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Measurement of national intellectual capital: application to EU countries

by

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Abstract The aim of the article is to present both an alternative approach to measurement of intellectual capital of a country (IC) and a calculation of IC index. In order to achieve it, at first a definition of IC was adopted and a conceptual model of IC was worked out. Then, a method of operationalisation of conceptual model was elaborated, which comprised: 1. method of transforming the theoretical concept and relations into more concise ones that enabled the measurement sensu stricto, 2. selection of indicators of each component of IC, 3. adoption of appropriate method of aggregation of indicators. Finally the measurement of each component of IC and IC itself for UE countries was executed. Proposed method of IC measurement can be regarded as the extension of the proposals of Bontis (Bontis, 2004) and Andriessen and Stam (Andriessen, Stam, 2004). Thanks to the application of different approach to data aggregation the subjective decision concerning weights imposed on IC indicators made by Bontis was confirmed. Different factor loadings and resulting from them factor scores for each measurement model of components of IC and IC itself proved the indicators are not of the same importance. Although it could be useful and interesting to compare their relative importance, unfortunately it was impossible to conduct due to the lack of entire comparability of the indicators used. Strong correlation between IC index and GDP per capita indicated that there was a significant level of information carried by the IC index. First of all, it should be pointed out that IC probably explains significant part of the difference in the level of development of various countries. Secondly, it does not carry the full information about the value of the GDP in economy, so it possibly carries also information about the future development of a country.

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Measurement of national intellectual capital – application to EU countries

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Introduction

Inspiration for the research came from two papers – *National Intellectual Capital Index* (Bontis, 2004) and *Measuring the Lisbon Agenda – the intellectual capital of the European Union* (Andriessen, Stam, 2004). It was followed by the participation in the project concerning the assessment of the intellectual capital of Lublin area that was conducted by A. Wodecki in Poland in 2005[1]. The extension of the object of research to selected European countries seemed natural as the tools applied in the latter project could have been applied on the country level.

Since a role of intellectual capital (IC) of microentities like companies and organizations (Stewart, 1991; Edvinsson and Sullivan, 1996; Roos and Roos, 1997; Sveiby, 1997; Brooking, 1998; Petty, Guthrie, 2000; Viedma, 2000, 2001, 2003; Bartnicki, Strużyna, 2001; Edvinson, Malone, 2001; Andriessen, 2004; Bueno, Salmador and Rodriguez, 2004; Pulić, 2005; Kasiewicz, Rogowski, Kicińska, 2006; Kasiewicz, Rogowski, 2006) or universities (Fazlagic, 2005a, 2005b) and macroentities like countries, regions, cities (Pomeda et al., 2002; Bontis, 2004; Andriessen, Stam, 2004; Bonfour, Edvinsson, 2005; Lerro, Carlucci, Schiuma, 2005; Pascher, Shachar, 2005) has been throughly described there is a need to evaluate, measure and map it.

First of all, the new approach to knowledge based economy and network society gave impulse to focus more on production factors that could not be observed directly. Although the factors are very difficult to capture and measure, knowing them facilitates forecasts of future development and makes it easier to grasp the key forces in one model. The sources of possible future successes can be enumerated and thus a suitable economic and social policy can be implemented to achieve desired goals. Secondly, IC can serve as an extension of GDP or other commonly used economic indicators. However GDP was designed and is used to describe present economic situation especially in terms of economic development, whereas IC index would rather be an indicator of future wealth, these two measures should be correlated positively. Thirdly, in growth models knowledge factors are described as determinants of economic development (Burda, Wyplosz, 2000). Due to that fact an

[1] http://www.kapitalintelektualny.pl/

additional effort should be made to measure them reliably and with highest possible precision. IC index, which is immensly connected with knowledge, can serve as an indicator of knowledge.

The aim of the article is to present both an alternative approach to measurement of intellectual capital of a country (IC) and a calculation of IC index.[2] In order to achieve it, at first a definition of IC was adopted and a conceptual model of IC was worked out. Then, a method of operationalisation of conceptual model was elaborated, which comprised:

1. method of transforming the theoretical concept and relations into more concise ones that enabled the measurement *sensu stricto*,
2. selection of indicators of each component of IC,
3. adoption of appropriate method of aggregation of indicators.

Finally the measurement of each component of IC and IC itself was executed.

Conceptual model of national IC

The conceptual model presented in the paper results from the critical review of already established in literature models and proposals of measurement of IC of a country or region, e.g. *Intellectual Capital Index* (Bontis, 2004), *Intellectual Capital Monitor* (Andriessen, Stam, 2004) and *Intellectual capital of Lublin area* (Roszkiewicz, Weziak, Wodecki, 2007).

Definition of national IC was adopted from Bontis' article '*National Intellectual Capital Index. A United nations initiative for the Arab region*' (Bontis, 2004). The intellectual capital includes *'the hidden values of individuals, enterprises, institutions, communities and regions that are the current and potential sources for wealth creation. These hidden values are the roots for nourishment and the cultivation of future wellbeing*' (Bontis, 2004. pp.14-15). Additionally, since the latent character of IC is directly indicated in the definition, it was assumed that IC cannot be observed directly.

In the literature there is no precise clue which and how many components of IC should be taken into consideration, but nobody doubts, that there are at least three of them.

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[2] The substantive results presented in the paper are only the illustration of accomplished goals and will not be discussed in details.

They differ with respect to the source but it is in line with current state of knowledge that IC is a multivariate construct. Author assumes in this paper that IC can be expressed by four components:

1. human capital (HC),
2. relational capital (RelC),
3. structural capital (SC),
4. renewal capital (RenC).

Figure 1. Classification of notions used in the model of IC of a country.

Intellectual Capital (IC) of a country					
	⇓				
Human Capital of inhabitants (HC)	Relational Capital of inhabitants (RelC)	Structural Capital of a country (SC)	Renewal Capital of a country (RenC)	←	Components of IC
⇓	⇓	⇓	⇓		⇓
Subcomponents of Human Capital	Subcomponents of Relational Capital	Subcomponents of Structural Capital	Subcomponents of Renewal Capital	←	Subcomponents
⇓	⇓	⇓	⇓		⇓
Indices of Human Capital	Indices of Relational Capital	Indices of Structural Capital	Indices of Renewal Capital	←	Indicators or variables

Again, there are many different definitions of IC components, but only these adopted in the paper will be presented.

Definition of human capital was based on the definition of OECD. According to it human capital (HC) includes knowledge, skills and attributes. Among them so called soft skills such as teamwork, perservance, flexibility and communication skills in line with ICT skills have been supposed to be of the highest importance. As a result, it was decided that the measurement model of HC should enable the assessment of:

1. level of education of inhabitants,
2. quality of educational system,
3. quality of workforce,
4. ICT skills of inhabitants and ICT usage,

5. health of inhabitants,
6. life satisfaction and happiness,
7. tolerance.

As it was stated in the OECD report *The Well-being of Nations: The Role of Human and Social Capital*, recent research on social capital prove that established relations, norms of behaviors and mutual trust may yield benefit to the economy. Since they facilitate the exchange of ideas and cooperation, they are likely to improve the economic well-being and economic development too. Taking it into regard the relational capital (RelC) being the broader counterpart of social capital was defined after Bontis as '*the intellectual capital embedded in national intra-relationships representing a country's capabilities and successes in providing an attractive, competitive solution to the needs of its international clients, as compared with other countries*' (Bontis, 2004) and also as the quality of relations among inhabitants of a country. In result, it was decided that the measurement model of RelC should comprise such elements as:

1. foreign relations,
2. international trade,
3. mutual trust,
4. norms of behavior.

The elements of structural capital (SC) one can find in the concept described by Bontis as *process capital*. According to him structural capital can be defined as '*non-human storehouses of knowledge which are embedded in technological, information and communications systems represented by the hardware, software, database, laboratories and organizational structures which sustain and externalize the output of human capital*' (Bontis, 2004). Taking it into regard it was decided that the measurement model of SC should comprise the following elements:

1. number of patents application and number of patents granted,
2. level of broadband penetration,
3. level of mobile phone network penetration.

It is easy to notice that the notion of structural capital is associated with infrastructure. Although the term infrastructure comprises the social and technical infrastructure and the latter consists of transport, communication and communal (water, sewage, heating, gas and energy supply, waste collection) infrastructure, it could be noticed that the structural capital is more connected with the technical infrastructure with the emphasis on the communication systems.

Renewal capital (RenC) reflects the capability to innovations of a country and as Bontis underlines, it is its *'future intellectual wealth'* (Bontis, 2004, p.24). It is visualized by actual investments in research and development, level of innovation and modernization processes and adoption of this innovation. In result the measurement model of RenC should comprise such components as:

1. level of investments in R&D,
2. number of scientific publications,
3. foreign patent applications (to consider),
4. share of workforce employed in R&D,
5. investment in education systems especially higher education,
6. investment in ICT systems.

The conceptual model of Intellectual Capital of a country adopted in the paper is presented on the Figure 2. The detailed lists of variables used in the measurement of each component of IC process are in the tables 1, 4, 8, 10. These lists resulted from:

1. critical review of indicators already used in the measurement models proposed by Bontis and by Andriessen and Stam,
2. conceptual definitions adopted in the paper.

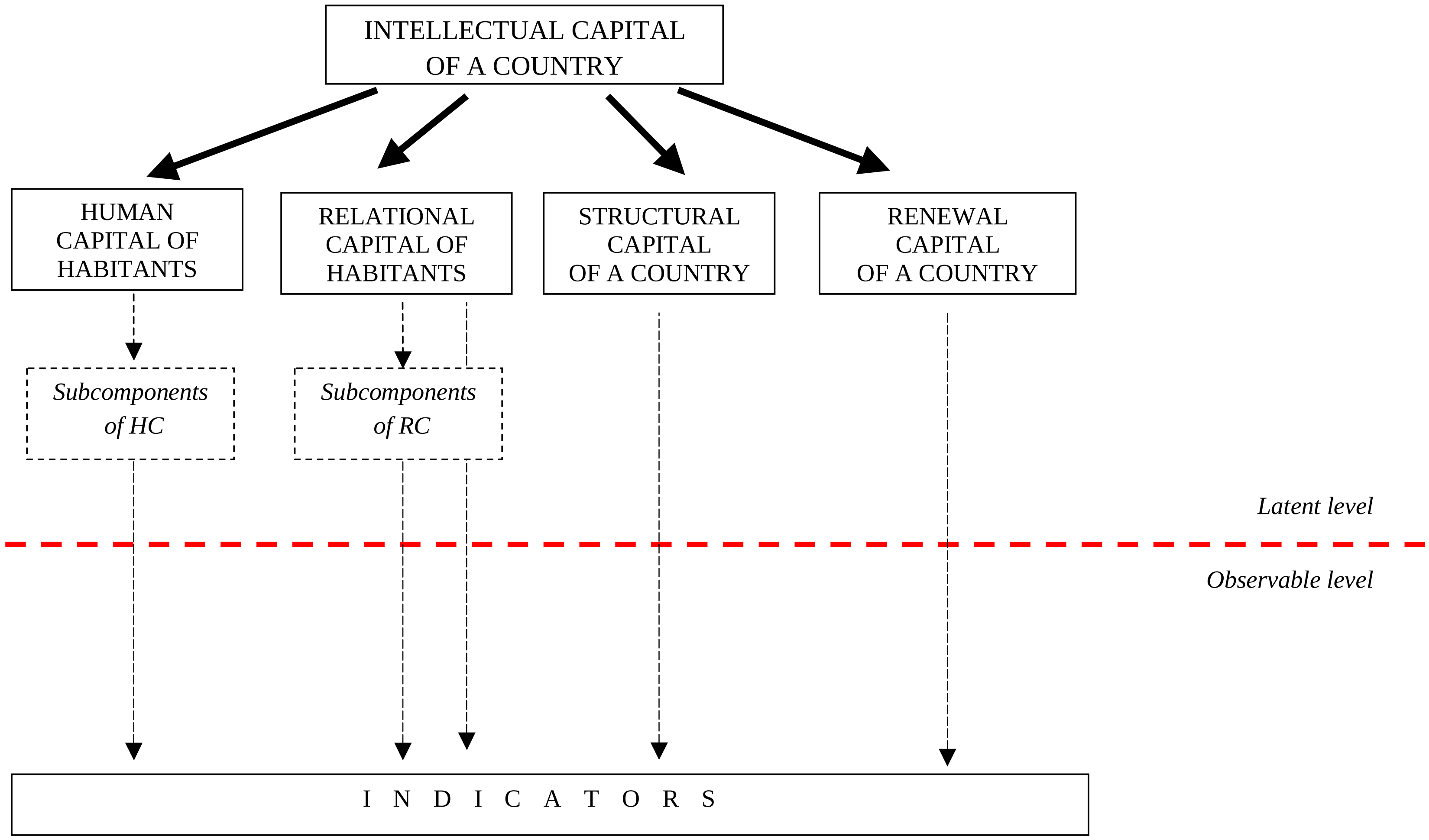
Such a procedure was undertaken to guarantee the best possible validity of IC index and its components. *Ab inito* these lists were much longer but during the process of reliability and validity verification considerable number of indicators was excluded. It was done to assure acceptable level of reliability but especially to obtain easily applicable measurement tool.

In the literature on IC, regardless if it is IC of a company, of a nation, of a region or of a country, there is a common agreement that intellectual capital is the phenomenon that cannot be observed, though the results of its existence can be very spectacular. This agreed latent nature of intellectual capital became the starting point for the elaboration of the measurement model of IC of a country. Having worked out and then analyzed the conceptual definitions of its components (HC, RelC, SC and RenC), it was also assumed that all of them had latent structure. Since all components of IC as well as IC itself cannot be observed directly, they cannot be measured directly either (therefore they are called latent factors or latent variables). There are their symptoms – visualized as specific indicators – that can be seen and registered and it is their existence that proves the existence of a latent variables.

These remarks were visualized in the conceptual model on the Figure 2. According to the model, there are two levels – latent one and observable one. Indicators of components and subcomponents of IC occur on the observable level, whereas components and subcomponents of IC themselves on the latent level. The relations among all elements on the figure are represented by arrows. Their directions visualize the reflective character of:

1. observable indicators towards components and subcomponents of IC,
2. subcomponents of HC and RelC toward HC and RelC respectively,
3. HC, RelC, SC and RenC toward IC.

Figure 2. Conceptual model of IC of a country.



Operationalisation of the model of national intellectual capital

In order to operationalize the conceptual model of IC of a country it was necessary to transform the theoretical concept and relations into the set of equations constituting the operational model of IC of a country. To do so, the operationalisation of each latent element (IC, components and subcomponents of IC) was based on its conceptual definition. Furthermore, the operational model was to take into regard two issues:

1. latent character of IC and its components (IC_i) and subcomponents (IC_{ij}),
2. multivariate character of IC and its components (IC_i) and subcomponents (IC_{ij}).

To achieve so all subcomponents IC_{ij} and components IC_i as well as IC itself were measured using confirmatory factor analysis (CFA) (in the operational model presented on Figure 3 the components of IC i.e. HC, RelC, SC, RenC were symbolised as IC_1, IC_2, IC_3, IC_4 respectively).

As a result, in the operational model of IC (Figure 3) there were directly observable as well as latent variables (IC_{ij}, IC_i and IC).

The following latent variables were designed:

- *IC* – intellectual capital of a country,

- IC_i – *i*-th component of IC (where $I = 1,\dots, 4$),

- $IC_{ij(i)}$ – *j*-th subcomponent of i-th component of IC (where $j(1) = 1,\dots,4$; $j(2) = 1$).

Observable variables were of two kinds: *X* and *Z*, where *X* were variables from the inhabitants level data (ESS) and *Z* were variables from the country level data (Eurostat).

As a result result, as presented on the Figure 3, in the operational model of IC there were endogenous observable variables that served as indicators of latent variables, where some of them described the countries (*Z*) and some – the inhabitants (*X*). Observable variables of IC_1 were $X^{ij}_{j,w}$ (w = 1,…,4) and $Z^{1j}_{k(1j)}$ (for $j = 2, 3, 4$, $k(12) = 1,\dots,4$; $k(13) = 1,\dots,4$ and $k(14) = 1,\dots,4$). Observable variables of IC_2 were $X^{2j}_{j,s}$ (for $j = 1,2$; $s = 4$; $t = 1,\dots,4$) and $Z_{2k(2)}$ ($k(2) = 1,\dots,6$). Observable variables of IC_3 and IC_4 were $Z_{3k(3)}$ and $Z_{4k(4)}$ respectively (where $k(3) = 1,\dots,6$; $k(4) = 1,\dots,5$).

There were also latent variables both endogenous like IC_i and IC_{ij} and exogenous like IC and IC_i in relation to IC_{ij}. Besides, IC was called third-order factor, IC_1, IC_2 were second-order factors, and IC_3, IC_4, IC_{1j} and IC_{2j} were first-order factors.

The quantification process involved three main stages:

1. measurement of four subcomponents of HC i.e. IC_{1j} (where j =1,…,4) and two subcomponents of RelC i.e. IC_{2j} (where j =1, 2);
2. measurement of each component of IC, i.e. IC_i (where i = 1,…,4);
3. aggregation of IC_i into one synthetic index IC corresponding to intellectual capital of a country.

Each of them, starting from stage 1, was performed separately. It was the consequence of the characteristics of the objects measured (i.e. countries) and characteristics and amount of data available.

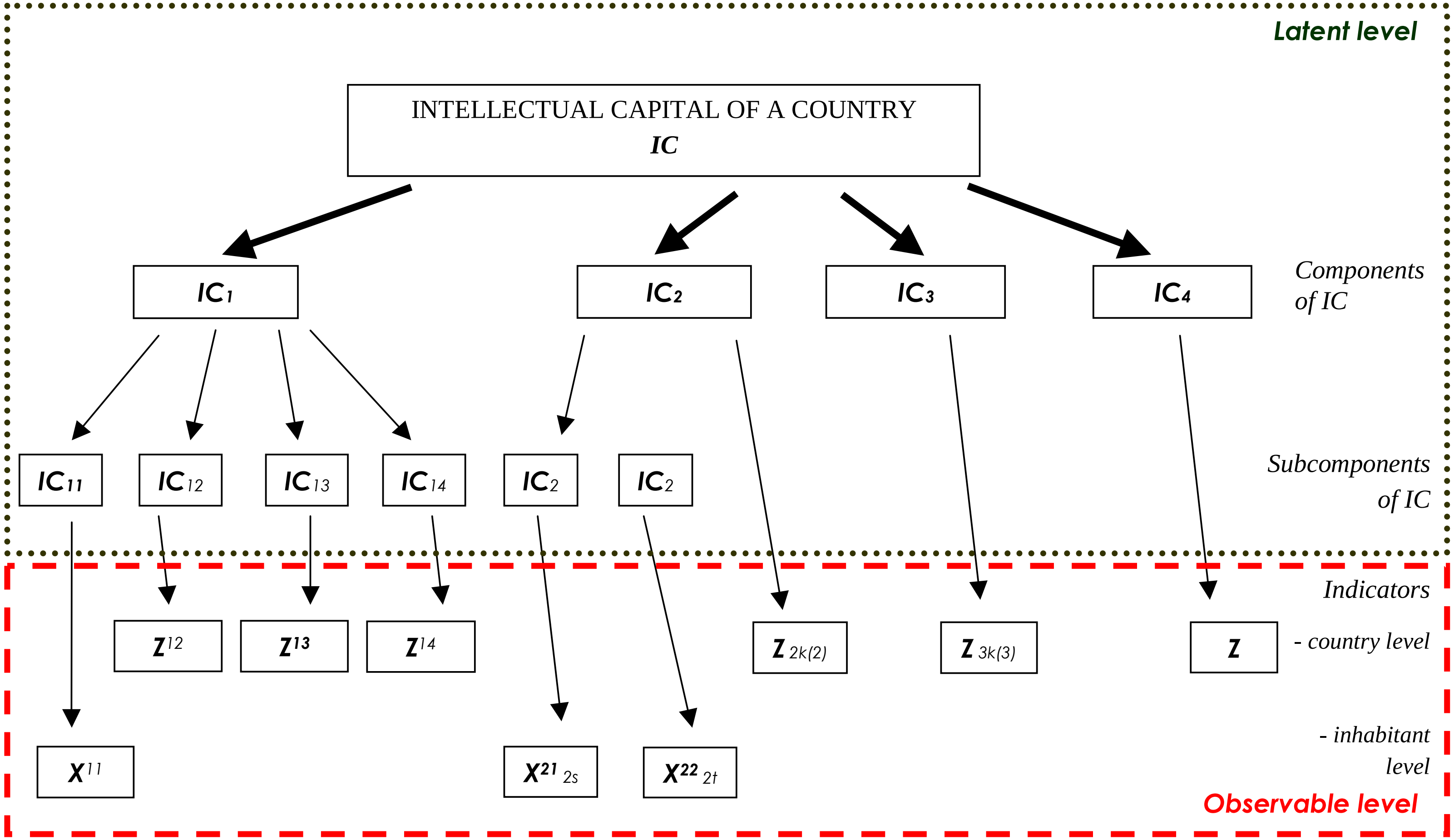
It was decided that the measurement of HC should comprise factors corresponding to life satisfaction, happiness etc. and measurement of RelC – mutual trust and norms of behaviors. Since data concerning them was taken from European Social Survey (ESS Round 2, 2004/2005), it was required to use proper method to incorporate them into one measurement system with data concerning countries. Therefore, before proceeding to measurement, it was necessary to consider two crucial issues. The former was devoted to the method of creation of the synthetic index and the latter – incorporation into this process variables from the country level and from the inhabitant level. Having examined the values of intraclass correlation coefficients for variables from ESS, they were accomplished by employing two-level confirmatory factor analysis (2-level CFA).

The quantification of HC and RelC was another important issue to consider. It should have reflected designed and presented on the Figure 2 the structure of these IC components. To make it clear, according to the conceptual model, HC and RelC have the subcomponents by which they are expressed. In line with nomenclature used in structural equation modeling (SEM) and in CFA, subcomponents of HC and RelC are called first-order factors, whereas HC and RelC in these cases are second-order factors and IC is third-order factor. It was required to take into regard this structure and it was done using CFA but due to aforementioned character and number of objects measured (i.e. countries) it should have been done again step by step.

To sum up, in order to quantify subcomponents, components and IC itself it was necessary to employ multivariate statistical methods that enabled measurement of latent variables and to provide a tool to do so with variables from two levels: country level and individual (here: inhabitant) level. It was multilevel structural equation modeling and its special case – twolevel confirmatory factor analysis – that satisfied these conditions.

Since there is no common agreement on the method of measurement of IC and its components and – what is more important – as it was assumed that they are not observable directly, it was necessary to verify if proposed method ensure valid and reliable results. To achieve this goal each scale and subscale – understood as abattery of variables designed to quantify given IC component or subcomponent – was verified with respect to its reliability – using Cronbach alpha coefficient – and validity – by exploratory factor analysis (EFA) (Keiser-Mayer-Olkin statistics and percentage of variance explained by the first factor). In the end the criterion validity of the IC index was revised using GDP per capita in PPS as the external criterion.

Figure 3. Operational model of IC of a country.



Data

Data applied in measurement were selected mainly from Eurostat databases and related to the situation in the year 2005. In the case of missing data from the year of analysis the corresponding data from years 2004 or 2003 were applied. The additional source of data to the analysis of soft factors of HC and trust and norms of behaviors of RelC was ESS. The detailed list of variables used for each IC component is presented in tables 1, 4, 8, 10 in the subsequent points of the paper[3].

4 out of 12 variables from ESS Survey had only 4 response categories. The remaining ones were measured on 5-point Likert scale. Nevertheless all of them were treated as continuous ones[4]. Furthermore a significant number of variables designed to the measurement process had many missing values. It was first decided not to replace them. However it resulted in obtaining values of all four components of IC for only 9 out of 24 countries taken initially into comparative analysis. There were many trial solutions examined with and without missing value imputations, in order to enable better comparison of European countries in terms of IC and its components. During the estimation of the latter ones the imputations of missing values – having assumed they were missing at random – were introduced. The comparison of results obtained with and without imputations showed no violations in the ranking of countries in each case. This decision, though subjective and possibly controversial, was needed to develop a full map of the IC in Europe.

Results

The measurement process of each component or subcomponent of IC began with the verification of the reliability and validity of scale designed to quantify it. Only having

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[3] Before proceeding to quantification of components and subcomponents of IC certain procedures on their indicators were performed:
- the negatively oriented variables from the ESS survey were recoded in order to ensure their positive orientation toward the scale quantifying given subcomponent or component of IC,
- the variables from Eurostat databases were standardized to make them comparable.

[4] Since even for variables with 5 response categories there is no common agreement on treating them as continous ones in SEM, it can be regareded as weakness of the solution presented. However, the two-level CFA model of norms of behaviours assuming categorical character of variables was not estimated successfully.

succeded in this stage the subsequent one i.e. measurement of IC, its components and subcomponents was executed. Since the main goal of this analysis was to create the index of IC, the assessment of values of fit indices – informing about the quality of measurement – was of crucial importance. Their insignificant values in the case of chi-square statistic or values of at least 0.9 in the case of CFI and TLI statistics and below 0.1 in the case of RMSEA are desired to assure the measurement process of good quality and precision. It is the case for some sets of data that these indices do not give coherent message. If such a situation occurred it was decided to rely on chi-square for two reasons:

1. this is the chi-square statistic that directly assesses the difference between the data and the model,
2. all other statistics are the transformation of the chi-square statistic.

To sumarise, the following strategy was adopted. Provided that the CFI and TLI were below 0.9 or RMSEA was above 0.1, it was insignificant chi-square statistic that sufficed to assessed the model as good.

Measurement of human capital

As presented on the conceptual model of IC (Figure 2) human capital is reflected by four subcomponents. The list of indicators for each of them is presented in (Table 1).

Table 1. Variables used in the measurement of human capital.

Life satisfaction	How satisfied with life as a whole (ESS 2004/2005)	
Subjective health	Subjective general health (ESS 2004/2005)	
Tolerance	Gays and lesbians free to live life as they whish (ESS 2004/2005)	
Happiness	How happy are you (ESS 2004/2005)	
Employment	Z47_2005	Human resources in science and technology as a share of the economically active population in the age group 25-64.
	Z52_2005	Employment in knowledge-intensive service sectors-share of total employment
	Z54_2003	Total researchers per 1000 habitants
	Z55_2005	Employment in high- and medium-high-technology manufacturing sectors as a share of total employment.
Internet usage	Z46_2005	Percentage of individuals aged 16 to 74 who accessed the Internet, on average, at least once a week; within the last three months before the survey. Use includes all locations and methods of access.
	Z49_2006	Individuals' level of computer skills – High or medium; his indicator presents the percentage of individuals who have carried out one or more of the following computer related activities: used a mouse to launch programs such as an Internet browser or word processor; copied or moved a file or folder; used copy or cut and paste tools to duplicate or move information on screen; used basic arithmetic formulae to add, subtract, multiply or divide figures in a spreadsheet; compressed files; written a computer program using a specialized programming language.
	Z56_2005	Share of workforce having main job involving working with computers, PCs, network, mainframe
	Z57_2005	Share of workforce having main job involving using Internet/email for professional purposes
Education	Z12_2005	Students at ISCED levels 5-6 enrolled in the following fields: science, mathematics, computing, engineering, manufacturing, construction - as % of all students
	Z14_2005	Graduates (ISCED 5-6) in mathematics, science and technology per 1000 of population aged 20-29,
	Z40_C2003	Participation in any learning activities (2003) (25 - 64 years) (percentage of population aged 25-64 years)
	Z53_2004	Doctorate students in science and technology fields (% of the population aged 20-29) participating in second stage of tertiary education (ISCED level 6) in science and technology fields of study (Science, Mathematics and Computing and Engineering, Manufacturing and Construction) as a percentage of the population 20-29 year old.

Measurement of soft components of human capital

It was decided to measure soft elements of HC by four statements from the ESS survey. Since Cronbach's alpha coefficient was at the level of 0.651 and share of variance explained by the first factor in EFA accounted for 56.9% the scale was assessed as reliable and valid.

In the next step the measurement model for IC_{11} was estimated. As the values of intraclass correlation coefficients in line with highly above 2 values of DEFF (Table 2) suggested the significant variation of the variables at the country level in relation to the inhabitant level the two-level CFA was applied to accomplish the desired goals.

Table 2. Intraclass correlation coefficients and DEFF for variables from scale for HC soft components measurement.

	Intraclass correlation coefficient	DEFF
Life satisfaction	0.126	240.4
Subjective health	0.090	172.0
Tolerance	0.200	381.0
Happiness	0.091	173.9
Average cluster size: 1900.8		

The quality of the model was very good (chi-square = 13.586, p=0.001, CFI = 0.991, TLI = 0.946, RMSEA = 0.011), though it was partially achieved thanks to imposing the correlations between error terms connected to variables measuring life satisfaction, happiness and health perception. Nevertheless, such correlations are justified as these aspects of life are closely interrelated what can be found in the quality of life literature. In addition, all factor loadings were positive as expected what was treated as additional proof of construct validity.

Measurement of employment subcomponent

As presented in the Table 1, the employment subcomponent (IC_{12}) was measured by four country level variables. They were aggregated into one synthetic index via one-level CFA. The reliability of the scale was at the very high level of 0.91. The share of explained variance by the first factor of 89.01% suggested that this scale was definitely unidimensional and the proposed set of indicators was likely to measure the employment factor precisely.

The values of fit indices obtained via CFA confirmed the aforementioned anticipation. Chi-square statistic of 6.657 was insignificant (p = 0.354), CFI and TLI amounted to 0.985 and 0.976 respectively and RMSEA statistic was at the acceptable level of 0.068. Furthermore, as expected, all factor loadings were positive.

To sum up, these findings were sufficient to expect that this model designed to measure employment would provide reliable and precise results.

Measurement of Internet usage subcomponent

The quantification of Internet usage subcomponent (IC_{13}) was accomplished using four country level indicators (Table 1). Again they were aggregated into one synthetic index using one-level CFA. The reliability of the scale was at the level of 0.64 and the share of explained variance by the first factor accounted for 51.47%. It suggested that this scale was reliable at the acceptable level and additionally that this set of four indicators could reflect the latent structure hidden behind them.

The values of fit indices obtained from CFA confirmed the above conclusions. Chi-square statistic of 0.114 was insignificant (p = 0.736), both CFI and TLI amounted to 1 and RMSEA statistic was at the level of 0.000. Furthermore, as expected, again all factor loadings were positive. To sum up, these findings proved that the tool would provide reliable and precise results.

Measurement of education subcomponent

The level of education of inhabitants (subcomponent education) was measured by four country level indicators (Table 1). However it is worth stating that at the early stages of research it was intended to measure also the quality of education. To do so data from Adult Literacy and Life Skills (ALL) Survey were to be used. The choice of these indicators was based on the suggestion made by R. Barro (Barro R., *Education and Ecnomic Growth*[5]) who have stated that it was the quality of education measured by test scores rather than years of schooling that had bigger explanatory power to explain the economic growth. Unfortunately it appeared that ALL Survey had not been conducted in sufficient number of European countries, so these indicators were not included in the analysis.

Again four finally chosen indicators of education subcomponent were aggregated into one synthetic index via one-level CFA. The reliability of the scale was at the level of 0.78 and the share of explained variance by the first factor accounted for 63.36%. It suggested that this scale was reliable at the acceptable level and additionally that this set of four indicators was really likely to reflect the latent structure hidden behind them.

The values of fit indices obtained from CFA confirmed the above conclusions. Chi-square statistic of 2.757 was insignificant ($p = 0.249$), the values of CFI and TLI were at the levels of 0.973 and 0.92 respectively. Despite the fact that RMSEA statistic, that amounted to 0.126, caused a little concern, the results were assessed as acceptable. Furthermore, as expected, again all factor loadings were positive. To sum up, these findings proved that the measurement model would provide reliable and precise results.

Human capital index

Having worked out the measurement models of good quality for all subcomponents of HC, their values were estimated. It was necessary to do so because due to relatively high number of indicators in relation to the number of cases (i.e. objects measured, countries) the CFA model with first-, second- and third-order factors was not estimable. Thus, it was required to estimate these factors in an ordered sequence. The same problem applied to RelC model and the same solution was employed there.

The second-order variable representing HC was quantified by aggregating four first-order variables (IC_{1j}, where $j = 1,\ldots,4$) generated in the previous steps. It is worth mentioning that since soft components of HC were aggregated using two-level CFA, only country-level

[5] http://www.oecd.org/dataoecd/5/49/1825455.pdf

latent variable was used in the subsequent aggregation This aggregation was again performed by CFA with imputations of missing values[6].

The measurement model of HC was of a good quality, what was proved by fit statistics. The chi-square statistic was insignificant (chi-square = 0.581, p = 0.747), both CFI and TLI amounted to 1, whereas RMSEA equaled 0. As expected factor loadings were positive and the comparison of their standardized values showed that HC was reflected with the strongest power by respectively:

1. internet usage,
2. soft components – among them on the country level by happiness, life satisfaction, tolerance and health,
3. employment,
4. education level.

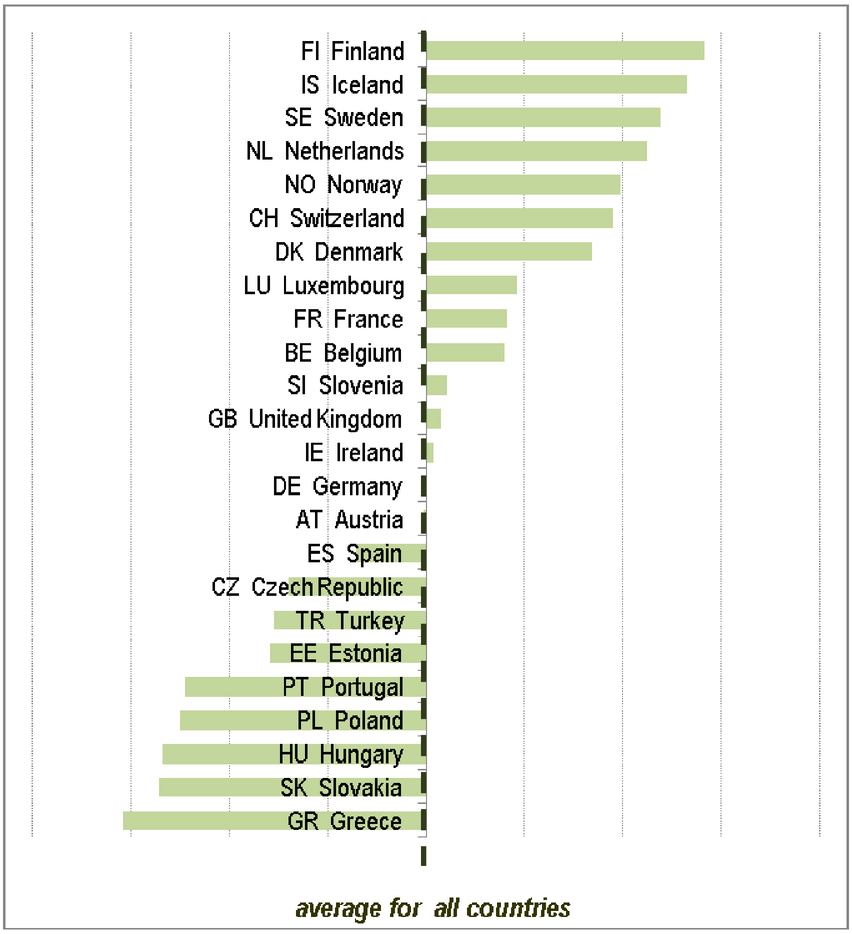
The results obtained were satisfactory and thus the measurement model of HC was used to estimate the value of HC for the European countries. Its standardized values are presented Table 3.

Table 3. Ranking of European countries according to the level of human capital.

Country	**HC index**		**Country**	**HC index**
FI Finland	1.416		IE Ireland	0.035
IS Iceland	1.326		DE Germany	0.009
SE Sweden	1.193		AT Austria	-0.012
NL Netherlands	1.125		ES Spain	-0.357
NO Norway	0.992		CZ Czech Republic	-0.701
CH Switzerland	0.953		TR Turkey	-0.772
DK Denmark	0.846		EE Estonia	-0.791
LU Luxembourg	0.466		PT Portugal	-1.228
FR France	0.410		PL Poland	-1.250
BE Belgium	0.400		HU Hungary	-1.339
SI Slovenia	0.106		SK Slovakia	-1.359
GB United Kingdom	0.075		GR Greece	-1.543

[6] The model was estimated using MISSING H1 option. The missing values were assumed to be MAR and were replaced using *Expected Maximization* (EM) algoritm.

Figure 4. Ranking of European countries according to the level of human capital.



The analysis of values in Table 3 allows to draw several conclusions mainly based on the comparisons between level of HC and GDP per capita expressed in Purchasing Power Standards (where EU-25=100). Firstly, it is evident and not surprising that the highest level of HC occur in Nordic countries. Secondly, countries from the southern Europe like Spain, Portugal and Greece have substantially lower human capital than other members of EU-15. Thirdly, countries that accessed UE in 2004 i.e. Czech Republic, Estonia, Poland, Hungary and Slovakia have lower human capital than its average level for countries included in the analysis. The positive exception is Slovenia that both is situated in the southern Europe and accessed EU in 2004, but it has to be remembered that it is a country that according to the development indicators is (and was even during the times of Centrally Planned economy) much better positioned than its counterparts from Central and Eastern Europe. Finally, the location in the ranking of Ireland was a little surprising taking into account enormous successes of this economy in the last decade.

Measurement of relational capital

Measurement of norms of behavior

Examination of the content of statements used in questionnaire of ESS Survey (Round 2) led to a conclusion that four statements designed to capture opinions about economic morality (rotating module E: http://www.europeansocialsurvey.org/) should be used as indicators of opinions about norms. These four statements formed the scale *norms* (Table 4).

Table 4. Variables used in the measurement of relational capital

z22_2003	Inflow of students (ISCED 5-6) from EU-27, EEA and Candidate countries - as % of all students in the country
z31_2003	Patent applications to the European Patent Office (EPO) - Number of applications per million inhabitants
z32_2003	Patents granted by the United States Patent and Trademark Office (USPTO) - Number of patents per million inhabitants
z37_2004	High-tech exports - Exports of high technology products as a share of total exports
TRUST	Trust plumber/builder/mechanic/other repairer deal honestly with you (ESS 2004/2005)
	Trust financial companies/bank/insurers deal honestly with you (ESS 2004/2005)
	Trust public officials deal honestly with you (ESS 2004/2005)
	Trust in the police (ESS 2004/2005)
NORMS	Someone paying cash without receipt to avoid VAT or tax, how wrong (ESS 2004/2005)
	Someone selling something second-hand and conceal faults, how wrong (ESS 2004/2005)
	Someone making exaggerated/false insurance claim, how wrong (ESS 2004/2005)
	Public official asking favour/bribe in return for service, how wrong (ESS 2004/2005)

The Cronbach's alpha coefficient calculated for this scale was at the level of 0.697 and the share of variance explained by the first factor in EFA accounted for 54.45%. These results permited to accept the scale and to employ it to measure the perception of obedience of informal social rules. In the next step the measurement model was estimated. As the values of intraclass correlation coefficients in line with again highly above 2 values of DEFF (Table

5) suggested the existence of significant variation of variables at the country level in relation to inhabitant level, the analysis was again performed by two-level CFA.

Table 5. Intraclass correlation coefficients and DEFF for variables constituting the norms scale.

Indicator	Intraclass correlation coefficient	DEFF
PYAVTXW	0.124	234.3
SLCNFLW	0.053	100.7
FLINSRW	0.073	138.4
PBOFVRW	0.034	65.0
Average cluster size: 1882.84		

The quality of two-level CFA model for norms was of acceptable quality (chi-square = 72.63 p=0.000, CFI = 0.942, TLI = 0.766, RMSEA = 0.022). Additionally, all factor loadings were positive as expected and it was the proof of construct validity.

To sum up, these findings proved that the measurement model for norms would provide enough reliable and precise results in order to be applied.

Measurement of mutual trust

The measurement of mutual trust subcomponent was based on four statements from ESS Survey. These statements described how strong the inhabitants believe in honest behavior of:

1. workers of different specializations performing repairs,
2. financial companies, bank and insurers,
3. public officials,
4. the police,

and constituted the *trust* scale (compare Table 4).

The Cronbach's alpha coefficient calculated for this scale was at the level of 0.659 and the share of variance explained by the first factor in EFA accounted for 49.56%. These findings suggested that the scale was likely to provide reliable results. Additionally it could have been treated as unidimensional and therefore used to measure latent factor corresponding to mutual trust.

Than, the measurement model of mutual trust was estimated. Since again the values of intraclass correlation coefficients along with values of DEFF highly above 2 (Table 6) suggested the significant variation of variables between countries compared to the one of within countries, the estimation was executed by two-level CFA.

Table 6. Intraclass correlation coefficients and DEFF for variables constituting the trust scale.

Indicator	Intraclass correlation coefficient	DEFF
TSTRPRH	0.025	44.1
TSTFNCH	0.041	71.6
TSTPBOH	0.054	94.0
TRSTPLC	0.153	264.6
Average cluster size: 1724.04		

The quality of two-level CFA model for mutual trust was of excellent quality (chi-square = 10.894 p=0.0278, CFI = 0.997, TLI = 0.991, RMSEA = 0.006). Additionally, all factor loadings were positive as expected and it was a proof of the construct validity. All these findings proved that the measurement model for mutual trust would provide very reliable and precise results.

Relational capital index

Good quality measurement models for two subcomponents of RelC were worked out and afterwards estimation of their values was executed. Similiarily to the HC measurement model such procedure was also required because the number of indicators in relation to the number of cases was too high to make the CFA model estimable. Therefore at the beginning the values of trust factor and opinions about norms factor were estimated and than they were incorporated into the measurement model of RelC. The values of relational capital were generated using again CFA. This process comprised the aggregation of six indicators. There were two latent variables – trust and opinions about norms – having performed as indicators of second-order latent variable – RelC. There were also four observable variables (data from Eurostat). All six indicators were country-level variables. In the case of latent indicators their country-level forms were achieved via estimating these latent construct both at the inhabitant and country level in two-level CFA, as described above. The Cronbach's alpha coefficient for these six variables amounted to 0.664 and the share of explained variance by the first factor in EFA was at the level of 41% (for four observable variables $\alpha = 0.694$ and share of explained variance accounted for 47%).

Estimation of RelC index was accomplished by CFA with imputations of missing values. The measurement model of RelC was of a very good quality, which was proved by fit statistics. Again the chi-square statistic was insignificant and at the level of 10.85 with $p = 0.369$. CFI and TLI amounted to 0.978 and 0.966 respectively, whereas RMSEA equaled 0.059.

As expected all factor loadings were positive. The comparison of their standardized values showed that RelC was reflected the strongest by variables presenting the level of patents application (Z31 and Z32) and the weakest by norms.

The results obtained were satisfactory and thus the measurement model of RelC was used to estimate the value of RelC index for the European countries. Its standardized values are presented in Table 7.

Table 7. Ranking of European countries according to the level of relational capital.

Country	RelC index		Country	RelC index
CH Switzerland	2.466		NO Norway	-0.111
DE Germany	1.515		IE Ireland	-0.444
FI Finland	1.463		SI Slovenia	-0.669
SE Sweden	1.291		ES Spain	-0.835
NL Netherlands	0.951		HU Hungary	-0.932
DK Denmark	0.880		CZ Czech Republic	-0.957
LU Luxembourg	0.585		EE Estonia	-0.960
AT Austria	0.540		GR Greece	-0.997
IS Iceland	0.194		SK Slovakia	-1.022
FR France	0.155		PT Portugal	-1.027
BE Belgium	0.117		PL Poland	-1.055
GB United Kingdom	-0.075		TR Turkey	-1.074

According to the data presented in Table 7 the highest level of relational capital occur in Switzerland, Germany, Finland and Sweden. The lowest is in Turkey and Poland.

Countries that accessed the EU in 2004 are generally characterized by lower level of relational capital than other member countries. Again it is Slovenia that positively differs.

Figure 5. Ranking of European countries according to the level of relational capital.

Measurement of structural capital

As suggested by conceptual model and than specified in operational model (Figure 2 and Figure 3 respectively) the structural capital was to be measured by only country-level variables (Table 8). There were six variables and according to the level of Cronbach's alpha coefficient they constituted consistent and reliable scale ($\alpha = 0.868$) that could have been assessed as unidimensional and used to quantify unobservable factor corresponding to structural capital (share of variance explained by the first factor accounted for 62.64%).

Table 8. Variables used in the measurement of structural capital.

Z31_2003	Number of patent applications to the European Patent Office (EPO) per million inhabitants
Z32_2003	Number of patents granted by the United States Patent and Trademark Office (USPTO) per million inhabitants
Z38_2005	Broadband penetration rate - Number of broadband lines subscribed in percentage of the population
Z43_2005	Percentage of enterprises having access to the Internet; without financial sector (10 employed persons or more)
Z48_2003	Mobile phone subscriptions (per 100 inhabitants) - the number of subscriptions to public mobile telecommunication systems using cellular technology related to the population divided by the number of inhabitants of the country and multiplied by 100. Active pre-paid cards are treated as subscriptions.
Z51_2003	European high-technology patents (per million inhabitants) - the ratio of patent applications made directly to the European Patent Office (EPO) or via the Patent Cooperation Treaty and designating the EPO (Euro-PCT), in the field of high-technology patents per million inhabitants of a country.

Having obtained satisfactory results from exploratory analysis the confirmatory one was executed. In this step the measurement model was estimated. Since all indicators were at the country-level the measurement was accomplished by one-level CFA. Thanks to excellent fit statistics (insignificant chi-square statistic of 3.662, $p = 0.93$, CFI =1, TLI = 1, RMSEA = 0.000) the estimation of values of SC index was possible. Furthermore, the index obtained can be regarded as reliable and precise.

Besides, it appeared that all factor loadings in the measurement model of SC were positive what was in line with the expectations formulated in the phase of conceptual model creation. This fact confirmed the validity of SC index.

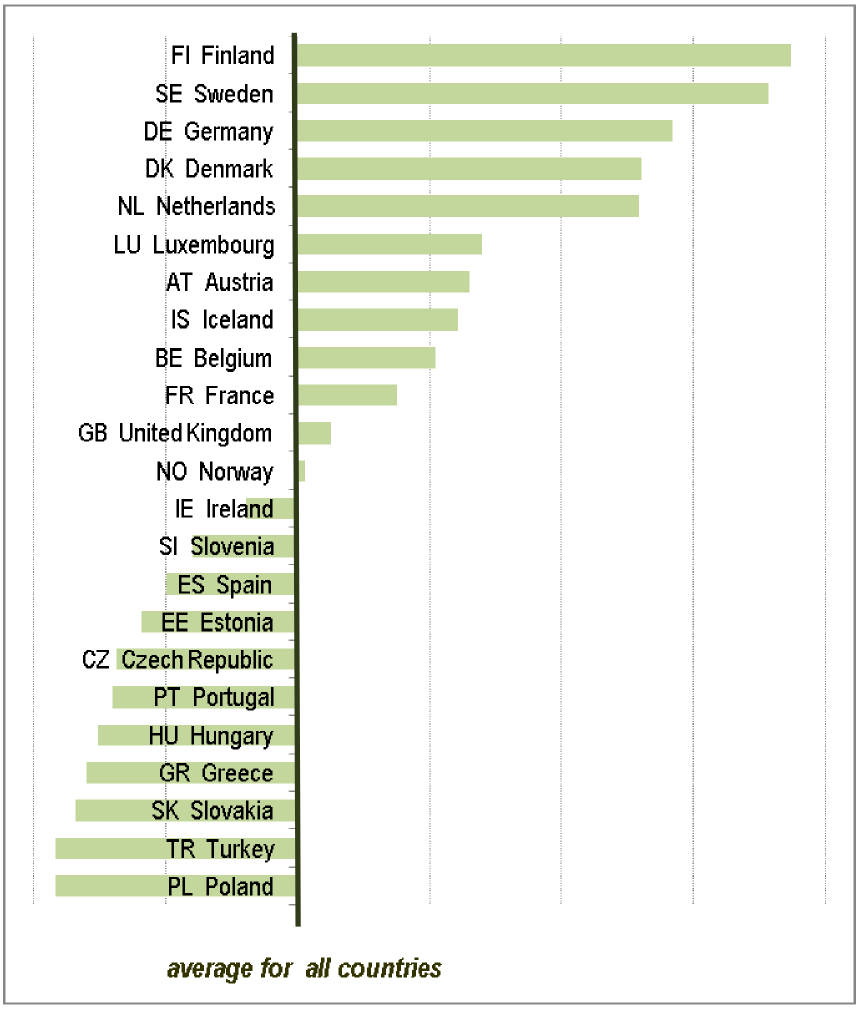
Taking into regard all conclusions presented above, it was decided that computation of values of SC index for European countries was strongly justified. The results obtained are presented in Table 9.

Table 9. Ranking of European countries according to the level of structural capital.

Country	SC index		Country	SC index
FI Finland	1.871		IE Ireland	-0.192
SE Sweden	1.787		SI Slovenia	-0.397
DE Germany	1.422		ES Spain	-0.497
DK Denmark	1.304		EE Estonia	-0.589
NL Netherlands	1.292		CZ Czech Republic	-0.683
LU Luxembourg	0.697		PT Portugal	-0.698
AT Austria	0.653		HU Hungary	-0.753
IS Iceland	0.611		GR Greece	-0.797
BE Belgium	0.525		SK Slovakia	-0.838
FR France	0.378		TR Turkey	-0.914
GB United Kingdom	0.129		PL Poland	-0.916
NO Norway	0.027			

There are Sweden and Finland that are the best in the ranking, whereas countries that accessed the EU in 2004 along with southern European countries like Greece, Portugal and Spain are among the laggers. Once more it is Slovenia that performs the best among accession countries.

Figure 6. Ranking of European countries according to the level of structural capital.



Measurement of renewal capital

According to the operational model of the renewal capital, it was designed to be quantified using only country-level variables. As presented in Table 10 finally there were five of them. To assess the reliability and consistency of the battery of these indicators the Cronbach's alpha coefficient was calculated and it amounted to 0.805. The validity of the scale was assessed by examination of the share of explained variance by the first factor in EFA and it accounted for 59.94%. These findings suggested that the scale was likely to provide reliable results. Besides, it could have been treated as unidimensional and therefore used to measure latent factor corresponding to renewal capital.

Table 10. Variables used in the measurement of renewal capital.

Z16_2004	Expenditure on educational institutions from private sources as % of GDP for all levels of education combined
Z20_2004	Annual expenditure on public and private educational institutions per student compared to GDP per capita, at tertiary level of education (ISCED 5-6), based on full-time equivalents
Z23_2004	Total public expenditure on education as a percentage of GDP
Z24_2004	Gross domestic expenditure on R&D (GERD) as a percentage of GDP
Z35_2003	Expenditure on Information Technology as a percentage of GDP

The next step involved the estimation of the measurement model of RenC and was successfully accomplished. The quality of achieved results was proved by insignificant chi-square statistic of 2.768 and the values of fit indices: CFI = 1, TLI = 1 and RMSEA = 0. The validity of model was confirmed by obtaining positive factor loadings for all indicators.

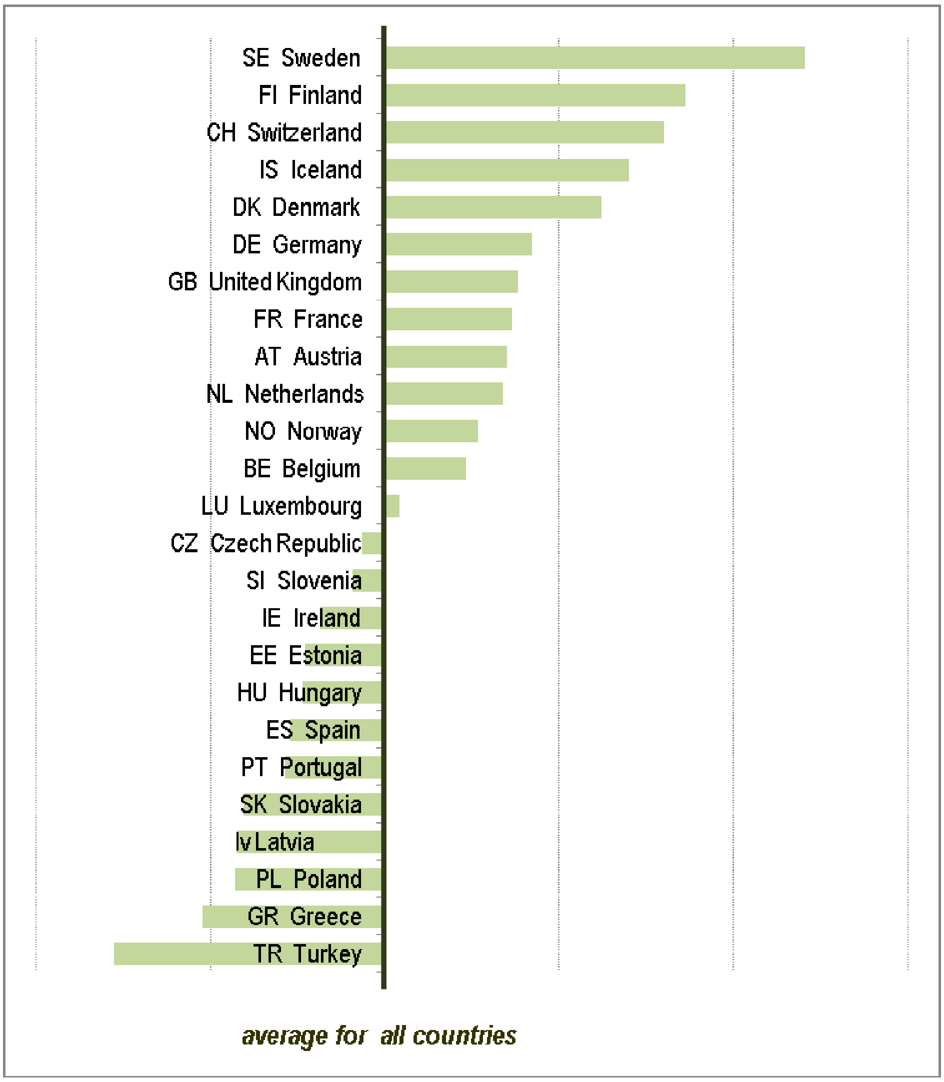
Taking into regard all arguments presented above, it was decided that computation of values of RenC index for European countries was strongly justified. The results obtained are presented in Table 11.

Table 11. Ranking of European countries according to the level of renewal capital.

Country	**RenC index**		**Country**	**RenC index**
SE Sweden	2.408		CZ Czech Republic	-0.129
FI Finland	1.721		SI Slovenia	-0.188
CH Switzerland	1.597		IE Ireland	-0.374
IS Iceland	1.397		EE Estonia	-0.457
DK Denmark	1.241		HU Hungary	-0.469
DE Germany	0.843		ES Spain	-0.545
GB United Kingdom	0.765		PT Portugal	-0.571
FR France	0.73		SK Slovakia	-0.806
AT Austria	0.703		lv Latvia	-0.852
NL Netherlands	0.676		PL Poland	-0.854
NO Norway	0.536		GR Greece	-1.045
BE Belgium	0.462		TR Turkey	-1.55
LU Luxembourg	0.086			

Distribution of values of RenC resembles the distribution of HC, RelC and SC indices. Once more Sweden, Finland, Switzerland are among the leaders, whereas Poland, Slovakia, Portugal, Greece and Spain among the laggers.

Figure 7. Ranking of European countries according to the level of renewal capital.



Index of intellectual capital IC

Finally, computed indices of IC components were aggregated into one synthetic index of IC. At first, the adequacy of these indices was checked. Their consistency and reliability was confirmed by high Cronbach's alpha coefficient (0.963). The unidimensionality of the scale created with application of them and its ability to measure one latent variable was justified by KMO statistic of 0.762 and share of variance explained by the first factor at the level of 90.96%. These results led to computation of IC index via CFA.

The quality of estimated measurement model of IC was good (chi-square = 8.601, p = 0.034, TLI = 0.965, CFI = 0.929, RMSEA = 0.285) and permitted to estimate the values of this index. It is worth noticing that though the RMSEA was strongly above the highest acceptable level of 0.1, the remaining statistics – with the emphasis on chi-square with *p*-value at 0.034 – were at acceptable level. It was decided to accept the model and to estimate the values of IC index according to it.

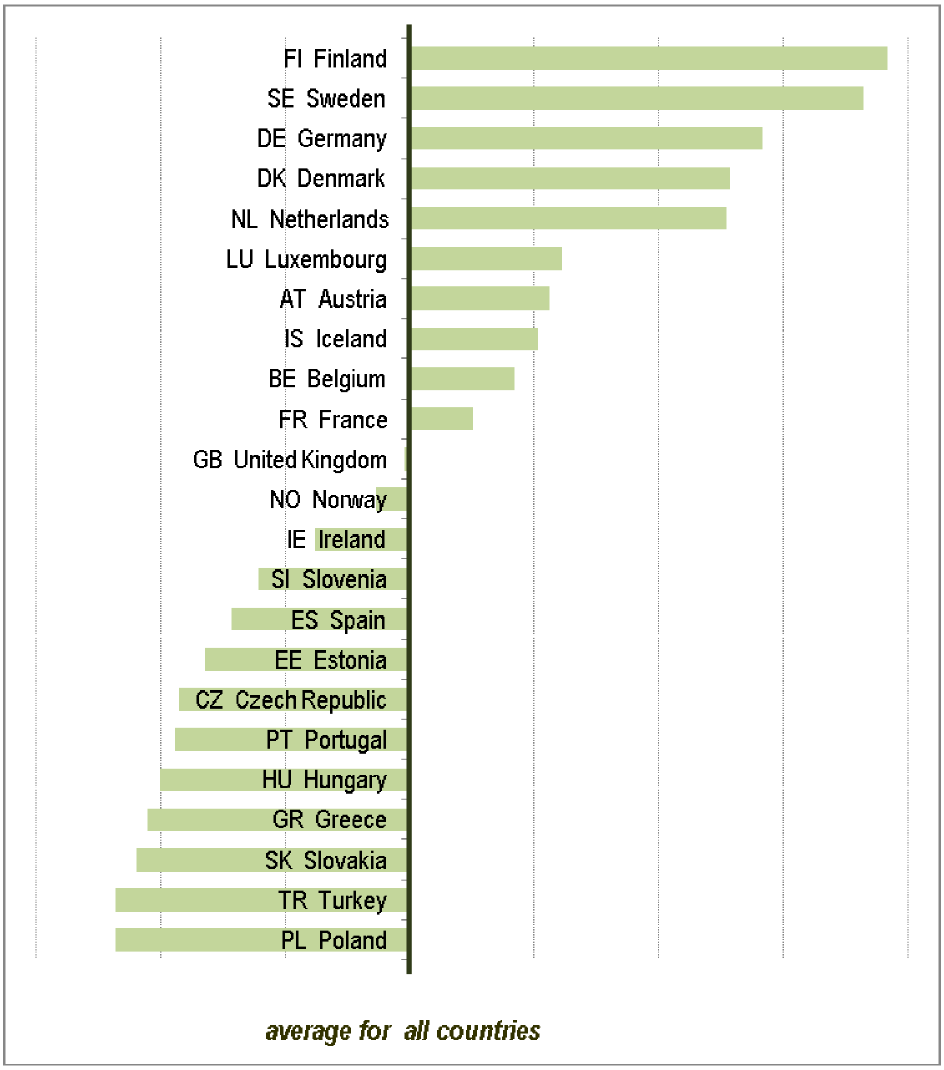
The factor loadings for all IC components were positive (and statistically significant). This indicated positive correlation between each of them and IC, but what is more, it proved that IC is expressed positively by its four components. Additionally, the values of the standardized factor loadings informed about the strength of this influence. Thanks to it, it could have been stated that IC manifests itself the most by structural capital, then by relational capital, renewal capital and finally by human capital. Since standardized factor loadings do not differ a lot from each other (from 0.847 to 1.000), the strength of influence of all IC components is comparable.

The ranking of countries according to the level of IC index are presented in Table 12.

Table 12. Ranking of European countries according to IC index.

Country	**IC index**		**Country**	**IC index**
FI Finland	1.914		NO Norway	-0.135
SE Sweden	1.821		IE Ireland	-0.379
DE Germany	1.415		SI Slovenia	-0.607
DK Denmark	1.284		ES Spain	-0.718
NL Netherlands	1.271		EE Estonia	-0.82
LU Luxembourg	0.609		CZ Czech Republic	-0.924
AT Austria	0.560		PT Portugal	-0.941
IS Iceland	0.514		HU Hungary	-1.002
BE Belgium	0.418		GR Greece	-1.051
FR France	0.255		SK Slovakia	-1.097
GB United Kingdom	-0.022		TR Turkey	-1.181
			PL Poland	-1.183

Figure 8. Ranking of European countries according to IC index.



In order to make the results more appealing, the classification of European countries according to the level of all four components of IC concurrently was presented in the Table 13. This grouping was accomplished by employing *k*-mean cluster method of classification and it is generally in line with the classification made only using as the criterion the values of IC index.

Table 13. Classification of European countries according to the level of all four components of IC.

	Leaders	Pretenders	Followers	Laggers
Mean of HC Index	1.187	0.492	0.476	-1.038
Mean of RelC Index	1.74	0.972	-0.031	-0.984
Mean of SC Index	1.829	1.168	0.222	-0.743
Mean of RenC Index	1.909	0.866	0.427	-0.714
Countries	FI Finland SE Sweden CH Switzerland	NL Netherlands DK Denmark DE Germany AT Austria	SI Slovenia IE Ireland NO Norway IS Iceland LU Luxembourg FR France BE Belgium GB United Kingdom	ES Spain CZ Czech Republic TR Turkey EE Estonia PT Portugal PL Poland HU Hungary SK Slovakia GR Greece

Relations among IC components and between IC index and GDP

To explore the relations among components of IC the Pearson correlation coefficients (Table 14) and partial correlation coefficients (Table 15) were computed. As can be seen in Table 14, all IC components are highly and positively correlated. The weakest correlation occurs between human capital and relational capital, whereas the strongest between structural and relational one. However, the inspection of partial correlation reveals that though it seems that between (1) HC and RelC and (2) RelC and RenC there are positive relations, controlling for SC and RenC in the former and for HC and SC in the latter the relations become negative.

To sum up, taking into regard the relation between any two given IC components separately the relations among them became smaller and in the case of two of them i.e. HC with RelC and RenC with RelC even negative. Since, according to the mode of conceptualization and operationalization method the components of IC have to be related to each other, the decrease in correlation when controlling for other variables was very likely to occur, so the results can be assessed as very satisfactory.

Table 14. Pearson correlation coefficients for IC components.

	HC	RelC	SC	RenC
HC	1			
RelC	0.789	1		
SC	0.847	0.989	1	
RenC	0.859	0.862	0.904	1

Table 15. Partial correlation coefficients for two IC components controlling for remaining two.

	HC	RelC	SC	RenC
HC	1			
RelC	-0.228	1		
SC	0.311	0.960	1	
RenC	0.287	-0.289	0.459	1

To confirm the validity (convergence criterion validity) of results, GDP per capita in PPS was correlated with IC components and with IC itself (Table 16). Expected positive correlation was confirmed in each case. Values of correlation coefficients varied from 0.486 for RenC to 0.655 for HC. Additionally, it was the human capital that was correlated the most with GDP regardless of the year of calculation and RenC that was correlated the least.

Table 16. Pearson correlation coefficients between IC component, IC and GDP per capita in PPS

	GDP_2003	GDP_2004	GDP_2005
HC	0.655	0.658	0.642
RelC	0.593	0.579	0.543
SC	0.591	0.580	0.546
RenC	0.524	0.518	0.486
IC	0.591	0.580	0.546

GDP per capita in PPS - GDP per capita in Purchasing Power Standards (PPS) (EU-25=100)

Take into consideration the fact that IC is believed to be the indicator of future development potential, its positive and moderately high correlation with GDP can be regarded as very good prognostic. Furthermore, not to high correlation implied that IC does not straightforwardly duplicate the information provided by GDP index, but is likely to become its extension. Nevetrtheless the further research is needed to check if there is the casual relation between GDP and IC. Then, provided the confirmation, it will be possible to thoroughly model this relation and better forecast the future development of a country.

To both scrutinize and confirm the relation among IC index and GDP, the mean level of the latter was calculated for four groups of countries defined with regard to four components of IC (see Table 13). The results obtained are presented in Table 17.

Table 17. GDP in four groups of countries

	GDP_{2003}	GDP_{2004}	GDP_{2005}
Laggers	58.08	58.74	59.63
Followers	118.08	119.35	119.85
Pretenders	120.13	119.41	118.70
Leaders	124.76	124.50	123.47

The results correspond with expectations. On the one hand countries with the higest level of IC components – leaders – are besting front according to the level of GDP *per capita* in PPS and on the other hand, the laggers in terms of the level of IC components are the worst in terms of GDP.

Discussion

Proposed method of IC measurement is an extension of the proposals of Bonits (2004) and Andriessen and Stam (2004). Thanks to the application of different approach to data aggregation the subjective decision concerning weights imposed on IC indicators made by Bontis was confirmed. Different factor loadings and resulting from them factor scores for each measurement model of components of IC and IC itself proved the indicators are not of the same importance. Although it could be useful and interesting to compare their relative importance, unfortunately it was impossible to conduct due to the lack of entire comparability of the indicators used.

Strong correlation between IC index and GDP per capita indicated that there was a significant level of information carried by the IC index. First of all, it should be pointed out that IC probably explains significant part of the difference in the level of development of various countries. Secondly, it does not carry the full information about the value of the GDP in economy, so it possibly carries also information about the future development of a country. This hypothesis is still to be verified. Thirdly, it was managed to distinguish four different groups of countries that have different levels of IC. First group included two Scandinavian countries, namely Finland and Sweden, and Switzerland. Nordic countries are very often presented as an example of countries with high level of development and low economic incentives. IC index might give a clue, where the strengths of these economies lie. As the relational capital plays such a crucial role, it might suggest that lack of economic incentives can be replaced by social relations. Intersting is the case of Norway – one of the most developed countries in the world. Nevertheless, it has to be remembered that to a large extent its development is connected with intensive use of natural resources. The question, that can be asked, is whether Norway will develop fast in the forthcoming years, as the level of IC is so low.

IC index can also be applied as an explanation to the occurring violation of the convergence hypothesis. According to it, less developed countries should have faster rate of growth and catch up with developed countries (Romer, 2000). The low level of IC in the countries accessing EU in 2004 indicates that there may occur significant problems in the process of catching up by the laggers.

In countries with low level of IC, low values of human and relational capital are of the most concerns. On the one hand, catching up process are supposed to be speeded up by the membership in the EU and funds flowing from the Community, on the other hand, it is very hard to improve social relations in the society with application of structural funds. The development of human capital requires also very long period of time to be effective. So the IC and especially its components might indicate, why the process of catching up is so bumpy and seem not to occur in desired pace.

To sum up, the conducted research extended the present state of art in the field of IC measurement by:

1. including into the measurement of IC so called soft elements such as norm of behaviours, mutual trust, life satisfaction, perception of health, happiness, tolerance,
2. using in the measurement the technique designed to quantification of latent variables,

3. confirmation of the conceptual model by validity and reliability analysis.

The limitation of the presented solution are:

1. relatively small sample size,
2. relatively large number of missing values in data,
3. resulting from point 2 – sequential measurement procedure.

Furhtermore, it must be stated that although the obtained substantive results can be dependant to the choice of indicators, it resulted from (1) the conceptual model, (2) availability of data corresponding to it, (3) the modification of lists of indicators used by Bontis (2004) and Andiressen and Stam (2004). Apart from it, thanks to the verification of reliability but especially of validity the measurement tool to assess the level of IC can be considered as precise and stable.

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