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Indicative diagnostics of the educational component of human capital based on mathematical modeling

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Abstract

The purpose of the research is to develop an indicative diagnostic system for the educational component of human capital based on a mathematical model of the dependence of the gross domestic product at purchasing power parity of different countries on the level of education of workers. The work shows that indicative diagnostics of the human capital educational component, as a basic factor of economic dynamics, provides a satisfactory accuracy of gross domestic product calculations, which is characterized by a relative standard error of 9% for the seven largest economies. The article defines the coefficients of contribution to the gross domestic product of various groups of workers by education and confirms that they depend exponentially on the number of years of education. The contribution of specialists at a bachelor level per year is 196 thousand intl. dollars. The growth of the contribution to the gross domestic product with an increase in education for one year is 76%, which is much more than the return on education in terms of wages. A system of indicative diagnostics of the human capital educational component is proposed. It contains two main indicators: the effective number of years of education and the conversion rate of the educational human capital at the gross domestic product. For most of the economies considered in the study, gross domestic product at purchasing power parity is directly proportional to the effective number of years of education.

Keywords: *human capital, indicative diagnostics, labor economics, return to education, earning function, economic dynamics, GDP, education, science, R&D specialists.*

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Diagnóstico indicativo del componente educativo del capital humano basado en modelos matemáticos.

Resumen

Resumen. El objetivo de la investigación es desarrollar un sistema de diag-nóstico indicativo para el componente educativo del capital humano basado en un modelo matemático de la dependencia del producto interno bruto en la paridad del poder adquisitivo de diferentes países en el nivel de educación de los trabajadores. El trabajo muestra que el diagnóstico indicativo del compo-nente educativo del capital humano, como factor básico de la dinámica económica, proporciona una precisión satisfactoria de los cálculos del producto interno bruto, que se caracteriza por un error estándar relativo del

9% para las siete economías más grandes. El artículo define los coeficientes de contribución al producto interno bruto de varios grupos de trabajadores por educación y confirma que dependen exponencialmente del número de años de educación. Se propone un sistema de diagnóstico indicativo del componente educativo del capital humano.

Palabras clave: capital humano, diagnóstico indicativo, economía laboral, retorno a la educación, función de ingresos, dinámica económica.

1. State of literature

The problem of human capital (HC) as an object of scientific research first appeared in the works of G.S. Becker and T. Shultz. Later, the development of assessment of HC impact on economic dynamics has become a wide class of scientific research using a variety of tools.

One of the most important HC research results is the determination of the dependence of labor results on the qualification of workers. According to J. Mincer's earning function, the worker's income (Y) is expressed by exponential dependence on the number of years of education (E) $\mathbf{Y = Y_0 e^{R\,E}}$.

In the works of R.J. Barro and J.W. Lee, it is shown that the dependence between the average number of schooling years of population and gross domestic product (GDP) per capita is well approximated by the exponential dependence $\mathbf{J} = \mathbf{438 \cdot 10^{0.2E}}$.

2. Contribution to literature

Based on the analysis of the contribution to GDP at purchasing power parity (PPP) for workers at four levels of schooling, the work [Orekhov, 2015] shows that their contribution is also described by the exponential equation $\mathbf{J = 138 \cdot 10^{0.2E}}$. However, the contribution of specialists of different levels, unlike R.J. Barro and J.W. Lee believe, is significantly different.

In this work, research is continued in terms of studying ways to improve the methods determining the impact of temporal drift on contribution to GDP, forming of an indicative diagnostic system that allows evaluating the effectiveness of an educational organization in different countries.

Unlike in previous studies, we found an increase in returns from education of up to 76% per year of study. The foundations for creating a new method for calculating economic dynamics were laid.

3. Introduction

Currently, HC has become the most important factor of production and is more than 80% of the national wealth of most developed and large developing countries [Nesterov, 2003]. The countries with a high HC level develop most rapidly and provide their people with the best standard of living. Therefore, it is very important to realize how HC affects society welfare growth and how to effectively increase its capitalization.

There are several approaches to the calculation of the value of HC:

– recovery approach, based on accounting investments in HC [Kendrick, 1976];

– capitalization of learning benefits [Becker, 1964; Mincer, 1994];

– accounting of natural indicators [Mulligan, 1995; Barro, 2001, Kary, 2015];

– the World Bank's discount method, based on the calculation of national wealth and its components [Dixon, 1997].

The calculation of HC can also be conducted at various levels: individually, regionally, at a company or macro level. Various studies use a wide range of quantitative characteristics affecting HC and its relationship with economic development, allowing one to determine the level of the HC contribution to economic dynamics from various theoretical and practical positions, as well as to structure the investment significance of the main HC components.

At the same time, many studies are characterized by the asymmetry of the positions of parties concerned with respect to evaluations of HC and its results. It arises as a result of the authors' initial orientation towards the target functions of the worker, their parents, employers, the institutions of the society or the state.

As a result, the assessment of HC as the basic factor of economic dynamics occurs in different directions, non-conjugately in its target, structural, instrumental and methodological aspects of implementation.

In this regard, there is a scientific and practical need for indicative diagnosis of the HC contribution to economic development, which has the minimum target asymmetry of parties concerned and makes it possible to predict the economic dynamics depending on the various educational characteristics of HC.

The use of indicative diagnostics of the HC educational component, as a basic factor of economic dynamics, makes it possible to determine the coefficients of the GDP contribution of workers with different levels of education, the effective number of schooling years for economic systems and the level of HC used to generate GDP, which is necessary to improve the efficiency of capitalization processes.

4. Literature review

The importance of HC as a basic component of the economic and social development of society was noted in the works of A. Smith, who believed that the knowledge and skills belong to the "capital assets" of an individual, which is part of the social wealth. Similarly, the works of A. Marshall emphasize the human abilities as a "means of production" of an individual being a special kind of capital.

The study of HC has become the most important area of economic research starting from the works of Becker [Becker, 1964] and Schultz [Shultz, 1968], who argued that the level of education determines the future level of labor income. Further, the assessment the impact of the HC on economic dynamics turned into a wide class of research using a variety of tools and methods for diagnosing the development of HC [McConnell, 2006; Korchagin, 2005; Koritsky, 2013], including both direct and indirect methods of HC assessment.

Direct methods for HC assessment are based on data from educational statistics, including the educational level [David, 2013], the number of schooling years at various levels [Polachek, 2013], etc. Indirect methods for HC assessment are based on a wider coverage of the HC characteristics and interconnection determinants, including informal education [Igaune, 2016], education and altruism of parents [Soares, 2006], life cycle and personal experience [Serneels, 2008], interrelation with happiness index, ecological efficiency [Bubis, 2014], etc. All these lead to the fact that HC assessment is built on different principles, carries different quantitative and qualitative certainties, has a different amount of evaluation information, availability, openness, completeness of databases and also has different functional limitations of the application. The combination of all these factors raises a number of questions on the correctness of the developed methods for HC calculating [Kiryanov, 2011].

Consideration of working activity using the systematic approach [Meadows, 2008; Spitsnadel, 2000] shows that in addition to the interests of the worker, investing in its own education and seeking to receive adequate wages [Fischer, 1988], there are other parties with objective functions that influence the formation and return of the HC components. For the employer, high labor productivity and profit are important. Society requires high labor productivity and GDP growth per capita, as well as social stability. There are many people unable or unwilling to work, but they need to be provided with a minimum of subsistence in order to maintain social stability. This results in a competition for labor results, which makes a number of assumptions used in the methods of HC calculation vulnerable. Therefore, it is important to minimize the impact of the target asymmetry of interested parties on the diagnosis of the educational component of HC.

The key stage to the formation of indicative diagnostics is the determination of the dependence of labor results on the workers' qualifications, the most important characteristic of which is the number of schooling years. According to the well-known J. Mincer's earning function [Mincer, 1974], the employee's salary (Y) exponentially depends $\mathbf{Y = Y_0 e^{R\,E}}$ on the number of years of education (E), where Y_0 is the salary without education, R is the rate of return on education for one year. In addition to traditional education, J. Mincer introduced training parameters at work into the earnings formula [Berndt, 1991], which does not change the exponential type of dependence on the duration of education.

Another example of the assessment of the labor activity results is the relation between the average number of population's schooling years and GDP at PPP per capita (J) for different countries, presented in [Barro, 2001]. Statistical data for workers over 25 years old is well approximated by the exponential dependence $\mathbf{J = 438 \cdot 10^{0.2E}}$ (in international dollars, as of 2017). However, the parameter used in the average number of schooling years implicitly means that the contribution of education to GDP at different levels is taken into account with the same weight, which requires clarification.

These examples demonstrate the existence of an exponential dependence of the labor activity results on the duration of education. Such a strong influence of the level of education is a very important factor in terms of economic dynamics and, therefore, it is necessary to examine it in detail with reference to the current state of the world's largest economies.

3. Research purpose and objective

The main objective of this work is to develop an indicative diagnostic system for the educational component of HC, with minimal target asymmetry of interested parties and reflecting the HC contribution to the economic development of various countries.

It seems that GDP at PPP, as a parameter that quantitatively summarizes the results of the company's work and is convenient for analyzing the economic dynamics, is among the most unbiased ones from the point of view of various interested parties.
However, GDP describes the state of society only from the economic side, which is also a factor of asymmetry. Therefore, the focus on the definition of indicators characterizing the intellectual (educational) state of society, which are the backbone of work and, in many respects, determine the magnitude of GDP, is of great importance.

Thus, the following positions are the source for this work:

– symmetric consideration of the interests of various parts of society and the use of one of the key indicators of the GDP parameter in PPP (G);
– the use of an indicator model of HC as potentially having the minimum disadvantages of the asymmetry of interested parties;
– the use of the fact of the HC domination in the national wealth of most developed and developing economies (except those rich in raw materials) in the formation of a mathematical model;
– the key importance of education for the growth of HC;
– the rapid growth (presumably exponential) of specialists' contribution to GDP in terms of the number of years of education;
– a focus on identifying integral indicators of the educational component of HC.

Among the specific tasks assigned to this work, we can note the following:

1. Confirmation of the exponential dependence of specialists' contribution to GDP on the number of years of schooling;
2. Determination of the coefficients of the contribution to GDP of groups of workers sorted by education in the present time period (2017);
3. The increase in the number of considered groups in the field of secondary education;
4. Expansion of the spectrum of basic economies, according to which the coefficients of contribution to GDP are determined;
5. Verification of the possibility of forecasting GDP values from educational data for the synchronous time period, i.e. including workers who have just received an education;
6. Determining the possibilities of using the developed model to characterize the effectiveness of the structure of education in different countries.

A comparative analysis of the study covers data from 19 economies (United States, European Union 23, China, Japan, Brazil, Turkey, Australia, Canada, India, Russia, Korea, Australia, Israel).

In accordance with the main purpose of the work, it is also important to check other various characteristics of the mathematical model used.

6. Methods

The key hypothesis is based on the above-mentioned positions and is the foundation for the mathematical model under study. The hypothesis is the existence of an indicator of educational HC (I_{HC}) related to GDP per capita by dependence (1).

$$\mathbf{G/N_C \approx K \cdot I_{HC}} \qquad (1)$$

The components of GDP generated by physical and natural capitals are a factor that increases the coefficient K and for most countries (excluding those rich in natural resources), equal to about 15% of its value [Nesterov, 2003].

The second basis of the model under study is the assumption that the value of the I_{HC} indicator can be calculated by summing the contributions of workers with different levels of education (2).

$$\mathbf{I_{HC} = \Sigma\, K_i \cdot D_i}\,. \qquad (2)$$

Here D_i is a share of each group of workers among the working-age population (25-64 years old), K_i – the coefficients of contribution to GDP. Normalize them to the contribution of bachelor-level specialists, for which $K_i = 1$.

Here, accept the assumption that other components of HC (health care, demography, etc.) are partially reflected by the current population size (N_C) and partially will not be taken into account and will increase the calculation error. However, since it is believed that the level of population's health only depends on health care on 8-10% and health part in human welfare is about 10% [Kiryanov, 2011], then they make a relatively small contribution to HC.

4.1. The method for determining the coefficients of the contribution of specialists to GDP

The following algorithm is used to determine the weighting coefficient Ki of the contribution of specialists with different levels of education to GDP at PPP of the country.

1. Form several basic groups of major economies (countries). According to Simon Kuznets, it is the size of the accumulated HC that determines the successful application of the accumulated experience of advanced countries.

2. Single out five educational groups (E_i) of workers, characterized by the duration of education: from incomplete secondary education to the level of R&D specialist.
3. It is considered that the specialists of each educational group are characterized by a certain quantitative contribution to GDP at the country's PPP (K_i), independent of the country. The coefficient K_i, corresponding to the bachelor's level, $K_4 = 1$.
4. For each economy, determine the share of specialists (D_i) of working age (25-64 years old) from different educational groups.
5. For each economy, determine the average value of the indicator of educational HC – I_{HC} (2) under variable coefficients K_i and later under the coefficients determined in the study.
6. For each economy, determine the predicted variable value of GDP at PPP (G_V), according to formula (1), as well as its relation to the real GDP of a country (G_C/G_V).
7. Under variation of coefficients K_i, determine their values, at which the minimum relative standard deviation of the value G_C/G_V ($\Delta(G_C/G_V)$) and the corresponding mathematical expectation value ($M = M(G_C/G_V)$) are ensured.
8. Analyze combinations of K_i for various groups of basic economies and select the most adequate group.
9. Determine the contribution to GDP of specialists with different levels of education and the overall dependence of GDP on E_i.

The parameters of the mathematical model are described in the next section.

4.2. Parameters of the mathematical model under study

This paper considers four groups of basic economies:

1. United States, European Union 23, China (3 economies).
2. United States, European Union 23, China and composition of the total characteristics of five countries: Japan, Brazil, Turkey, Mexico, Indonesia (conditionally, four economies).
3. United States, European Union 23, China, Japan, Brazil, Turkey, Mexico, Indonesia (eight economies).
4. United States, European Union 23, China, Japan, Brazil, Turkey, Mexico, Indonesia, Germany, United Kingdom, France, Italy, Spain, Canada (14 economies).

Also, five educational levels were presented (Table 1) in accordance with the international classification ISCED 2011 [UIS UNESCO, 2013]. The fifth of them relates directly to scientific activities since it is science and not a scientific degree that makes a real contribution to GDP. It should be noted that the same levels of education in different countries correspond to a different number of years of schooling. Therefore, average values for the country are used.

Table 1. Considered educational groups of workers.

Level	International standard of educational level	Russian standard of educational level	E, years of schooling	ISCED 2011
E_1	Below upper secondary education	Incomplete secondary	~6	1–2
E_2	Upper secondary education	Secondary education	11	3–4
E_3	Short-cycle tertiary education	Secondary special	13	5
E_4	Bachelor, Master (tertiary education)	Higher education	16	6, 7
E_5	R&D specialist	Scientific activity	22	8

Information on the share of specialists with different levels of education was used in accordance with [OECD. Stat., 2018], data on the number of R&D specialists [Researchers in R&D, 2015], GDP data at PPP of countries in 2017 [Indicators, 2018]. Used data are presented in Table 2.

Table 2. Data on the contribution of education to GDP.

Country	**Code**	**G_C, $**	**D_1, %**	**D_2, %**	**D_3, %**	**D_4, %**	**D_5, %**	**N_C, mil**	**E_{ef}, years**	**C_{HC}**
European Union 23	EUU	20,986	18.7	46.3	5.4	28.9	0.70	510	10	0.95
United States	USA	19,391	8.5	44.3	10.9	35.5	0.85	326.5	12.7	1.07
China	CHN	23,301	53.4	30	10.1	6.5	0.24	1,388	3.8	1.01
Japan	JPN	5,487		48.6	21.2	30.2	1.05	126.0	13.6	0.88
Brazil	BRA	3,241	51.1	34.1		14.8	0.14	211.2	4.0	0.80
Turkey	TUR	2,140	60.7	19.3	5.5	14.5	0.23	80.4	4.9	1.30
Mexico	MEX	2,358	62.3	20.2	0.5	16.9	0.05	130.2	4.2	0.94
Indonesia	IDN	3,243	62.1	26	2.8	9.1	0.02	263.5	2.6	1.04
Germany	DEU	4,187	12.6	57.9	0.5	28.1	0.89	80.6	9.9	1.18
United Kingdom	GBR	2,857	18.0	35.4	10	35.7	0.89	65.5	12.7	0.79
France	FRA	2,857	20.8	43.2	14.2	21	0.83	64.9	9.8	1.02
Italy	ITA	2,387	38.7	42.2		18.7	0.40	59.8	5.9	1.52
Spain	ESP	1,770	40.4	22.7	11.2	25.2	0.53	46.1	9.2	0.95
Canada	CAN	1,714	8.0	34.4	25.5	31.2	0.90	36.6	13.8	0.81

Data on the proportion of different levels of education D_i refer to the population of 25-64 years old. The number of researchers is also given to a similar (50%) share of the population and not to the entire population. Here, Nc is the population of countries. The value of GDP at PPP (G_C) for each country is given in international dollars as of 2017 according to [Deflator, 2018]. The data for India, Russia and South Korea were not used to optimize the K_i coefficients, since, as shown by previous studies [Orekhov, 2015], they give significantly mismatching results.

There are OECD data on educational levels of the population in China only until 2010. According to [Karpenko, 2008], in China in 2005, the number of higher education students (level 6-7 according to ISCED 2011) was 10.8 million people. Data on the total number of tertiary students is rather ambiguous. In [Altbach, 2013], the number of 29.3 million people is mentioned and, according to [Donetskaya, 2018], in 2016, the number of students was 28.9 million, although the increase in the number of students after 2011 was 0.8 million per year. To assess the dynamics of workers with tertiary education in China, a linear growth model was taken. Considering the length of training, the estimates were actually based on the number of students in 2012. It was also believed that the annual increase in the share of workers with higher education is 90% of the number of applicants. The calculations used data from the World Bank on the number of the working-age population in China. Estimates of the share of workers with higher education are shown in Table 3.

Table 3. Assessment of the dynamics of tertiary education in China in 2010-2017.

1.	Level of education (ISCED 2011)	5	6, 7	Total
2.	Share of workers with tertiary education in 2010, %	5.8%	3.9%	9.7%
3.	Number of students in 2012, mln	11	14	25
4.	Years of schooling	2	4.2	
5.	Graduates per year, mln	4.8	2.9	7.8
6.	Share of workers with tertiary education in 2017, %	10.1%	6.5%	16.6%

According to the results of previous studies [Orekhov, 2015], the contribution of a specialist with higher education (K_4 = 1, E = 16 years) to GDP at PPP is J J_4= 137•$10^{E/5}$ = 137• $10^{3,2}$ ≈ 218,000 dollars per year in 2017 (3).

$$J_4 = 218{,}000 \text{ dollars per year} \quad (3)$$

Value (4) was taken as a preliminary for calculations, during which, for each country, the calculated (variable) value of GDP at PPP was determined using formula (4).

$$G_V = 0.5 \cdot J_4 \cdot I_{HC} \cdot N_C \quad (4)$$

Here, a coefficient 0.5 is taken to consider that approximately 50% of the country's population does not contribute to GDP. It would be possible to take into account the share of the working-age population, but in addition, there are still unemployed and part-time employed people. At the same time, in countries with a large share of the working-age population, as a rule, there are many unemployed people. Therefore, in order to not complicate the design scheme, all deviations from 50% are attributed to the individual results of the countries.

For each economy, the G_C/G_V ratio was calculated and then a search was made for K_i values providing the minimum relative standard deviation $\Delta(G_C/G_V)$ for the whole group of basic economies, as well as the expectation value M = $M(G_C/G_V)$. Such calculations were made for each of the four groups of basic economies.

7. Results

As a result of the calculations, the values of the K_i coefficients for the studied groups of economies were obtained (Table 5).

Table 4. The results of the optimization of the coefficients of education contribution to GDP.

	Number of economies				Average		Number of economies				Average
	3	4	8	14			3	4	8	14	
M	0.320	0.488	0.897	0.892	0.65	$\Delta(G_C/G_V)$	8.2%	6.5%	15.2%	14.3%	11.0
K_1	0.05	0.04	0.002	0.04	0.033	K_1•M	0.016	0.020	0.002	0.036	0.02
K_2	0.025	0.050	0.025	0.22	0.08	K_2•M	0.008	0.024	0.022	0.196	0.06
K_3	0.50	0.520	0.58	0.03	0.41	K_3•M	0.158	0.254	0.520	0.027	0.24
K_4	1.0	1.0	1.0	1.0	1.0	K_4•M	0.316	0.488	0.897	0.892	0.65
K_5	140	70.0	16.0	12.0	60	K_5•M	44.2	34.2	14.4	10.7	25.9

7.1. Results of assessing the contribution to GDP of various levels of education

To use the calculated values of K_i to predict the calculated value of GDP (Gp), use expression (5), considering the fact that $G_C/G_V \approx M$. Therefore,

$$\mathbf{Gp \approx G_C \approx G_V \cdot M = 0.5 \cdot J_4 \cdot (I_{HC} \cdot M) \cdot N_C} \qquad (5)$$

Since the mathematical expectation M is different for different groups of economies, then formula (5) shows that for comparing the levels of contribution to GDP according to different groups of economies, its not the K_i values themselves that are important, but their work with the $K_i \cdot M$ expectation values, given in Table 4.

Graphically obtained values of the complex $K_i \cdot M$ are presented in Fig. 1. The dotted line shows the exponential trend for the eight-economies option ($R^2 = 0.95$) and the solid line shows the approximately averaged dependence for all the options. It can be seen that they diverge, mainly with the minimum values of education.

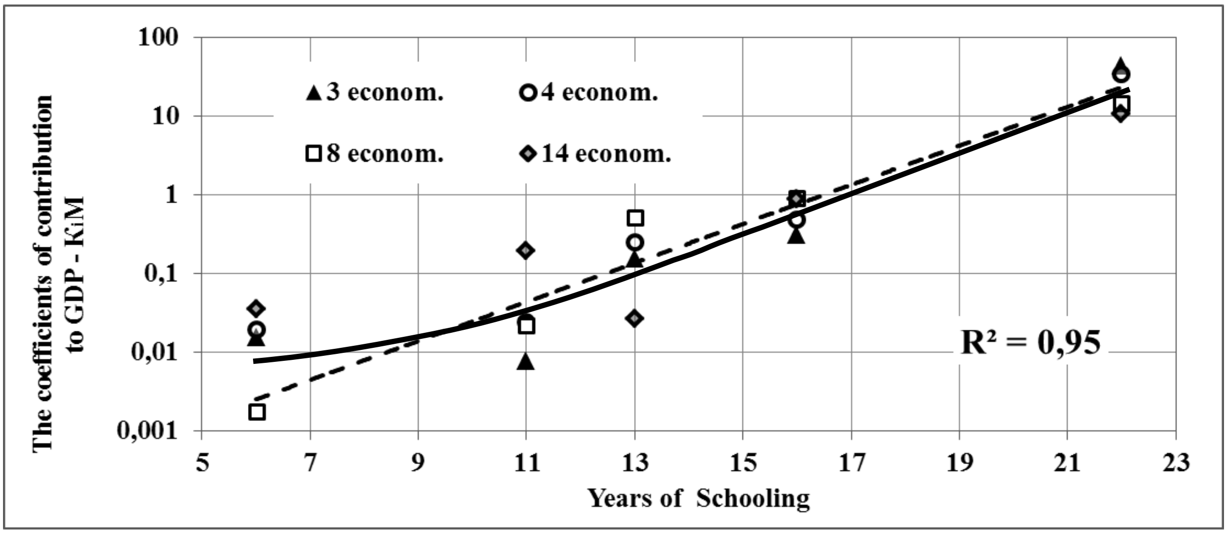

Figure. 1. The calculation results of the coefficients of the education contribution to GDP – K_iM.

In order to convert the obtained $K_i \cdot M$ coefficients to the contribution value of specialists to the country's GDP (6), they must be multiplied by J_4 (4) coefficient mentioned above. The obtained contribution to GDP at PPP in international dollars as of 2017 is presented in Table 5 and the corresponding schedule for eight economies is given in Fig. 2. The exponent approximating the calculated points in Fig. 2 has the form (6).

$$\mathbf{J_E = 20.5 \cdot 10^{0.246\,E}} \qquad (6)$$

Table 5. GDP contribution by specialists with different levels of education.

Educational group	E_1	E_2	E_3	E_4	E_5
Education, years	6	11	13	16	22
Coefficients of contribution to GDP – $K_i \cdot M$	0.0018	0.0224	0.520	0.897	14.36
Contribution to GDP at PPP, thousand dollars	0.39	4.89	113.5	195.6	3 130

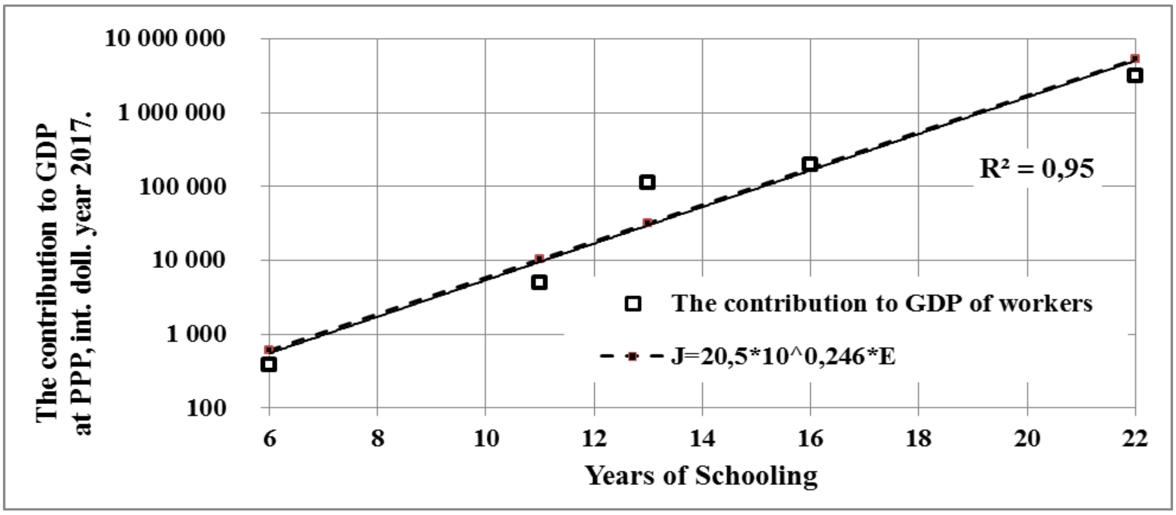

Figure 2. Contribution to GDP at PPP of specialists with different education for eight economies.

The above-mentioned deviation from the exponent at the level of secondary education should be taking into account the small number of basic economies that are appropriate to use. It leads to the individual characteristics of different countries. In particular, in the three-economies option, it results in a relatively small contribution to GDP of a full secondary education.

As a hypothesis, it can be assumed that this is a consequence of the fact that China, having many specialists with incomplete secondary education, was able to organize the effective work of such specialists at the expense of catching-up development and high workload. In contrast to China, the USA and Europe seem to use numerous (45%) specialists with complete secondary education at the same level than those with incomplete secondary education. As a result, a discrepancy is revealed between the efficiency of using different groups of workers with secondary education in the three largest economies.

Note that the option of 14 economies, with prevailing developed countries of medium size, demonstrates that short-term tertiary education (E_3) is ineffective compared to high-quality and numerous secondary education. However, the weights of the coefficients in these educational groups are relatively small in magnitude and the GDP of developed countries is rather weakly affected. Therefore, the errors in determining these coefficients are relatively large.

It is also important to note the differentiation in terms of the contribution of science (E_5) in the options of three-four leading economies and 8-14 economies, in which the contribution rate of science is about three times lower (Table 4).

This probably corresponds to the real power ratio of scientific schools in these groups of economies and, accordingly, to the contribution of science to GDP [Shinkareva, 2018].

Fig. 3 compares the studies conducted according to the data for 2017 with the previous ones (for 2011) for four economies [Orekhov, 2015]. It can be seen that the results obtained from data for different years are fairly well coordinated, with the exception of secondary education. Differentiating it into two levels showed that secondary education does not increase the contribution to GDP compared to the incomplete secondary education.

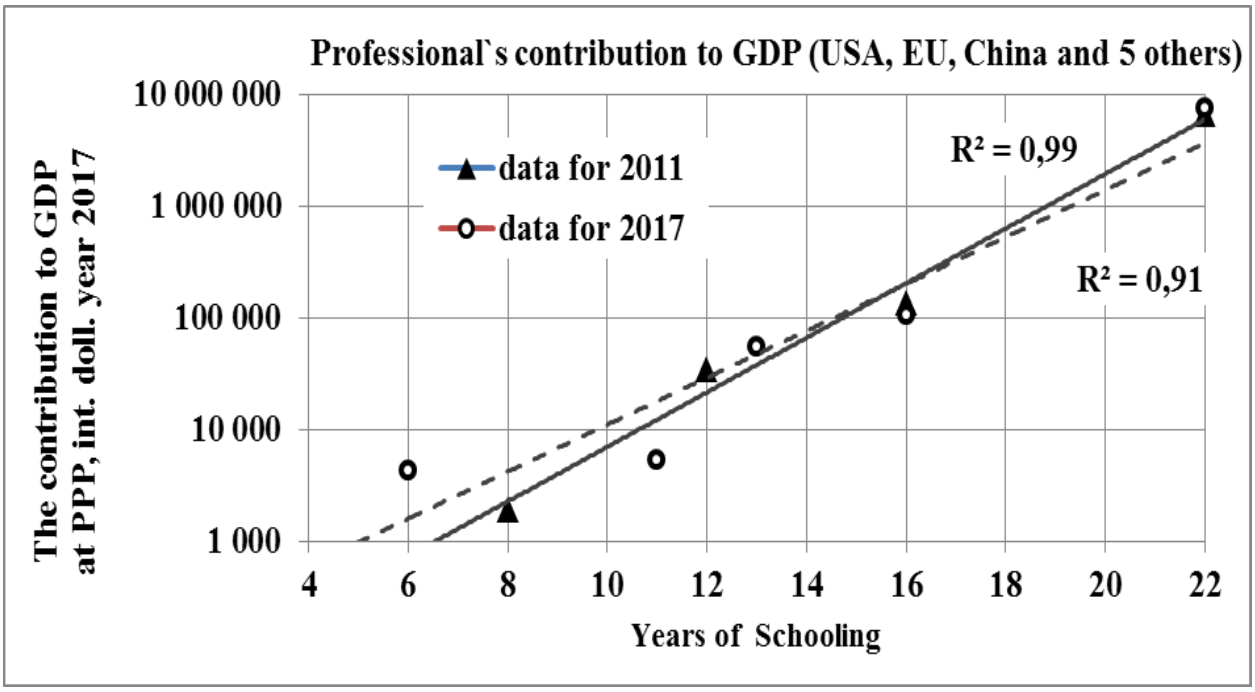

Fig. 3. Contribution of workers to GDP according to the data for 2011 and 2017 for four economies.

In order to use the results obtained, choose the most appropriate version of the basic economies. Fig. 4 and the above analysis show that the option of three-four economies and 14 economies have significant specificity, different from the average patterns. It seems that the most suitable is the option of eight economies since it is mostly devoid of focus on a limited number of major economies, as well as a large number of relatively small developed economies. Another positive feature is the fact that the obtained values of the coefficients $K_i \cdot M$ for this option are fairly well approximated by an exponential dependence with a coefficient of determination (R^2 = 0.95).

The contribution of specialists with higher education (6, 7 levels, ISCED 2011) to GDP at PPP for the option of eight economies was J_4 = 195.6 thousand dollars, which is 11% less than the previous results (15), although these studies were conducted under conditions significantly different from previous ones.

However, the rate of return from education in one year is higher than in previous studies and equals to $10^{0.246} - 1 \approx 76.2\%$. The obtained values of the factors contributing to GDP in the option of eight economies are characterized by the relative standard deviation $\Delta(G_C/G_V)$ = 15% for eight economies, 6.3% for the three largest economies and 21% for 14 economies.

5.2. Indicators of education impact on the contribution to GDP in different countries

The obtained coefficients $M{\bullet}K_i$ allow one to calculate the total indicators of the influence of education on the contribution to GDP. As the first one $M{\bullet}I_{HC}$ can be used and as the second – the ratio of G_C/Gp (real GDP at PPP of countries in 2017 to the calculated value at previously determined $M{\bullet}K_i$ values).

The first indicator characterizes the effective – in terms of GDP production – level of educational HC in the country's workers in accordance with the averaged coefficients of contribution to GDP (across eight economies). It evaluates only the educational component and is not aimed at considering the individual characteristics of a country.

The second indicator characterizes the country's individual conversion efficiency of the educational HC to GDP, calculated in relation to the calculated (averaged) parameter (G_P), which makes it possible to determine the first indicator.

An effective level of education can be represented in the form of an effective number of schooling years of workers – E_{ef}. For this purpose, choose the conversion factor from $M{\bullet}I_{HC}$ to E_{ef}. If this coefficient is equated to 25 (7), then the averaged mean and the effective number of years of study will be equal for the largest developed economy (USA), which is convenient as a baseline.

$$\mathbf{E_{ef} = 25{\bullet}M{\bullet}I_{HC}} \qquad (7)$$

The values of E_{ef} for the considered countries are given in Table 2 above. Fig. 4 shows a comparison of the arithmetic mean (E_m) and effective (E_{ef}) durations of training for 19 economies presented in Tables 2 and 6. Black points are marked for the following countries (successively from left to right): China, European Union, Russia, USA and Israel.

Table 6. Data on the contribution of education to GDP of countries not included in the baseline.

Country Name	Code	G_C, $	D_1, %	D_2, %	D_3, %	D_4, %	D_5, %	N_C, mil	E_{ef}, years	C_{HC}
Russia	RUS	3,817	5.4	40.9	25.1	28	0.626	143.4	12.0	051
India	IND	9,449	71.3	18.1	0.8	9.8	0.043	1,342	2.6	0.62
Korea	KOR	1,973	11.0	39.9	13.5	34.2	1.417	50.7	14.7	0.60
Israel	ISR	333	10.9	36.5	14.3	36.6	1.651	8.3	16.2	0.56
Australia	AUS	1,192	18.1	35.6	11.5	33.9	0.906	24.6	12.6	0.88

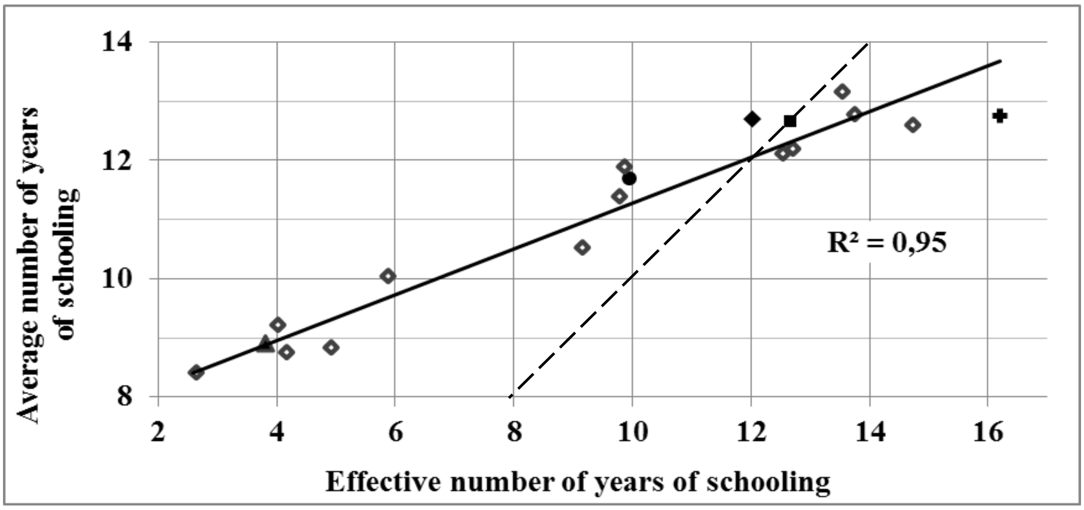

Fig. 4. Comparison of the average and the effective number of years of education.

It is shown that the effective value of the number of schooling years, in terms of the formation of GDP at PPP, differs significantly from the arithmetic mean. For education levels below 12 years, effective values are less than the average. For low levels of education (~ 9 years), the effective value may be less than the average up to 3 times, and for high levels – more than 1.3 times. The approximation dependence between the mean and effective values of the number of years of education is as follows (8).

$$\mathbf{E_{ef} = 2.6 \bullet (E_m - 7.4)} \quad (8)$$

Therefore, under the average number of years of education less than 7.4, the effective value of the number of years of education is close to zero. Although this conclusion is approximate, it reflects the fact that workers with a low level of education, as a rule, make an extremely small contribution to GDP.

The ratio $G_C/Gp = C_{HC}$ of real GDP at PPP of countries to the calculated value ($Gp = 0.5 \bullet J_4 \bullet (I_{HC} \bullet M) \bullet N_C$) can be interpreted as the conversion rate of the educational HC (9), characterized by I_{HC} or E_{ef}, to GDP at PPP.

$$\mathbf{C_{HC} = G_C/Gp = (G_C/N_C)/(4370 \bullet E_{ef})} \quad (9)$$

The expression (9) equals the ratio of GDP per capita to the value of the educational HC. The values of the HC conversion – C_{HC} are given in Tables 2, 6. According to this indicator, the leaders are Italy (1.52), Turkey (1.3), Germany (1.18), USA (1.07). The UK (0.79), Brazil (0.8) and Canada (0.81) have relatively low values. If we consider the countries that are not included in the list of basic ones (Table 7), then there are countries, such as Russia, Israel and South Korea, with a highly effective level of education, defined by general laws (7, 8), but a low conversion level of HC at C_{HC} = 0.5-0.6, which can be considered as a potential reserve.

The distribution of the 19 economies under study in the indicative space $E_{ef} – C_{HC}$ is shown in Fig. 5.

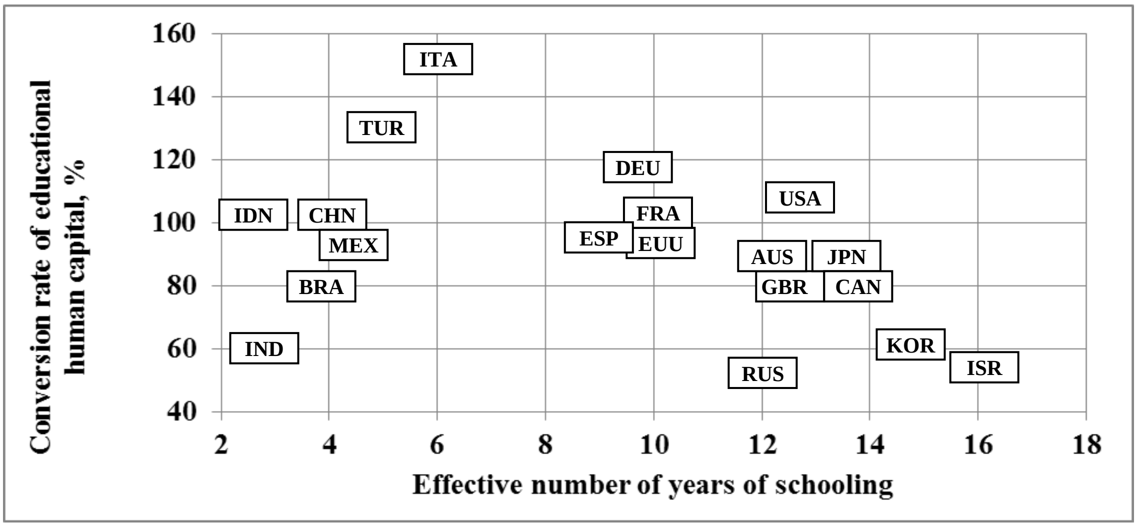

Fig. 7. Effective education level and its conversion rate to GDP.

Though for a number of the largest economies (EUU, USA, CHN, JPN, IDN, MEX), which constitute 67% of world GDP, the conversion rate of HC – $C_{HC} \approx 100\%$. There are countries that deviate significantly from this pattern. Among them, there are also countries with a high level of education (RUS, KOR, ISR, GBR, CAN), which are distanced from the main civilizational core. These also include India and, in part, Brazil. A positive deviation in the conversion of educational HC is typical for countries with a relatively low level of E_{ef} located near the center of Europe (Italy, Turkey and Germany).

From a methodological point of view, it is important that among the selected eight basic economies, a rather insignificant part has a conversion rate significantly different from 100% (Turkey and Brazil). The average value for eight economies of the base group is C_{HC} = 99.8% and the relative standard deviation is 15.2%. A significant part of the deviation, in this case, creates a high C_{HC} of Turkey. If to exclude it from this basic group, then the relative standard deviation decreases to 10% and if to optimize the coefficients Ki – to 8.8%. At the same time, a change in the coefficients of contribution to GDP occurs only in relation to science, for which it increases to $M \cdot K_5 = 18.2$.

A relatively small relative standard deviation means that other errors (except for some economies) are relatively small too. In particular, this means that the key assumption is confirmed that the components of physical and natural capital that are not proportional to HC are small and formula (1) is sufficiently correct.

8. Discussion

The choice of the basic group of economies for calculating the coefficients of the contribution to GDP is not a completely unambiguous point in this approach. Limited educational statistics for a number of developing countries, in particular for China, also makes the considered problem complicated. However, it appears that these interferences generate an acceptable error and other methods for calculating the value of HC are subject to similar problems.

The duration of schooling at different levels of education given in this work may raise questions since it is different in various countries. In this work, there is no orientation to the prototypes of developed countries, in which these figures are shifted to a greater direction. In addition, it should be borne in mind that these figures are increasing over time, but it is necessary to correctly take into account a significant number of workers who have been studying in the previous time and are still working. It also does not sufficiently reflect the fact that there is a significant part of specialists with a longer period of higher education at a master's level. However, as a result of the exponential nature of dependencies and the relatively large spread of data, this factor does not have a significant impact at this stage of the study.

9. Conclusion

The proposed model of indicative diagnostics of the educational component of HC as a basic factor of economic dynamics showed that most part of the GDP of countries is formed by the HC of workers with different levels of education. Natural and physical capitals are considered as correction parameters, largely proportional to HC. The relative standard deviation of the estimated value of GDP at PPP is 15%, according to the basic model of eight economies, and 9% for seven economies.

Within the framework of understanding that the results of labor activity are naturally exponential, it was shown that their growth can significantly exceed the value characteristic of wage growth and reach 76% per year of study in relation to the indicator of the growth of the employee's contribution to GDP at PPP.

The generalized dependence of the contribution to GDP at PPP on the number of years of education is as follows: $\mathbf{J_E = 20.5 \cdot 10^{0.246\,E}}$. The contribution of bachelor-level specialists per year was 196 thousand intl. dollars in 2017. The contribution of workers with short-term higher education – 114 thousand dollars and R&D specialists – 3,130 thousand dollars.

In the model of indicative diagnostics of the educational component of HC, a system of two main indicators is proposed: the effective number of years of education – E_{ef} and the conversion rate of the educational HC to GDP – C_{HC}. For most countries, GDP at PPP is directly proportional to the effective number of years of education (E_{ef}), which is related to the average number of years of schooling by the approximation dependence $\mathbf{E_{ef} = 2.6 \cdot (Em - 7.4)}$. The conversion rate for countries, in particular, with a very high level of education, can significantly reduce the GDP (up to 50%) calculated according to E_{ef}, which must be taken into account in order to increase the capitalization processes of HC.

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