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MEASURING HUMAN CAPITAL: A STATISTICAL APPROACH

Evaluation of human capital has always represented quite a challenge for researchers. Although many different methods have been proposed, no particular approach is agreed upon. In this paper, statistical I-distance method is proposed and employed on the data set of 50 countries. In addition, crucial indicators for ranking are emphasized and elaborated.

Keywords: *human capital; I-distance method; multivariate statistical methods.*

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СТАТИСТИЧНИЙ ПІДХІД ДО ВИМІРЮВАННЯ ЛЮДСЬКОГО КАПІТАЛУ

У статті показано, що оцінювання людського капіталу завжди було проблемою для дослідників. Хоча існує значна кількість методів його вимірювання, жоден з них не є універсальним. Представлено статистичний метод оцінювання людського капіталу, його застосування продемонстровано на вибірці з 50 країн. Вказано, які саме показники при такому оцінюванні є найбільш значущими.

Ключові слова: *людський капітал; дистантний метод Івановича; методи багатофакторної статистики.*

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СТАТИСТИЧЕСКИЙ ПОДХОД К ИЗМЕРЕНИЮ ЧЕЛОВЕЧЕСКОГО КАПИТАЛА

В статье показано, что оценка человеческого капитала всегда была проблемой для исследователей. Хотя существует достаточно много методов его измерений, ни один из них не является универсальным. Представлен статистический метод оценки человеческого капитала, его применение продемонстрировано на выборке из 50 стран. Показано, какие конкретно показатели в такой оценке являются наиболее значимыми.

Ключевые слова: *человеческий капитал; дистантный метод Ивановича; методы многофакторной статистики.*

Introduction. Human capital is an important driver of economic and social development of a country (Jappelli, 2010; Burdett et al., 2011; Javalgi and Todd, 2011; Winters, 2011). In line with this, it is crucial to provide an appropriate framework for evaluating and measuring human capital. However, in absence of well-defined measures of human capital, many researchers used various indicators which are chosen rather arbitrary (Klomp, 2011; Wallenius, 2011). In order to overcome these obstacles, human capital should be observed as multi-dimensional concept. In line with this, we will use multivariate I-distance approach on the selected human capital variables. With this approach, many different variables will be synthesized into one value which will represent the rank. Also, we will apply Ward hierarchical classi-

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fication method and divide our data set into 5 clusters. Differences between countries will be evaluated and crucial indicators for ranking countries emphasized.

The I-distance Method. Quite often, ranking of specific marks is done in a way that can seriously affect the process of taking exams, sport competitions, universities ranking, medicine selection and many others (Al-Lagilli et al., 2011; Ivanovic, 1973; Ivanovic and Fanchette, 1973; Jeremic and Radojicic, 2010; Jeremic et al., 2011a).

I-distance is a metric distance in an n-dimensional space. It was proposed and defined by B. Ivanovic in various publications that have appeared since 1963 (Ivanovic, 1973). Ivanovic devised this method to rank countries according to their level of development based on several indicators. Many socioeconomic development indicators were considered and the problem was how to use all of them in order to calculate a single synthetic indicator, which will thereafter represent the rank.

For a selected set of variables $X^T = (X_1, X_2, \ldots X_k)$ chosen to characterize the entities, the I-distance between two entities $e_r = (x_{1r}, x_{2r}, \ldots, x_{kr})$ and $e_s = (x_{1s}, x_{2s}, \ldots, x_{ks})$ is defined as:

$$D(r,s) = \sum_{i=1}^{k} \frac{|d_i(r,s)|}{\sigma_i} \prod_{j=1}^{i-1} \left(1 - r_{ji.12\ldots j-1}\right) \quad (1)$$

where $d_i(r, s)$ is the distance between the values of variable X_i for e_r and e_s, e.g. the discriminate effect:

$$d_i(r,s) = x_{ir} - x_{is}, \; i \in \{1, \ldots, k\}, \quad (2)$$

σ_i is the standard deviation of X_i, and $r_{ji.12..j-1}$ is a partial coefficient of the correlation between X_i and X_j, $(j<i)$, (Ivanovic, 1973; Jeremic et al., 2011d).

The construction of the I-distance is iterative; it is calculated through the following steps:

- calculate the value of the discriminate effect of the variable X_1 (the most significant variable, that which provides the largest amount of information on the phenomena that are to be ranked (Ivanovic, 1977));
- add the value of the discriminate effect of X_2 which is not covered by X_1;
- add the value of the discriminate effect of X_3 which is not covered by X_1 and X_2;
- repeat the procedure for all the variables (Jeremic et al., 2012).

Sometimes, it is not possible to achieve the same sign mark for all the variables in all the sets, and, as a result, a negative correlation coefficient and a negative coefficient of partial correlation may occur (Jeremic et al., 2011b). This makes the use of the square I-distance even more desirable. The square I-distance is given as:

$$D^2(r,s) = \sum_{i=1}^{k} \frac{d_i^2(r,s)}{\sigma_i^2} \prod_{j=1}^{i-1} \left(1 - r_{ji.12\ldots j-1}^2\right) \quad (3)$$

In order to rank the entities (in this case, countries), it is necessary to have one entity fixed as a referent in the observing set using the I-distance methodology. The entity with the minimal value for each indicator or a fictive maximal or average values entity can be set up as the referent entity. The ranking of entities in the set is based on the calculated distance from the referent entity (Jeremic et al., 2011c).

The results. In order to evaluate human capital and propose potential framework for measuring it, we selected the data set of 50 developed and undeveloped countries

(among these 50 – two Chinese regions, Shanghai and Hong Kong). Selection of human capital indicators (see Table 1) is done with respect to many previous researches in this field (Klomp, 2011; Barro and Lee, 2010; Altinok and Murseli, 2007).

Table 1. **Human capital indicators**

Education
Enrolment rate (primary education)
Enrolment rate (secondary education)
Enrolment rate (tertiary education)
Skills
Mathematics scores
Sciences scores
Reading scores
Science and technology
High technological export as % of GDP
Number of the researchers in R&D
Scientific and technical journal articles
Number of patents per 1,000 people

The results achieved with the I-distance ranking method for evaluating human capital are presented in Table 2. As we can see, the United States lead the way ahead of Japan and Shanghai, China. These 3 are absolute leaders by the number of patents, scientific and technical journals articles etc. In addition, Shanghai is way ahead of others in the category skills (PISA score): reading, science and mathematics scores. We also divided our data set into 5 clusters according to Ward's method of hierarchical clustering. As it appears, Serbia is in the worst (fifth) cluster and has to improve dramatically its human capital. Although some increases in PISA scores have been noticed, it is far from satisfactory results.

Table 2. **The Results of the Square I-distance Method, I-distance Value, Rank and Clusters**

Rank	Country	I-distance	Cluster
1	United States	59.475	1
2	Japan	51.542	1
3	Shanghai - China	48.912	1
4	Finland	44.349	1
5	Australia	43.479	1
6	Singapore	38.471	2
7	Iceland	35.367	2
8	New Zealand	32.848	2
9	Netherlands	31.516	2
10	Denmark	31.154	2
11	Hong Kong - China	30.187	2
12	Norway	29.814	2
13	France	28.225	2
14	Canada	27.529	2
15	Ireland	27.084	2
16	United Kingdom	25.529	3
17	Sweden	25.286	3
18	Spain	25.133	3
19	Portugal	24.969	3
20	Belgium	24.332	3
21	Greece	24.142	3

The End of *Table 2*

Rank	Country	I-distance	Cluster
22	Switzerland	22.876	3
23	Slovenia	22.408	3
24	Hungary	22.357	3
25	Germany	22.285	3
26	Estonia	20.906	3
27	Poland	19.773	3
28	Italy	19.334	3
29	Lithuania	17.918	3
30	Latvia	17.738	3
31	Czech Republic	17.559	3
32	Austria	16.386	4
33	Russian Federation	15.792	4
34	Brazil	15.506	4
35	Argentina	14.809	4
36	Colombia	14.705	4
37	Uruguay	14.413	4
38	Slovak Republic	14.344	4
39	Mexico	13.399	4
40	Luxembourg	13.167	4
41	Indonesia	13.140	4
42	Croatia	12.040	4
43	Chile	11.509	4
44	Romania	10.117	4
45	Serbia	8.642	5
46	Thailand	8.356	5
47	Turkey	8.109	5
48	Bulgaria	8.074	5
49	Tunisia	6.799	5
50	Panama	6.060	5

This data set was further examined and a correlation coefficient of each indicator with the I-distance value was determined, the results of which are presented in Table 3 (Pearson correlation test has been used).

As it appears to be the most significant variable for determining ranking is reading scores, with $r=.767$, $p<0.01$. Particularly interesting is the fact that 3 most important indicators are from "Skills" category (reading, science and mathematics scores); next 4 important variables are from category "Science and technology". Enrolment rate in secondary and tertiary education are barely significant, while enrolment rate in primary education is insignificant.

Table 3. **The Correlation between I-distance and Input Indicators**

Indicators	r
Reading scores	.767**
Sciences scores	.727**
Mathematics scores	.713**
Number of researchers in R&D	.676**
Number of patents per 1,000 people	.637**
Scientific and technical journals articles	.604**
High technological export in % to GDP	.562**
Enrolment rate (secondary education)	.410*
Enrolment rate (tertiary education)	.339*
Enrolment rate (primary education)	.087

** $p<.01$ * $p<.05$

Conclusion. Knowledge economy is becoming the most important factor in the development of society and regions (Toma, 2010; Heeks, 2010). In line with this, it is essential to evaluate human capital and propose adequate framework for measuring it (Walter, 2011; Zhang and Lee, 2011). In this paper, we propose a novel method for measuring human capital. I-distance method can synthesize many indicators into one single numerical value which will represent the rank. With this approach, not only countries can be ranked but also differences between them can be elaborated. In addition, our approach can identify crucial indicators for the process of ranking. We hope that this method can complement to the raising number of studies concerning human capital measurement.

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