INDEX FOR QUANTITATIVE MEASUREMENT OF THE SCIENTIFIC LEVEL OF TERTIARY EDUCATION IN DEVELOPING COUNTRIES: THEORY AND APPLICATION

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Annotation

New quantitative index for measurement of the scientific level of tertiary education in developing countries is constructed. Index shows the level of readiness of the new generation to function in a developed country. Index characterizes the degree of intimacy of knowledge and competencies of the new generation for the conditions, which the domestic country strives to achieve. Index is based on the calculation of the quantity of talents in science, who are able to adapt to the conditions of working and living in developed countries. The available statistical data uses as example for index calculation. Surprisingly, the values of the index for the level of tertiary education in Russia and Ukraine are extremely low.

Keywords: tertiary education, science level, developing countries, measurement, index, empirical analysis

Introduction

The quality of human capital is foundation for economical growth and development (Acemoglu 2009; Acemoglu & Autor 2012). The system of tertiary education is principal institution, which prepares a new generation for economics activity. The system of tertiary education gives a signal to employers about the level of work's performance for graduates (Spence 1973; Stiglitz 1975). The talent has a highest level of performance.

The term "talent" is often used without definition – e.g., see (Acemoglu 1995). Sufficiently meaningful definition is given in (Michaels, Handfield-Jones and Axelrod 2001): "What do we mean by talent? In the most general sense, talent is the sum of a person's abilities – his or her intrinsic gifts, skills, knowledge, experience, intelligence, judgment, attitude, character, and drive. It also includes his or her ability to learn and grow." This definition is unconstructive: the criteria, which are necessary for identification of a talent, are absent. Shiyan and Nikiforova (2011) define the talent (which they named as "coordinator") as follows: the people who have the ability to introduce new information or to adequately recover it missing part. The paper uses the term "talent" in the sense (Shiyan and Nikiforova, 2011).

Today, the individual rankings of universities, such ARWU (Shanghai), THES (QS – Times) and Webometrics, are widespread (Salmi 2009). But small part students learn in universities, which were named in these rankings (especially in ARWU and THES). Therefore, these rankings give incomplete information about the level of tertiary education in the country as a whole. The construction of University's ranking is still continues: for example, Boni and Gasper (2012) propose a list of dimensions for a human development orientation in research, teaching, social engagement and university governance.

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The finding of the integral parameters (indexes or indicators), which could to describe the individual vectors for development in tertiary education for a country, still is an open problem. The identification of such index is especially important for developing countries, as it specifies the potential opportunities for economic growth.

Human Development Index (Human Development Report 2011) is an integral characteristic and describes the country as a whole. This index still improves. For example, there are the propositions of the methods for improving this index in field both of the per capita GDP (Herrero et al. 2012) and of the internal migrational status (Harttgen and Klasen 2011. We propose to improve this index vu using of quantitative index for the level of tertiary education in developing countries.

Human Development Index uses a data, which ignores the quality of tertiary education. For example, it focuses on the averaged number of years for resident's training. That is, Human Development Index makes the implicit premise that the quality of education in all countries is the same. For correcting this error, we need to have an independent index for the quality of higher education in the country. This index can be used as a weight for finding of human capital quality in the country. Thus, obtained in paper the quantitative index for the level of tertiary education in developing countries can to use for improving of Human Development Index.

Recently U21 Ranking of National Higher Education Systems 2012 was published (Williams et al. 2012). But there are a number of problems, which arises with application of these results. For example, a question is: "Ranking of Higher Education for Ukraine (25 in ranking) is higher, than the ranking both Poland (27 in ranking) and Italy (30 in ranking). Can we say that the European employer prefers the graduates from Ukraine more, than graduates from Poland or Italy?" Naturally, answer is "No".

Probably, there is a mistake in creation of U21 Ranking of National Higher Education Systems 2012 (Williams et al. 2012). We think that this mistake exists only for developing countries. It takes place owing to the absence an index, which describes the quality of tertiary education. For improving it, the ability to successfully compete in the international labor market should be described for the graduates of country. For developed countries, this ability is built into the system of tertiary education. Therefore the results of the U21 Ranking of National Higher Education Systems 2012 (Williams et al. 2012) are correct for developed countries only. In contrast to developed countries, the ability to successfully compete in the international labor market is not included in systems of tertiary education in many developing countries.

Thus, similar mistake exists for developing countries both in Human Development Index (Human Development Report 2011) and in U21 Ranking of National Higher Education Systems 2012 (Williams et al. 2012).

There is a plethora of statistical data on various parameters for developed countries. They also have many specialists who study the dynamics of human capital. In contrast, much statistical data in developing countries was not measured, or it is hard to express them in terms of western statistics. For instance, in Ukraine the percentage of graduates who have not found the work within six months after graduation is not measured.

The paper constructs an index for measurement of the level of tertiary education in developing countries. This index answers on question: "How is the level of domestic system of tertiary education for preparing of talented people to the life and work in developed country?" This index is aggregate, since it takes into account both general preparation for life in a developed country, and training for work in a developed country. The talent is used as a marker for measurement of the level of tertiary education. An important feature is that for the calculation of this index the statistical data on tertiary education and scientific institutions are used only from the developed countries.

The remainder of the paper proceeds as follows. The second section describes the method for calculating of index for a level of development for tertiary education in a developing country. The third section describes as developing country may use the index. The fourth section describes an example of the calculation of the index using previously obtained data. The fifth section describes the reasons for the low values of the indicator for Russia and Ukraine. The sixth section describes the reasons for difference between indexes for India and China. The final section encompasses conclusions. In Appendix the detailed derivation of relative error for an index is described.

2. Methodology

In developing country the tertiary education should outpace the current state of its economy. New jobs, which will have higher labor productivity, can be created only in this case. Therefore tertiary education is a key element for economic development in developing countries.

Employees with tertiary education occupy jobs with higher wages. Tertiary education is the social elevator, which is the most affordable for the majority of the population in developing countries.

Young people oriented to obtaining of tertiary education already at the stage of secondary education. Therefore, in developing country the tertiary education is a model for the young people.

A specific feature of tertiary education in developing countries is the following. It simultaneously prepares a new generation for participation in both economic and social life in the developing country. Teaching of public life skills in university should to outpace the current state of the society's development level, too.

Thus, tertiary education should to prepare a new generation for economic and social activities, which are typical for developed countries. Only in this case the country will be able to constantly develop.

The scientific level of tertiary education in developing country may be determined by comparison with the scientific level of its development in developed countries. The indicator, which characterizes the proportion of graduates from tertiary education, who have successfully adapted to scientific job and life in developed countries, can be used.

For any country, the next relationship is true:

$$t = p \times o \times l \tag{1}$$

Here t – the quantity of realized scientific talents, p – the country's population, o – proportion of population, which is involved in tertiary education (mostly students), l – the level of development of tertiary education.

In (1) the value of l is in the range $0<l<1$. Value $l=1$ notes that all the scientific talent correctly identified, selected and taught by a system of tertiary education in a country.

Why is our attention drawn to talent? Firstly, the talents are the most active participants in country's development. Secondly, the system of tertiary education has the greatest ratio of development when the fraction of identified talents is the highest. Thirdly, the talents constitute the most visible and outstanding part of society; they implement the adjustment the intensity of signal for employers (Spence 1973).

From (1) is followed that parameter l characterizes the level of success in functioning of tertiary education in a domestic country. In this sense (1) can be applied to any country (both developed and developing).

Equation (1) contains several indicators, which are unknown for developing countries: the quantity of talents and level of development of tertiary education. Fortunately, the statistical data from developed countries can be used. Migration from developing to developed countries exists, and talents comprise a part of this migration. Statistical data for migration are always monitored in developed countries. The indexes for migration from developing countries are well known. The problem is only how to determine the quantity of talents, which came from a developing country and which came true in a developed country.

Let we choose the talents, which have successfully implemented the academic career in a developed country. Here a talent uses all competencies, which he/she learned in the domestic country. Here a talent from developing country has a priority in as compared with average person (from developing or developed countries). The level of implementation of academic career for a talent will be exactly depended on his/her level preparing for adaptation to conditions of work and life in developed countries.

The level of success for academic career can be measured as a level of citations. The realized talent is a highly-cited researcher. Thus, the scientometric data can be used for measuring of the quantity of talents from developing countries. The scientometric data is well developed today and have a high level of reliability and breadth of scientific publications. Of course, the systems of tertiary education in developed countries are "imperfect", - but better is absent in the world. The differences in the tertiary education systems of various developed countries are not counted in this method.

As a result, the level of tertiary education in the developing country can be measured as follows.

$$l_c = \frac{t_{dc}}{p_c \times o_c \times m_c} \tag{2}$$

Here l_c is a scientific level of tertiary education in the developing country; t_{dc} is a quantity of highly-cited scientific researchers from the developing country, which working at academic career in a developed country; p_c is the number of people in the developing country; o_c is a proportion of the population, which is involved in tertiary education in the developing country; m_c is a proportion of the population, which migrates from the developing country.

The equation (2) is based on several assumptions (some of them briefly summarize the arguments from above).

1. The percentage of migration from the developing country is equal for all educational levels.
2. The talent, who chose an academic career, serves as a marker for the level of tertiary education (this talent has been oriented on the higher education in the developing country). For example, during of secondary education, he/she is preparing to take part in tertiary education. And he/she is a hard-working student and preparing for tertiary education. He/she has knowledge about university, which is based only on universities in developing country.
3. Proportion of the migrants with developing country's tertiary education, which chooses an academic career in a developed country, is identical for the people from different developing countries.
4. The tertiary education in developing country influences not only on a scientific talent readiness to scientific activity. The system of tertiary education should also prepare a scientific talent for life in the scientific community. It should prepare a scientific talent for communication with environment in developed countries and for organization their private lives in a developed country.
5. The proportion of scientific talents in every population is equal. The arguments see in (Shiyan and Nikiforova, 2011). It is interesting that the opposite point of view is racism.

The index for the scientific level of tertiary education in developing countries can be used for them comparing. Developing countries can be classified according to their level of development of tertiary education.

The time, which needs for scientific talent for achieving of the highly-cited status in a developed country, can be estimated at 10-20 years (it depends on the area of scientific activity and the level of talent). Therefore, the data for (2) should be chosen as the average quantity over the time interval of 10 years, from 10-20 years ago to the present time. Of course, the characteristics will change during this period of time. So the result – the index for a scientific level of higher education in a developing country l_c – will be measured with some accuracy only.

Let us estimate the error in the calculation of index introduced in equation (2).

Relative error of the index value (2) can be calculated by the formula (see Appendix)

$$\varepsilon_{lc} = \sqrt{\varepsilon_{tdc}^2 + \varepsilon_{pc}^2 + \varepsilon_{oc}^2 + \varepsilon_{mc}^2} \qquad (3)$$

Here ε_{lc} is the relative error in the index; ε_{tdc} is the relative error in the quantity of talents; ε_{pc} is the relative error in the quantity of population in a developing country; ε_{oc} is the relative error in the proportion of access to tertiary education; ε_{mc} is the relative error in the ratio of migration from developing countries. All relative errors are calculated as the relationship of the standard deviation to the mean value of the investigated parameters.

There is certain arbitrariness in determining of the quantity of scientific talents. However, one can to consider more quantity of people, when the requirements for the level of talent will be reducing. For example, only the scientists, who have “middle-cited” or “high-cited” papers (not “highly-cited”), can be selected. The correctness can be increased for the index by this way.

The duration for a time delay for the index can be reduced. The analysis of “high-cited” or “middle-cited” researchers can be used. For this case, a time delay can be up to 5 years. In addition, the quantity of such researchers will be increased.

The statistical data about PhD students from developing countries, who came in developed countries 4-5 years ago, can be promising for index calculation, too. As scientific talents we can take a quantity of young researchers from the developing countries, which have the papers in peer-reviewed scientific journals with high impact factor. It should be taken into account that “the level of the height” for impact factor will be different for different areas of science.

One can count the quantity of scientific talents at the next procedure, too. Talent, which migrated from developing countries, could achieve of success not only in science. Scientific talent makes progress in other areas of economic and social activity after arriving to developed countries. But the criteria for the selection of scientific talent will be less clear for these cases.

The ability to use several different databases can allow obtaining the values of the index for different points of time for developing countries. This allows identifying the trend of development of tertiary education in a developing country.

Thus, the index for a scientific level of tertiary education can be calculated from different non-overlapping databases for the same period of time. This allows assessing the validity of the index and calculating its reliability.

3. Purpose of the index

Introduced index can offer a framework for action toward an increasing of a level of tertiary education in a developing country.

Firstly, the index increases when the level of involvement of university professors in the creation of a scientific product rises. This primarily reflects in the increase of a quantity of teachers' publications in international scientific journals (especially with high impact-factors). Only the teacher, who creates scientific result, is able to teach students specific patterns of scientific activity.

Secondly, professor should be able to include his/her scientific results in the training courses. Students should receive modern scientific information. Author of scientific results (university professor) is the most effective source of information about the new knowledge.

Thirdly, university professor should be involved into the economic and social activities. Activities for implementation of received scientific results are the most appropriate. Scientific result is firstly obtained in the world (for example, the attempting to publish a scientific result "again" (with new name for author) is regarded as plagiarism). Thus, publication of scientific results is regarded as fixing copyright and intellectual property rights.

Professor should involve students in activities in implementation of scientific results. As result, students get the necessary skills for participation in economic and social life. It is important that such implementation can be carried out also abroad, in developed countries.

Thus, developing country, which chooses increasing the index of tertiary education, should create the next conditions:

1. University professor should be able to obtain the scientific results.
2. Professor should be able to use (and be encouraged to use) these results in teaching students.
3. University professor should be able to implement the scientific results.
4. Students should to join to professor's work, participate on their own (under the leadership of the university professor) in all steps of creation of scientific knowledge.

Note that via establishing such conditions we simultaneously provide an environment necessary for establishing of the effective innovation institutes in a certain developing country (Shiyan and Nikiforova, 2012).

4. Example of index calculation

Weinberg (2011) studied the process of brain drain from developing countries. He used information of the birthplaces of the highly-cited scientific researchers in the world. The highly-cited researchers were investigated within period 1981–2003. Weinberg's paper contains statistical data that can be applied for calculation of the level of tertiary education in some developing countries.

Table 1 presents the data for proportion of highly-cited scientific researchers based on their place of birth. This Table is Table 2 from (Weinberg 2011). We display only the part of the data, which we will to use for following calculation.

The proportions for scientific talents from the developing country in the total number of scientific talents (highly-cited researchers) were presented in (Weinberg 2011). Naturally, the calculated index allows comparing the levels of tertiary education only in the database in (Weinberg 2011).

Data from Table 1 can be used for calculation of the scientific level of tertiary education in developing countries.

Table 1

Birth countries of highly-cited researchers (only the part of the data from (Weinberg 2011))

East Asia: 0.0265		Total former communist: 0.0340		Total rest of developing world: 0.0588	
Peoples Republic of China	0.0119	Hungary	0.0085	India	0.0140
Hong Kong	0.0042	Poland	0.0068	Israel	0.0114
Republic of Korea	0.0021	Russia	0.0047	Argentina	0.0055
		Romania	0.0034	Iran	0.0025
		Ukraine	0.0017	Mexico	0.0021
				Turkey	0.0021
				Brazil	0.0017
				Egypt	0.0017
				Lebanon	0.0017
				Morocco	0.0017

The time, which the scientific talents use for coming to highly-cited state in database (Weinberg 2011), is unknown. Therefore we use the data for the period at the beginning of the 2000s for calculation of the index. This led to uncontrolled relative error, which we estimate in the range of 20-30%. The error has origin from variation of quantities of population, migration rate and proportion of population, which involved in tertiary education. We hope that the values of these parameters can not to receive a sharp change during 1980-2000 for investigated countries. Therefore, we will use calculated values for scientific indexes of tertiary education in different countries only for preliminary test of method.

We used the World population data obtained by World Bank for 2000 year (Population total 2012). Tertiary education data are extracted for the period 2001-2010 (Human Development Report 2011). The coefficient of migration is used for 2000-2002 (Human Development Report 2009).

In our calculations we multiplied all numeric values by identical number 10n in order to bring them to the range from 0 to 10.

Table 2 shows the results – the level of tertiary education in some developing countries from Table 1. They were calculated by equation (2). We omitted the data from Table 1 for countries containing less than 4 talents.

Despite the fact that for different countries numerical values in equation (2) had 10-fold differences, the values for the index were in the same range. This testifies that the introduction of the indicator is correctly defined.

For China, India and Brazil the data have a large error, since the statistical data on migration coefficient has a large error (these coefficients contained only one significant digit).

Index significantly differs within the data in Table 2 for Russia and Ukraine.

Firstly, these indexes have similar values, although all parameters in the equation (2) significantly differ. This indicates that this index is an objective characteristic.

Secondly, a small value for the index of the level of tertiary education in Russia and Ukraine requires a separate explanation. At first glance, this value of the index seems even impossible. In the next section we show that tertiary education in these two countries really correspond to low values of this index.

Weinberg's (2011) data allow making a comparison of the averaged levels of efficiency for systems of tertiary education in developed and developing countries. Table 1 show that the proportion between the number of talents from developed and developing countries is 0.8731 to 0.1269 (the countries listed in the footnote, included as well). The population in developed

and developing countries can be set equal to 1 to 5 (in billions of people, at 2000). Then 0.8731 can be regarded as an index to the average level of tertiary education in developed countries, and 0.0254 (= 0.1269 / 5) as an index of the level of tertiary education in developing countries. Thus, the averaged level of tertiary education in developing countries is 34 times less than its level in developed countries.

Table 2

Calculated index for measurement of the level of tertiary education in some developing countries

Country	Index for measurement of the level of tertiary education
East Asia	
Hong Kong	1.172
Peoples Republic of China	0.770
Republic of Korea	0.144
Former communist	
Hungary	3.415
Romania	0.491
Poland	0.486
Russia	0.054
Ukraine	0.039*
Rest of developing world	
Israel	2.214
India	1.354
Argentina	1.341
Iran	0.806
Lebanon	0.671*
Brazil	0.567*
Morocco	0.565*
Egypt	0.304*
Turkey	0.205
Mexico	0.084

Note: * – 4 highly-cited researchers.

5. Analysis of the systems of tertiary education in Ukraine and Russia

The state of systems of tertiary education requires an independent and more careful study in Russia and Ukraine. The indexes for the level of tertiary education in these countries are much lower than in others. It is even more surprising that Russia and Ukraine have a number of characteristics, which are similar to developed countries. For example, the space research (Russia, Ukraine) and military equipment (Russia) are at frontier.

We made a detailed analysis of systems of tertiary education in Russia and Ukraine in the frame of studying of innovation institutions in (Shiyan and Nikiforova 2012). We showed that the gap between science and tertiary education has historically originated in the late 1920s – early 1930s. It emerged during the transition from market to the communist ideology as a temporary measure. However, the gap still persists today.

The systems of tertiary education are preserved the tradition of the Soviet Union in Russia and Ukraine (Shiyan and Nikiforova, 2012). Today situation can be characterized as follows.

1. Research institutions are separated from the higher education.

2. The university professors simply paraphrase textbooks.
3. 2-3 years of practical training are needed for graduate of the University.
4. University professors, students, and the majority of people in Russia and Ukraine (including Government officials, parliamentarians and Government experts, etc.) do not have any information concerning functioning of developed economics (especially about the market economy works.)

Thus, the institutions for training of a new generation for experience in both activity in science and conditions of living in the market economy are absent in Russia and Ukraine. Therefore the many barriers exist for migrants from Russia and Ukraine for their adaptation in scientific community and for work in a market economy. Especially big obstacle for youth is the lack of knowledge and skills for operating in a market economy.

The data about cited publications for Ukrainian universities are available at the database Scopus. The data for quantity of universities, which have most 500 cited publications in 2014-2016 years, presented in Fig. 1. We used the data from (Rating of University…, 2014), (Rating of University…, 2015) and (Rating of University…, 2016).

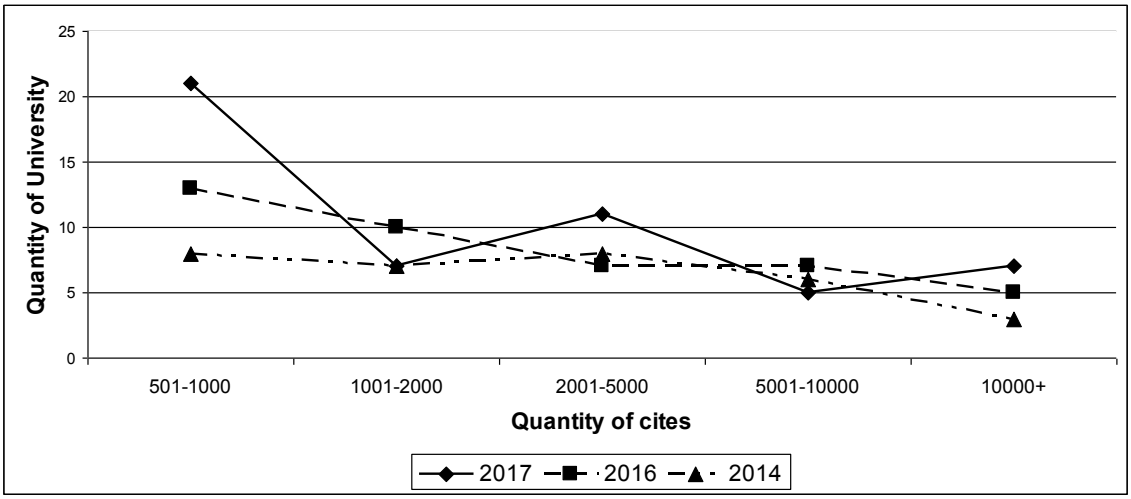

Figure 1. Distribution of Universities by the number of citations in the Scopus database

Ukraine has 269 universities, which are included in the Consolidated ranking universities in Ukraine in 2016 (Consolidated rating…, 2016). It is shown from Figure 1, only 12 Universities (4.5%) have more than 5,000 citations and only 30 Universities (11.2%) have more than 1,000 citations in the Scopus database. Thus, Ukrainian universities are much weaker than the universities of developed countries in the scientific field.

The situation is more tragic in economics. Tom Coupé (2008) investigated the quantitative contribution of Ukrainian economists in the world economy: "A total of 86 Ukrainians published in journals that are indexed in Econlit in the period 1969–2005. They together contributed to 121 articles. If we attribute coauthorship proportionally, 92 papers have been written by these Ukrainian authors. Note in this list of 86 we do not only have academics, we also have politicians like former Prime Minister Yekhanurov and President Yuchenko. Moreover, remember that our initial search in EconLit gave us 229 publications related to Ukraine – since these 121 articles include several articles that are on subjects unrelated to Ukraine, most of the international research on Ukraine has been done by foreign researchers."

Coupé (2008) notes: "The more recent publications are typically written by Ukrainian economists with a Western Ph.D. degree, and not by economists with a Ukrainian Candidate or Doctoral Degree. That things are improving is hence mainly due to the fact that the number

of Ukrainians with Ph.D.s is increasing – at least 35 Ukrainians graduated with a Ph.D. from a Western University since 1995."
Thus the tertiary education in Ukraine has no professors who can teach people of a modern market economy.
The Peer Review of the Ukrainian Research and Innovation System was carried out by the Horizon 2020 Policy Support Facility in 2016 year (Peer Review…, 2016). This analysis shown that the system of tertiary education in Ukraine must be essentially modified.
Osipian (2012) shown that the corruption in doctoral education was widespread in Russia. He wrought: "Fake doctorates undermine the credibility of real, earned doctorates, and erode the gold standard of quality in research and scholarship". Thus, the talents of the new generation in Russia will have incorrect knowledge about tertiary education in developed countries.
Atkinson, Ezell and Stewart (2012) shown that the indicators for education in Russia were in lower ranges. The low value for index for scientific level of the tertiary education calculated in our paper is consistent with these results.
The state of one of the leading universities of Ukraine – Ternopil National Economic University – was estimated in (Norén et al., 2010). They showed that many serious problems arise due to failure of management, which takes place at the level of the University. As a result, university professors do not use they scientific potential in teaching; their scientific results are very low. Students are very rarely involved in research and practice. This situation in Ukraine is the norm, and is typical for many universities.
These reasons lead to such low values of the index for the level of tertiary education in Russia and Ukraine.

Conclusion

The paper constructs a quantitative index for measurement of the level of development of tertiary education in developing countries. This indicator characterizes the system of tertiary education for the country as the whole. The quantity of talents, which have successfully implemented the academic career of a scientist in a developed country, is used for index calculation. The statistical data from developed countries can be used for index calculation. The index can to use for comparing of different developing countries. The relative error of the index value is investigated.
The statistical data on highly-cited researchers from (Weinberg 2011) is used for calculation of index a number of developing countries.
The indexes for Russia and Ukraine are significantly smaller in comparison with other developing countries. We discussed the reasons for this situation.

Appendix

Derivation of relative error for the index for measurement of the level of tertiary education in developing countries

The absolute error Δy for indirect measurements can be calculated with using the function $y=f(x_1,x_2,\ldots,x_n)$ by the formula (Grabe 2005)

$$\Delta y = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial f}{\partial x_i}\Delta x_i\right)^2} \qquad \text{(A1)}$$

Here Δx_i are the dispersion of the measurements for i-th variable.

It is easy to see that the relative error $\varepsilon_y = \Delta y / y_m$, where y_m are the average value of (A1), we can obtain with following formula.

$$\varepsilon_y = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial \ln f}{\partial x_i} \Delta x_i \right)^2} \tag{A2}$$

Logarithm of formula (2) is expressed as

$$\ln l_c = \ln t_{dc} - \ln p_c - \ln o_c - \ln m_c \tag{A3}$$

When we substitute (A3) into (A2), we obtain

$$\begin{aligned} \varepsilon_{lc} &= \sqrt{\left(\frac{1}{t_{dc}} \Delta t_{dc} \right)^2 + \left(-\frac{1}{p_c} \Delta p_c \right)^2 + \left(-\frac{1}{o_c} \Delta o_c \right)^2 + \left(-\frac{1}{m_c} \Delta m_c \right)^2} = \\ &= \sqrt{\varepsilon_{tdc}^2 + \varepsilon_{pc}^2 + \varepsilon_{oc}^2 + \varepsilon_{mc}^2} \end{aligned} \tag{A4}$$

(A4) is identical to (3).

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