Composite indicator ECAICI and positioning of Georgia's innovative capacities in Europe-Central Asia Region

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The Composite ECAICI: Positioning Of Georgias Innovative Capacities In The Europe-Central Asia Region

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Abstract: This paper presents a brief analysis of the current innovative capabilities of Georgia based on the Europe-Central Asia Innovative Capability Indicator (ECAICI). This composite indicator is constructed using factor analysis tools. Research reveals that innovative processes in the Europe-Central Asia (ECA) region (by the World Bank classification) are mainly affected by four unobservable factors: knowledge creation, economic sophistication, knowlege absorption-diffusion, and human capital production. We show that the ECAICI is closely related to other well-known innovation indicators and to GDP per capita. The ECAICI was used to analyze the innovative capability dynamics during 1996–2010. This study serves as an illustration for the use of the ECAICI as an instrument for innovative capability assessment and analysis in Georgia and other post-USSR countries

Index Terms: National innovation systems, Developing countries, Countries in transition, Composite indicator, Factor analysis

1. INTRODUCTION

In the present-day world, innovations in the economic literature are considered to be an important factor for economic development and improvement in competitive ability [11]. According to a current working definition, “An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations” ([14], p. 46). Hence, innovative capabilities of countries depend on various factors: human capital, research activity, infrastructure, business environment, foreign economic relations, etc. Consequently, innovative capability measurement of a certain country requires construction of special instruments that consider the complicated and multidimensional nature of innovative processes and adequately reproduce them. Composite indicators represent instruments of this type. Various organizations and researchers have recently accumulated a large amount of experience in constructing composite indicators. The application of composite indicators by the European Union (EU) to assess the progress achieved under the Lisbon Strategy is a striking example of their practical use (see[6],[7]). Based on an analysis of the extensive experience with composite indicator development, one can conclude that, within the existing theoretical and methodological framework [12], problems related to availability of high-quality initial statistical data constitute the main obstacle in constructing certain composite indicators. It should be noted as well that restricted availability of statistical data leads to methodological difficulties, particularly when a comparison across countries on different levels of development becomes necessary [2]. Statistical data unavailability is a daunting problem, especially for developing countries (see [4], [15]). At the same time, these are the very countries that need composite indicators of their innovative capabilities to allow comparison between the developed and developing countries. These indicators enable developing countries to position their innovative capabilities and devise measures aimed to bridge the gap with the developed In this century, we observe increasing concern about the problems of introducing composite indicators to reflect the innovative capabilities of developing and transitional economies. Thus, several recent studies [1],[10],[16],[17],[18] described probably the most well-known and widely applicable composite indicators reflecting the innovative capabilities of developing and transitional economies (for a comparative analysis of various indicators, see [2] and [3]. The aforementioned indicators are entirely “global” and, unfortunately, usually represented by short time sequences. At the same time, developing countries need also to position their innovative capabilities within their regional space (in other words, historically and politically determined “neighbourhood”) for quite a long time interval. In particular, Georgia utterly needs to analyze her development within the framework of the Europe-Central Asia region in view of her post-USSR experience and due to strong European ambitions. Georgia is also a useful case study because its small-scale developing economy presents special challenges concerning the availability of initial statistical data. In the present article, we will design a special composite indicator, the Europe-Central Asia Innovative Capability Indicator (ECAICI), and with its help provide a brief analysis of Georgia’s innovative capability evolution.

2. METHODOLOGY AND DATA PROCESSING

2.1. Initial Indicators

Initial indicators were selected for the construction of the ECAICI based on extensive experiences in designing similar composite indicators. In addition, we carried out tests to determine the proportion of missing data and the correlation of initial indicators. Based on this procedure, 17 initial indicators were chosen. A brief review of these indicators is given below (for detailed definitions, see Annex, Table A1.). We use the following indicators to describe the functioning of the educational system:

LFT – Labor force with tertiary education (%)

GTA– Total number of graduates from all tertiary programs per 100 inhabitants

PSE – Public expenditure on education (GDP share, %)

TST – Total number of tertiary teaching staff per 1 million inhabitants

In order to describe the functioning of research and development (R&D) systems, we use the following indicators:

RRD – Number of researchers per 1 million inhabitants

RDE –Research and development expenditure (% of GDP)

STA – Number of articles published in scientific and technical journals per 1 million inhabitants

PAT – Number of patent applications per 1 million inhabitants

TRM – Number of trademark applications per 1 million inhabitants

HTE – High-tech export (% of GDP)

We use the following indicators to describe the economic environment:

DCP – Domestic credit to the private sector (% of GDP)

MCP– Market capitalization (% of GDP)

EPC – Electric power consumption (kWh per capita)

IUS – Number of Internet users per 100 inhabitants

DIO – Openness to foreign direct investments (% of GDP)

SSO – Openness to special services (% of GDP)

FIO – Openness to factor incomes (% of GDP)

2.2. Data

We used publicly accessible World Bank databases to obtain initial data required for the construction of the ECAICI. Pilot analysis carried out at the preliminary stage showed that as of the time of writing this article data for the pre-1996 and post-2011 period were unsatisfactory, based on quality and/or availability, for a number of Europe-Central Asia (ECA) countries (particularly former USSR countries). Therefore, we limited our investigation to the 1996–2010 period. We also considered it reasonable to exclude the following 13 countries of the ECA region because of population size (not exceeding 750,000 as of 2000) or special status: Andorra, Channel Islands, Faeroe Islands, Gibraltar, Greenland, Iceland, Isle of Man, Liechtenstein, Luxembourg, Monaco, Montenegro, San Marino, and Kosovo. Hereafter, the other 45 states of the ECA region will be simply referred to as the ECA region countries (see Table 1). At the preliminary stage, we tested the data based on the following criteria: The percentage of missing data must not exceed 40% and the absolute value of the correlation coefficient must be less than 0.9. In order to reconstruct missing data, we used a special statistical procedure known as the multiple imputation method [8].

TABLE 1
SAMPLE OF ECA REGION COUNTRIES

Code	Country	Code	Country	Code	Country
ALB	Albania	GEO	Georgia	PRT	Portugal
ARM	Armenia	DEU	Germany	ROM	Romania
AUT	Austria	GRC	Greece	RUS	Russian Federation
AZE	Azerbaijan	HUN	Hungary	SRB	Serbia
BLR	Belarus	IRL	Ireland	SVK	Slovak Republic
BEL	Belgium	ITA	Italy	SVN	Slovenia
BIH	Bosnia and Herzegovina	KAZ	Kazakhstan	ESP	Spain
BGR	Bulgaria	KGZ	Kyrgyz Republic	SWE	Sweden
HRV	Croatia	LVA	Latvia	CHE	Switzerland
CYP	Cyprus	LTU	Lithuania	TJK	Tajikistan
CZE	Czech Republic	MKD	Macedonia, FYR	TUR	Turkey
DNK	Denmark	MDA	Moldova	TKM	Turkmenistan
EST	Estonia	NLD	Netherlands	UKR	Ukraine
FIN	Finland	NOR	Norway	GBR	United Kingdom
FRA	France	POL	Poland	UZB	Uzbekistan

2.3. Construction of the Composite ECAICI

We now introduce the following notations: C designates a finite set ($|C| = M$) of countries and functions

$$x_{ti} : C \to R, \quad i = 1, \ldots N, \ t = 1, \ldots, T,$$

where N is a number of initial indicators, T the length of the time interval, and R the set of real numbers. Hence, $x_{ti}(c)$ designates the value of the i -th indicator at time t for the country c. Further, we specify that initial indicators have the "same direction"; that is, the lesser value corresponds to "worse" and the greater value to "better". Although initial indicators may be given in different measurement scales, they should be normalized. For this purpose, we use a standardization procedure (z-scores) and introduce the function I_{ti}, defined by the following equation:

$$I_{ti} : C \to R, \quad I_{ti}(c) = \sigma_i^{-1}\left(x_{ti}(c) - \overline{x}_i\right)$$

where symbols $\overline{x}_i$ and σ_i designate the mean and standard deviation of the i-th indicator, $i = 1, \ldots N, \ t = 1, \ldots, T$. Further, this function is referred to as the normalized initial indicator. Choosing an aggregation procedure for composite indicator construction is very important. Because the solution for this problem is ambiguous and difficult, see [12], we use the simplest and most widely applied method of linear aggregation:

$$I_t(c) = \sum_{1 \le i \le N} w_i I_{ti}(c); \ c \in C, t = 1, \cdots, T$$

$$w_i \geq 0, 1 \leq i \leq N; \sum_{1 \leq i \leq N} w_i = 1$$

where w_i is the weight of the i-th normalized initial indicator. Our decision reduces the choice of an aggregation procedure to a weight choice problem.

TABLE 2
WEIGHTS OF INITIAL INDICATORS AND SUB-INDICATORS

Sub-Indicators	Normalized Initial Indicators	ECAICI Normalized Initial Indicators Weights in Corresponding Sub-Indicator	ECAICI Sub-Indicator Weights	ECAICI Normalized Initial Indicators Weights
Knowledge creation (KNCR)	PAT	0.27604871	0.378436	0.1044670
	RRD	0.22850693		0.0864754
	RDE	0.20697372		0.0783264
	EPC	0.18781536		0.0710762
	STA	0.10065528		0.0380916
Economic sophistication (ESPH)	DCP	0.30974646	0.2930011	0.0907560
	TRM	0.26376279		0.0772827
	MCP	0.24826056		0.0727406
	IUS	0.14256781		0.0417725
	PSE	0.03566238		0.0104491
Knowledge absorption-diffusion (KNAD)	SSO	0.51601671	0.185186	0.0955591
	HTE	0.24862114		0.0460412
	FIO	0.19162185		0.0354857
	DIO	0.04374000		0.0081000
Human capital production (HCPR)	TST	0.36931500	0.143375	0.0529508
	GTA	0.33977500		0.0487155
	LFT	0.29091000		0.0417094

We apply factor analysis to select the weights. The results of principal components analysis (PCA), applied to normalized initial indicators, showed that four unobservable factors (corresponding to eigenvalues >1) explained about 72% of data variation. After factor rotation, we used the sub-indicator formation procedure described in [13] to find weights for the initial indicators and aggregated them into sub-indicators corresponding to the revealed factors, see Table 2. We denote the sub-indicators, which may be interpreted according to their composition, by the following names and abbreviations: knowledge creation (KNCR), economic sophistication (ESPH), knowledge absorption-diffusion (KNAD), and human capital production (HCPR). ECAICI and sub-indicator values for 2010 are given in Annex, Table A2.

2.4. Comparison with Other Indicators and Relationship with GDP per capita

To test its potential, we compared the ECAICI with other well-known indicators: ArCo [1], Summary Innovation Index - SII [9], Innovation Capability Index - ICI [16], TechAchv [17], TechRead [18], and Global Innovation Index – GII [10]. Although constructed by different organizations/authors and based on different initial indicator compositions, as shown in Table 3 and Fig. 1, these indicators appear to be closely related to the ECAICI.

TABLE 3
COMPARISON THE ECA ICI WHITH OTHER INDICATORS

Index	Reference Year	Correlation	Regression y = ax + b; y = ECAICI reference year		
			a	b	R^2
TechRead	2009	0.913	0.5885	-2.366	0.833
TechAchv	2002	0.771	3.422	-1.518	0.594
ICI	2001	0.857	3.577	-2.517	0.735
EC SII	2006	0.894	3.181	-0.967	0.800
GII	2010	0.944	0.061	-2.377	0.892
ArCo	2000	0.940	4.321	-2143	0.883

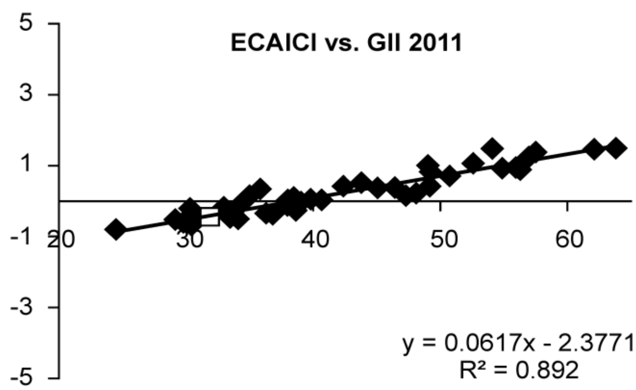

Fig.1. The ECAICI compared with GII. Horizontal axis – GII indicator, vertical axis –ECAICI. Square indicates Georgia.

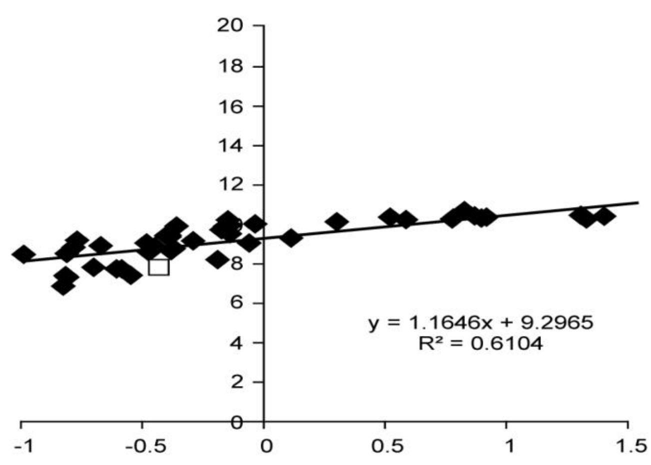

Fig.2. Relationship of ECAICI with GDP per capita. Horizontal axis –ECAICI, vertical axis - GDP per capita (PPP2005). Square indicates Georgia.

According to current economic thinking, innovative capabilities have a direct impact on the main economic indicators [11]. Considering this, we investigated the relationship between the ECAICI and GDP per capita (2005 PPP) and found a close association between them, see Fig. 2.

3. Results: Positioning of Georgia's Innovative Capabilities within the ECA Region

The ranking of ECA countries based on the 2010 ECAICI is given in Annex, Table A2 and Fig A1. The data shows that Georgia ranks 36th among 45 countries. This means Georgia's innovative capabilities are rather modest.

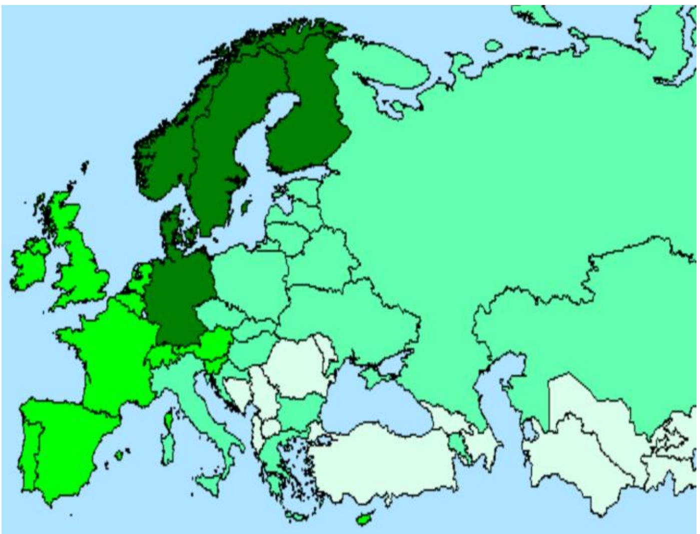

Fig. 3. Innovation clusters of ECA region. For explanation, see the text.

To examine this problem, we carried out a cluster analysis of ECA countries based on the 2010 ECAICI. The cluster analysis identified the following groups of countries: CLS1= {FIN, NOR, DEU, SWE, DNK}; CLS2= CHE, GRB, FRA, NDL, BEL, SVN, AUT, ESP, PRT, CYP, IRL}; CLS3={HUN, ITA, CZE, SVK, GRC, HRV, BGR, RUS, UKR, BLR, POL, LTU, LVA, EST, KAZ, ARM}; CLS4={TUR, MKD, BIH, SRB, ROM, MDA, GEO, AZE, TKM, KGZ, TJK, UZB, ALB}, see Fig. 3. Considering this fact, as well as the composition of clusters, we can identify CLS1 members as innovation leaders, CLS2 as innovation followers, CLS3 as moderate innovators, and CLS4 as innovation adapters. We see that Georgia is placed in CLS4. Analyzing Fig. 4. we can suppose that exist universal evolutionary track of innovation development for each country. The first stage is the accumulation of human capital (CLS4 members are in this stage). After accumulation of "enough" human capital, countries begin to increase innovative capabilities through knowledge generation, absorption-diffusion, and economic sophistication (this phase describes CLS3 countries). CLS2 includes countries that have reached a definite limit value of knowledge absorption-diffusion and economic sophistication. An inherent feature of the last stage is intense development of knowledge generation—this stage corresponds to CLS1 economies. Thus, Georgia can be considered to be in the first phase of her innovative capability development as of 2010.

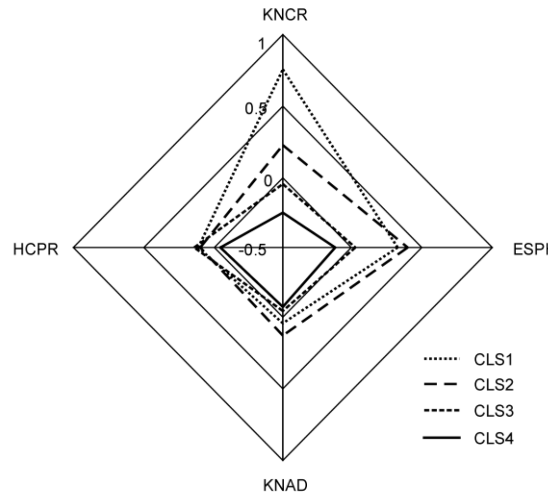

Fig.4. Axis - Mean values of ECAICI sub-indicators. For explanation of cluster and sub-indicator abbreviations, see the text.

Consider now the evolution of ECAICI and its sub-indicator mean values for the cluster CLS4 during 1996–2000. The Fig. 5. shows a clear trend toward overall improvement of innovative capabilities in CLS4.

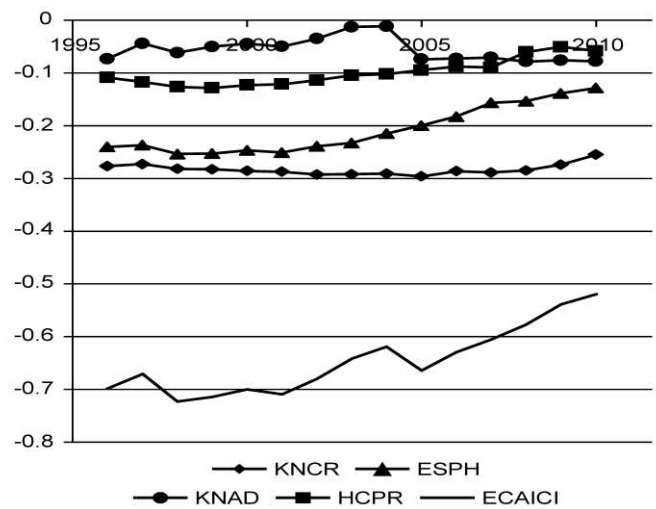

Fig. 5. Evolution of ECAICI and sub indicators for CLS4. Horizontal axis – Years, vertical axis – ECAICI and sub-indicator mean values. For explanation of sub-indicator abbreviations, see the text.

It is noteworthy that the dynamics of Georgia's innovative capability development is inconsistent with the main trends of CLS4, see Fig. 6. In particular, it shows an increase only in economic sophistication, but stagnation (knowledge absorption-diffusion and knowledge generation) or decline (human capital production) in other directions.

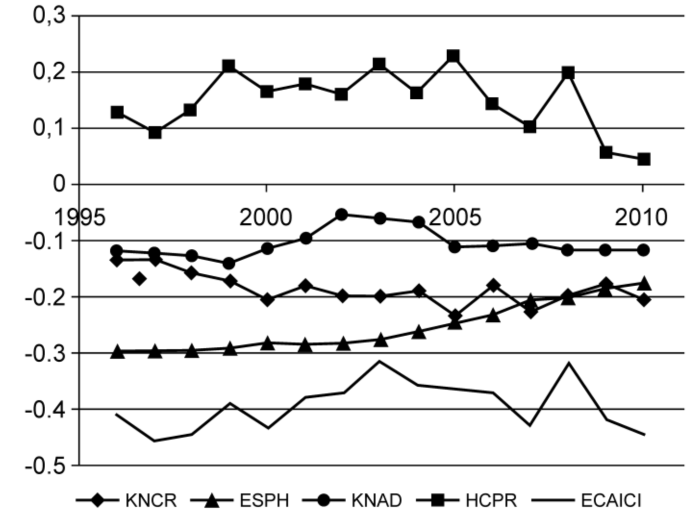

Fig. 6. Evolution of ECAICI and sub indicators for Georgia. Horizontal axis – Years, vertical axis – ECAICI and sub-indicator mean values. For explanation of sub-indicator abbreviations, see the text.

More detailed analysis (see Fig. 7.) shows directions that deserve careful study for further improvement of Georgia's innovative capabilities. Georgia needs to make all-out efforts in the immediate future to increase its human capital, upgrade the economy, and improve knowledge generation. These are the challenges that Georgia faces today

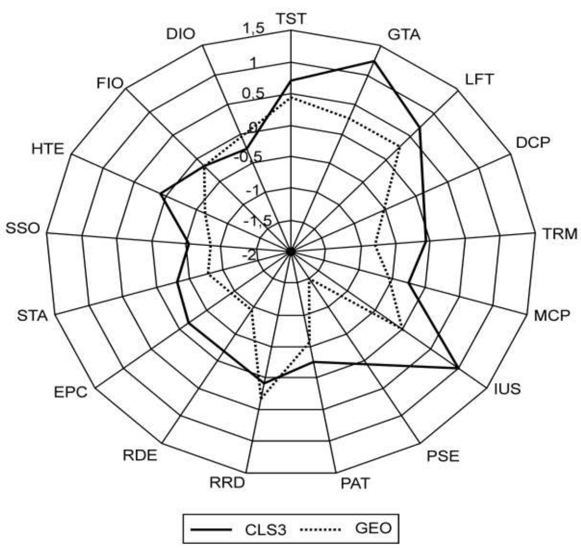

Fig.7. Comparison of ECAICI initial indicator values for Georgia and ECAICI initial indicator mean values for CLS3, 2010

4. Conclusion

Measurement of a country's innovative capabilities requires the construction of special instruments that enable investigators to consider the complicated and multidimensional nature of innovation processes and adequately describe them. Composite indicators represent instruments of this type. The problem of data availability in developing countries is a serious obstacle in constructing composite indicators that reflect innovative capabilities. These difficulties greatly affect the methodological and practical aspects of constructing composite indicators, particularly when countries with different levels of development need to be compared. In the present article, we presented the composite ECAICI, which allows analysis of the innovative capabilities of ECA countries during the period 1996–2010. Our research revealed that the innovative processes in the ECA region are related to four important factors: knowledge creation, economic sophistication, knowledge absorption-diffusion, and human capital production. The ECAICI is closely related to other well-known indicators as well as GDP per capita. It may be applied as an instrument for innovative capability assessment and analysis.

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ANNEX

TABLE A1
INITIAL INDICATORS OF THE COMPOSITE ECAICI

#	Initial Indicator	Code	Description
1	Labor force with tertiary education (% of total)	LFT	Labor force with tertiary education is the proportion of labor force that has a tertiary education, as a percentage of the total labor force.
2	Total number of graduates from all tertiary programs (per 100 of population)	GTA	Total number of graduates from all tertiary institutions.
3	Public spending on education, total (% of GDP)	PSE	Public expenditure on education consists of current and capital public expenditure on education, including government spending on educational institutions (both public and private), education administration as well as subsidies for private entities (students/households and other privates entities).
4	Total number of tertiary teaching staff (per million people)	TST	Total number of teaching staff (full- and part-time) in all programs of tertiary institutions (public and private). Teachers are persons employed full-time or part-time in an official capacity to guide and direct the learning experience of pupils and students, irrespective of their qualifications or the delivery mechanism. This definition excludes educational personnel who have no active teaching duties and persons who work occasionally or in a voluntary capacity in educational institutions.
5	Researchers in R&D (per million people)	RRD	Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included.
6	Domestic credit to private sector (% of GDP)	DCP	Domestic credit to private sector refers to financial resources provided to the private sector, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, establishing a claim for repayment. For some countries, these claims include credit to public enterprises.
7	Market capitalization of listed companies (% of GDP)	MCP	Market capitalization (also known as market value) is the share price times the number of shares outstanding. Listed domestic companies are domestically incorporated companies listed on the country's stock exchanges at the end of the year. Listed companies do not include investment

			companies, mutual funds, or other collective investment vehicles.
8	Electric power consumption (kWh per capita)	EPC	Electric power consumption measures the production of power plants and combined heat-and-power plants less transmission, distribution, and transformation losses and own use by heat-and-power plants.
9	Internet users (per 100 of population)	IUS	Internet users are people with access to the worldwide network.
10	Direct investment openness (% of GDP)	DIO	Direct investment openness is the sum of foreign direct investment net inflows and foreign direct investment net outflows. Foreign direct investments are the flows of investment to acquire a lasting management interest (10% or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments.
11	Special services openness (% of GDP)	SSO	Special services openness is the sum of exports and imports of special services. Special services are communications, computer, information, and other services—comprising international telecommunications and postal and courier services; computer data; news-related service transactions; construction services; royalties and license fees; miscellaneous business, professional, and technical services; personal, cultural, and recreational services; and government services not included elsewhere.
12	Factor income openness	FIO	Factor income openness is the sum of factor income payments and receipts. Factor income refers to employee compensation paid to nonresident workers and investment income (payments on direct investment, portfolio investment, and other investments). Income derived from the use of intangible assets is excluded from income and recorded under business services.
13	Research and development expenditure (% of GDP)	RDE	Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development.
14	High-technology exports (% of GDP)	HTE	High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. Data are in current U.S. dollars.
15	Patent applications, residents (per million people)	PAT	Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office.
16	Trademark applications, direct resident (per million people)	TRM	Trademark applications filed are applications to register a trademark with a national or regional intellectual property (IP) office. Direct resident trademark applications are those filed by domestic applicants directly at a given national IP office.
17	Scientific and technical journal articles (per million people)	STA	Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

TABLE A2
ECAICI AND SUB-INDICATORS VALUES BY STATE, 2010

Country	ECAICI 2010		Sub-Indicators			
			KNCR	ESPH	KNAD	HCPR
	Rank	Score	Score	Score	Score	Score
CHE	1	1.486	0.449	0.720	0.184	0.134
IRL	2	1.480	0.178	0.254	0.848	0.201
SWE	3	1.456	0.779	0.466	0.103	0.108
FIN	4	1.379	1.003	0.196	0.059	0.120
DNK	5	1.239	0.597	0.459	0.070	0.113
NOR	6	1.060	0.702	0.274	-0.048	0.132
BEL	7	0.997	0.212	0.483	0.184	0.118
GBR	8	0.945	0.358	0.450	0.019	0.118
DEU	9	0.921	0.661	0.219	-0.014	0.055
NLD	10	0.880	0.253	0.440	0.113	0.074
FRA	11	0.827	0.379	0.369	-0.049	0.128
AUT	12	0.707	0.486	0.179	0.024	0.017
ESP	13	0.519	0.070	0.434	-0.082	0.096
EST	14	0.416	0.022	0.146	0.066	0.183
PRT	15	0.412	-0.020	0.433	-0.063	0.062
CYP	16	0.375	-0.217	0.427	0.169	-0.003
SVN	17	0.370	0.253	0.141	-0.065	0.042
RUS	18	0.332	0.152	-0.012	-0.123	0.316
HUN	19	0.219	-0.085	0.027	0.244	0.033
CZE	20	0.151	0.043	0.069	0.043	-0.004
UKR	21	0.146	-0.100	-0.009	-0.074	0.328
LTU	22	0.102	-0.089	0.048	-0.091	0.234
LVA	23	0.050	-0.129	0.105	-0.059	0.133
POL	24	0.033	-0.063	0.023	-0.085	0.158
ITA	25	0.030	0.038	0.144	-0.106	-0.046
BLR	26	0.025	0.006	-0.085	-0.124	0.228
SVK	27	-0.033	-0.042	0.032	-0.066	0.043
BGR	28	-0.131	-0.133	0.020	-0.070	0.052
HRV	29	-0.133	-0.096	0.040	-0.091	0.015
GRC	30	-0.143	-0.064	0.056	-0.133	-0.002
ARM	31	-0.181	-0.197	-0.118	-0.093	0.227
KAZ	32	-0.207	-0.149	-0.082	-0.102	0.125
MDA	33	-0.263	-0.188	-0.072	-0.036	0.033
SRB	34	-0.344	-0.176	-0.069	-0.071	-0.028
ROM	35	-0.374	-0.202	-0.059	-0.084	-0.029
GEO	36	-0.444	-0.203	-0.175	-0.115	0.048
MKD	37	-0.468	-0.261	-0.033	-0.078	-0.096
TUR	38	-0.501	-0.251	-0.004	-0.163	-0.083
AZE	39	-0.521	-0.225	-0.175	-0.125	0.004

BIH	40	-0.526	-0.295	-0.092	-0.117	-0.021
TKM	41	-0.534	-0.280	-0.252	0.087	-0.090
KGZ	42	-0.603	-0.310	-0.189	-0.041	-0.063
ALB	43	-0.683	-0.301	-0.140	-0.092	-0.151
UZB	44	-0.685	-0.287	-0.195	-0.052	-0.150
TJK	45	-0.806	-0.334	-0.214	-0.127	-0.130
Avrg		**0.200**	**0.043**	**0.104**	**-0.009**	**0.062**
Med		**0.050**	**-0.064**	**0.040**	**-0.065**	**0.052**
Min		**-0.806**	**-0.334**	**-0.252**	**-0.163**	**-0.151**
Max		**1.486**	**1.003**	**0.720**	**0.848**	**0.328**