.51	10.9	44	69	Lithuania	0.70	37.2	-5
34	Switzerland	0.80	60.0	15	70	Cameroon	0.42	5.6	-33
35	Belgium	0.75	46.8	9	71	Uganda	0.41	5.0	-60
36	Singapore	0.77	53.4	90	72	Nepal	0.41	5.0	-39

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
Received: 17 Mar 2020/Accepted: 18 Apr 2020

It can be seen that the deviation from the forecast is large enough for some countries, which is associated with the specifics of these countries. For example, the positive deviation for the USA is 20 %, which is probably due to the competitive advantages of this leading economy. The record deviations of the UAE (+115 %) and Panama (+147 %) are associated with the natural resources of these countries. It can be noted that some Mediterranean countries have a positive deviation: Turkey (+70 %), Iran (+63 %), and Egypt (+67 %). These three large deviations lead to the fact that the regression for the G24 sample is significantly different from the average (Figure 7). Some developed countries remote from the civilization center observe a negative deviation with this method of analysis: Japan (-13 %), UK (-15 %), Canada (-18 %), South Korea (-9 %), Australia (-8 %), etc. However, a significant positive deviation is observed in such countries as Singapore (+90 %), Malaysia (+33 %), and Ireland (+55 %). There is a significant negative deviation among developing countries that have experienced armed conflicts.

Similar results were obtained in the work (Orekhov *et al*., 2019) using only indicators of educational and scientific human capital for the 14 largest economies. However, in view of the narrower indicative orientation of this study, the quantitative conclusions were noticeably different, as shown in Figure 8, where the conversion of educational capital describes how much GDP/C of the countries is greater than the forecast based on the detailed account for the number of years of schooling.

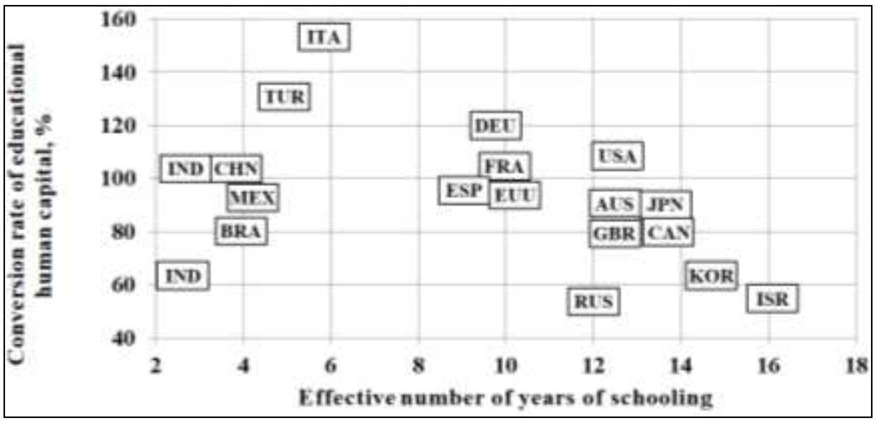

Figure 8: Effective Education Level and its Conversion Rate to GDP

According to the results presented in Table 6, the deviation of GDP/C from the forecast was 2 % for Russia, the deviation of which from the average conversion value (Figure 8) served as the basis for this study. As such, the forecast using only the educational component of human capital for this country was not accurate enough. However, the deviations from the average values found for Turkey and Italy were also confirmed in this study.

It must also be noted that the negative deviation from the forecast indicates that these countries have the potential for fairly rapid growth. Using various indicative approaches allows to identify the areas that countries need to focus on in order to use their existing potential.

The analysis of the standard deviation of Δ values provided in Table 6 for different country samples is presented in Figure 9. It indicates that this indicator is growing rapidly for countries following the G12 sample, due to the characteristics of the economies of Turkey, Iran, and Egypt, as shown above. This leads to a decrease in the coefficient of determination and the deviation of the regression equation for G24 from the general patterns.

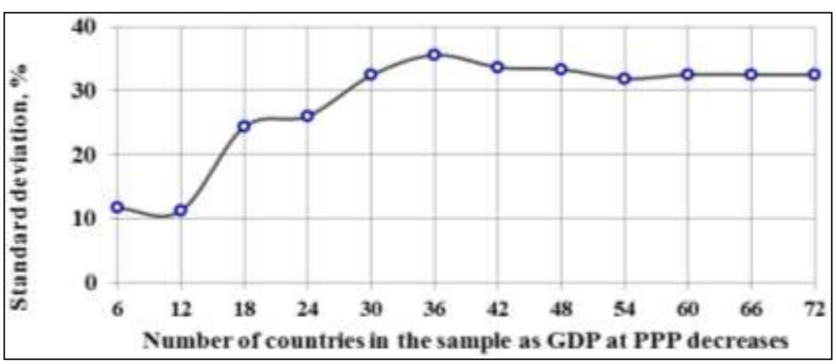

Figure 9: Standard Deviation of the difference between Real GDP/C and the Forecast

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
Received: 17 Mar 2020/Accepted: 18 Apr 2020

The global indices used in the study do not account for such factors as availability of rich natural resources, geographical location, and the history of armed conflicts. Therefore, their application does not eliminate forecasting errors. However, the developed forecasting method is quite accurate for the largest world economies.

IV. Discussion

The dependence of GDP/C on ten global indices and indicators has been studied in this article. The authors did not use the WHI and LPI in previous similar works, and it was found that their use significantly reduced the regression model errors. However, there are a number of indices that have not yet been used. The possibility of a more complete use of the set of global indices existing in the world should be considered in the future.

As the number of indices included in the complex predictor increases, the weight of many of them decreases to an insignificant level, although they could be considered important with a smaller number of indices. Multidimensional indices, such as the LPI and those describing the directions of socioeconomic life, which are weakly reflected in other indices – for example, the WHI, – begin to dominate. However, indices with a high aggregation level are "opaque", i.e., they make it difficult to understand what factors influence the overall situation. It is necessary to analyze what properties the components of the set of indices should have and what system characteristics this complex should have.

The study allowed to reveal some factors important for the GDP/C growth that were not covered by the existing global indices – in particular, natural, especially oil resources, as well as geographical location and postconflict situations. It is advisable to develop a special index of "special conditions" that would compensate for these gaps. The data on the deviations presented in Table 6 can be taken for the initial option.

This study was conducted for the same time sample, which makes it impossible to study the dynamic effects of the GDP/C growth in more detail. It is important to take into account the dynamics of the used indices in the future, although this is not easy to do, as the technique and coefficients of some indices vary over time.

The results of the study can be applied in the strategic planning of economic growth of countries by forming the plans for the growth of the key indices included in the predictor CP_1: the HCI, MYS, WHI, and LPI. It is also advisable to refuse to include such indicators as growth in the Doing Business Ranking position in economic growth plans. Confirmation of the WHI impact on the GDP/C growth can positively influence the introduction of this index in the practice of socioeconomic management.

V. Conclusion

1. The developed model for the indicative diagnostics of GDP/C depending on the ten-index predictor (CP1), optimized by minimizing the regression error (ΔR2 = 1 – R2), has indicated that the indices describing human capital (the HCI and the MYS) make the main contribution to CP1 (44 %), but are not absolutely dominant.
2. The WHI (24 %) and the LPI (19 %) make a significant contribution to the predictor. The indices of Economic Freedom and R&D Expenditure are not in demand as part of the optimized predictor.
3. The generalized regression model of GDP/C from the predictor CP1 is as follows: GDP/C = 139·CP13.75. In this case, the average value of the coefficient of determination is R2 ≈ 0.92, and it is R2 > 0.97 for the largest 12 economies (65 % of the world GDP at PPP).
4. It has been proved that the previously observed deviation of GDP/C of Russia from the forecast using only human capital indicators can be corrected using a wider range of indicators, and the deviation is reduced to 2 %.
5. The developed regression model allows to identify the countries where GDP/C differs significantly from the predicted values due to natural resources, geographical factors, and postconflict situations. This makes it relevant to develop the index of "special conditions" that would compensate for the inclusion of factors not considered in the existing global trends.

Acknowledgments

The reported study was funded by the RFBR, project No. 19-29-07328.

DOI: 10.5373/JARDCS/V12SP5/20201867
ISSN 1943-023X
Received: 17 Mar 2020/Accepted: 18 Apr 2020

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Received: 17 Mar 2020/Accepted: 18 Apr 2020