The composite indicators used in assessing innovation at national level

Indicatorii compoziţi folositi în evaluarea inovării la nivel naţional

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Abstract

The purpose of present paper is to present some recent developments in constructing composite innovation (or even, science and technology S&T) indicators on a national level. Measuring innovation at the national level is crucial in developing appropriate long term strategies for economic growth, because it is widely believed technological innovation is one of the main drivers of sustained economic-social welfare, if not the single most important driver of economic growth. Our purpose is to present a mapping exercise of metrics – based on composite indicators - found in the STI literature, pointing out those used in practice, with a view to corresponding values in the case of Romania. It has become standard practice to combine several indicators for science, technology, and innovation to form composite numbers. Composite indicators are increasingly being used to make cross-national comparisons of country performance in specified areas such as competitiveness, globalisation, innovation, etc.

Keywords: *Innovation, innovation metrics, Science and Technology indicators, composite indicators, National Innovation Systems, Scoreboards*

Rezumat

Scopul acestei lucrări este de a prezenta câteva dintre dezvoltările produse recent în construirea unor indicatori compoziti pentru activitatea de inovare (sau pentru stiinţă şi tehnologie) la nivel naţional. Măsurarea activităţii de inovare la nivel naţional este deosebit de importantă în formularea strategiilor de dezvoltare economică pe termen lung, deoarece inovarea tehnologica constituie unul dintre cei mai semnificativi vectori de creştere economică. Scopul propus impune expunerea unor tehnici de măsurare – bazate pe indicatori compoziţi – referiţi în literatura ştiintei, tehnologiei şi inovării, accentul fiind pus pe evaluările sistemului naţional de inovare din România. Deja, există practica de combinare a mai multor indicatori pentru ştiinţă, tehnologie şi inovare pentru construirea *unor indicatori compoziți. Acestia sunt folosiți mai ales în comparații internaționale pentru reliefarea unor aspecte specifice: competitivitate, globalizare, inovare etc.*

Cuvinte-cheie: *Inovare, metrică, indicatori de ştiinţă şi tehnologie, indicatori compoziți, sistem național de inovare, tabel de scoruri*

JEL Classification: O31, O32, C54

Introduction

Innovation can be defined as the development, deployment and economic utilization of new products, processes and services, and is an increasingly important contributor to sustained and sustainable economic growth, both at micro-economic and macro-economic levels. It enables firms to respond to more sophisticated consumer demand and stay ahead of their competitors, both domestically and internationally, and contributes to the growth of multifactor productivity. Beyond its contribution to economic growth and efficiency, innovation facilitates the fulfillment of other societal needs, such as improved health and environmental protection. Innovation and its diffusion through economies are continuous processes which exert a major influence on growth. Many innovations target the development of new products or different production methods within specific sectors. Other innovations are brought about by the development of new, general-purpose technologies that give rise to changes across a wide range of industries and affect production methods, inter-industry relationships, work organization and skill requirements.

There is a numerous series of academic research and a wealth of grey literature that address the practice of innovation measurement. Cooper & Edgett (2008) (quoted in Adams, Neely, Yaghi, & Bessant, 2008) found that the most popular metrics to gauge the performance of individual new product projects are sales and profit measures: revenue achieved versus forecasted revenue is used the most followed by profitability. The Boston Consulting Group discovered the three metrics that executives consider most valuable are time to market, new product sales, and return on investment in innovation (Boston Consulting Group, 2006).

To the extent that they are guided by a conceptual or theoretical model, **innovation indicators** are generally guided by a stage model of the innovation process and its contribution to economic benefits. Such models postulate at least implicitly: (1) that innovation consists of a series of stages of activity of different kinds – such as basic research, applied research, development, and commercialization – that may lead to economic benefits of different kinds, such as productivity improvements and economic growth and (2) that certain statistics are valid measurements of different stages of the innovation process.

In simple terms, innovation indicators are statistics that describe various aspects of innovation. Individual indicators are generally partial, that is, they do not measure innovation as a whole. Collections of selected indicators are used to measure innovation more broadly. Innovation indicators are often *indirect*, because the underlying phenomenon of interest, innovation, is intangible or not directly observable. While some indicators are *statistics* that are generated specifically for the purpose of measuring an aspect of innovation – such as national statistics on research and development funding and personnel – other widely used indicators are based on existing statistics that are generated for a purpose other than measuring innovation – such as patent statistics that are generated as part of the patent application process to obtain intellectual property protection (Graversen & Siune, 2008).

As stated before, the innovation performance can be measured using a selection of indicators which either directly or indirectly (***'proxies'***) measure innovation. For example, R&D expenditure/personnel, Patents, Publications, Exports, Internet access/use, University students/graduates are ***proxies*** not directly measuring innovation (Hollanders, 2010). Average performance can be captured using composite indicators thereby facilitating the interpretation and visualization of innovation performance. This is convenient under the prudence's assumptions-one has to be aware that we need to look beyond composite indicator scores. All the users of such indicators always need to find explanations for differences in composite indicator scores and composite indicator components.

Multi-dimensions analysis conducted by composite indicators

Composite indicators are generally used to summarize a number of underlying individual indicators or variables. An indicator is a quantitative or qualitative measure derived from a series of observed facts that can reveal relative position in a given area and, when measured over time, can point out the direction of change. Indicator is a metric that provides insight into a specific process's improvement activities concerning a previously stated goal attainment. In the context of policy analysis at national and international levels, indicators are useful in identifying trends in performance and policies and drawing attention to particular issues.

Composite indicators compare and rank countries in areas such as industrial competitiveness, sustainable development, globalisation and innovation and which cannot be subject to an empirical test. Composite indicators are valued for their ability to integrate large amounts of information into easily understood formats for a general audience. However, composite indicators can be misleading, particularly when they are used to rank country performance on complex economic phenomena and even more so when country rankings are compared over time. They have many methodological difficulties which must be confronted and can be easily manipulated to produce desired outcomes.

There are a number of steps to be followed in constructing composite indicators: developing a theoretical framework for the composite, identifying and developing relevant variables; standardising variables to allow comparisons; weighting variables and groups of variables; conducting sensitivity tests on the robustness of aggregated variables.

In the case of comparing the performance of countries on different dimensions, a typical composite indicator will take the form: $I = \sum_{i=1}^{n} w_i \cdot X_i$ where: I is the composite index, X_i is the normalised variable and w_i is the weight of the X_i, under the constraint $\sum_{i=1}^{n} w_i = 1$ and $0 \leq w_i \leq 1$ for $i \in \{1,2,...n\}$ (Nardo, Saisana, Saltelli, Tarantola, Hoffman & Giovannini, 2005).

Variables need to be standardised or normalised before they are aggregated into composite indicators. Variables come in a variety of statistical units and different variable sets have different ranges or scales. Variables need to be put on a common basis to avoid problems in mixing measurement units (*e.g.* number of firms, people, money). They must be adjusted on dimensions such as size/population/income and smoothed through time against cyclical variability. Variables are normalized to avoid having extreme values dominate and also to partially correct for data quality problems. There is reason to believe that values extremely far from the average or normal range are more likely to reflect poor underlying data. If certain variables have highly-skewed distributions, they can be leveled through logarithmic transformations and the data can be truncated if there are extreme outliers.

Distance from the best and worst performers, where positioning is in relation to the global maximum and minimum and the index takes values between 0 (*laggard*) and 1 (*leader*): $\left(\frac{\text{actual value - minimum value}}{\text{maximum value - minimum value}}\right)$.

In practice, it is extremely difficult to integrate individual variables in a manner which accurately reflects economic reality. As a starting point, one need an understanding and a definition of what it is that is being measured. A theoretical framework is needed to combine individual indicators into a meaningful composite and to provide a basis for the selection of components and weights in the formula above. Ideally, this framework will allow variables to be selected, combined and weighted in a manner, which reflects the dimensions or structure of the phenomena being measured. The variables selected should carry relevant information about the core components and be based on a paradigm concerning the behavior being analyzed. It is this framework, which indicates which variables to include, and how to weight them to reflect their relative importance in the overall composite. But as yet, the theoretical underpinning of most composite indicators is very underdeveloped.

In Grupp and Schuberta (2010) it is shown that the existing and well accepted methods, like equal weighting, Benefit of the Doubt weighting (BoD) and principal component analysis weighting (PCA) may lead to drastically differing results. Especially, weights should be carefully chosen on the basis of shadow prices, rather than, using equal weighting or automatic methods.

In the utilitarian prospective, the composite indicators set benchmarks, which both inform a wider (than scientific) public about the position of a country and they also reward successes in measured changes with respect to this position. Unfortunately, composite indicators are frequently used also for the actual design of policy measures, even though, in '*aggregating away*' the reasons for the observed performance-level, they do not say much about ways to improve. Thus without a proper information basis, the composite indicator rankings alone tend to result in mere politicking, where measures are taken on an ad hoc basis without analysing the problem. In a relative conclusion, many authors in the literature recognize the merit of the composite indicators, stating that they have a valuable communication and competition function, but they should be accompanied by multidimensional representations, which provide the basis for the construction of policy measures.

Knowledge Assessment Methodology

The World Bank Institute's Knowledge for Development Program has developed a **Knowledge Assessment methodology** (KAM) as a tool for benchmarking a country's position vis-a-vis others in the global knowledge economy (http://web.worldbank.org). The KAM Web-based tool on country knowledge assessments is a user-friendly tool designed to assist client countries to understand their strengths and weaknesses in terms of their ability to compete in the global knowledge economy. The KAM is designed to proxy a country's preparedness to compete in the knowledge economy through a series of relevant and widely available measures that benchmark how an economy compares with other countries. This simple benchmarking tool is a first step in helping to identify the **problems** and **opportunities** that a particular country faces in the four pillars of the knowledge economy, and where it may need to focus policy attention or future investments. The KAM consists of 109 structural variables (quantitative and qualitative) for 146 countries to measure their performance on the four Knowledge Economy (**KE**) pillars: Economic Incentive and Institutional Regime, Education, Innovation, Information and Communications Technologies. Variables are normalized on a scale of 0 to 10 relative to other countries in the comparison group. The arguments for including all these aspects in the four pillars are that:

- **An** ***economic and institutional regime*** provides incentives for the efficient use of existing and new knowledge and the flourishing of entrepreneurship;
- **An** ***educated and skilled population*** can create, share, and use knowledge well;

- **A** ***dynamic information infrastructure*** can facilitate the effective communication, dissemination, and processing of information;
- **An** ***efficient innovation system*** of firms, research centers, universities, consultants and other organizations that can tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new technology.

Knowledge Index (KI) is the simple average of the normalized country scores on the key variables in three pillars – education, innovation and ICT. **Knowledge Economy Index (KEI)** measures performance on all four previously presented pillars.

The evaluation for KAM Innovation - Romania 2009

Table 1

Innovation System	Romania	
	actual	normalized
FDI Outflows as % of GDP, 2003-07	0.09	3.23
FDI Inflows as % of GDP, 2003-07	6.82	7.94
Royalty and License Fees Payments (US$ mil.), 2007	242.00	6.38
Royalty and License Fees Payments (US$/pop.), 2007	11.23	5.78
Royalty and License Fees Receipts (US$ mil.), 2007	41.00	6.18
Royalty and License Fees Receipts (US$/pop.), 2007	1.90	6.00
Royalty Payments and receipts(US$mil.), 2007	283.00	6.39
Royalty Payments and receipts(US$/pop.) 2007	13.13	5.71
Science and Engineering Enrolment Ratio (%), 2007	22.91	5.50
Science Enrolment Ratio (%), 2007	4.68	1.30
Researchers in R&D, 2006	20,506.00	6.67
Researchers in R&D / Mil. People, 2006	952.36	5.15
Total Expenditure for R&D as % of GDP, 2006	0.46	4.51
Manuf. Trade as % of GDP, 2007	51.83	6.72
University-Company Research Collaboration (1-7), 2008	3.10	4.72
S&E Journal Articles, 2005	887.26	6.94
S&E Journal Articles / Mil. People, 2005	41.01	5.90
Availability of Venture Capital (1-7), 2008	3.00	5.28
Patents Granted by USPTO, avg 2003-2007	8.80	6.58
Patents Granted by USPTO / Mil. People, avg 2003-2007	0.41	5.62
High-Tech Exports as % of Manuf. Exports, 2007	4.00	4.20
Private Sector Spending on R&D (1-7), 2008	3.00	4.80
Firm-Level Technology Absorption (1-7), 2008	4.40	3.60
Value Chain Presence (1-7), 2008	3.80	5.68
Capital goods gross imports(US$ mil), 2003-07	12,272.17	6.83
Capital goods gross exports (US$ mil), 2003-07	0.38	0.08
S&E articles with foreign coauthorship (%), 2005	67.80	5.52
Avg number of citations per S&E article, 2005	0.87	1.61

The most-powerful aggregation level based on several dimension is done in a so-called "***spider***" diagram which brings indexed indicator scores from one or various countries into one picture.

The data for Romania in 2009 (the latest up-dating for statistical database) brings the following representations (Figure 1, 2 and 3 ant Table 1, 2, 3 and 4).

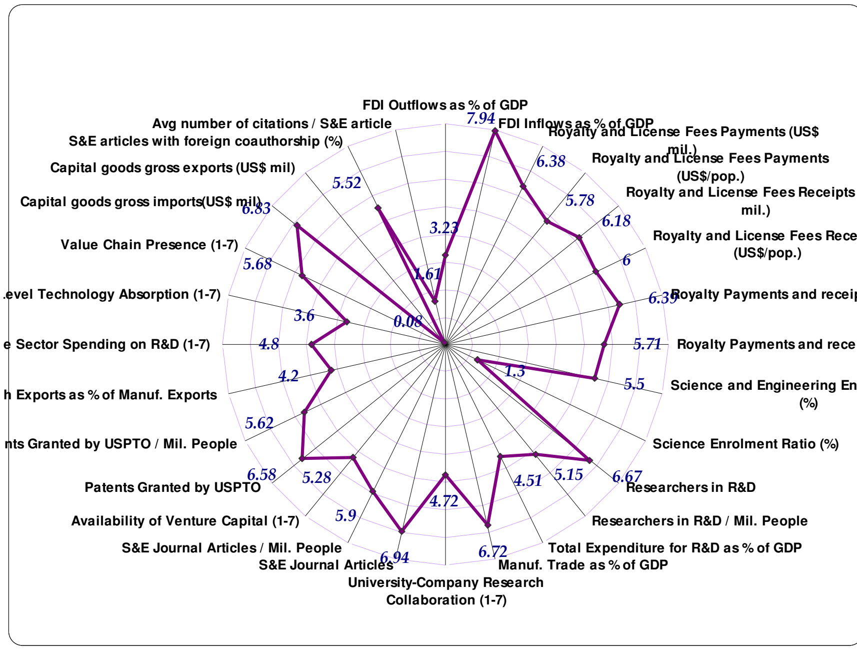

Figure 1. The "spider" representation of Romania KAM - Innovation 2009

The evaluation for KAM Education - Romania 2009

Table 2

Education	Romania	
	actual	normalized
Adult Literacy Rate (% age 15 and above), 2007	97.60	6.58
Average Years of Schooling, 2000	9.51	8.61
Gross Secondary Enrollment rate, 2007	85.87	5.07
Gross Tertiary Enrollment rate, 2007	58.26	7.75
Life Expectancy at Birth, 2007	73.00	6.04
Internet Access in Schools (1-7), 2008	4.00	6.32
Public Spending on Education as % of GDP, 2007	3.00	2.64
4th Grade Achievement in Math(TIMSS), 2007	n/a	n/a
4th Grade Achievement in Science(TIMSS), 2007	n/a	n/a
8th Grade Achievement in Math(TIMSS), 2007	461.00	4.78

Education	Romania	
	actual	normalized
8th Grade Achievement in Science(TIMSS), 2007	462.00	4.35
Quality of Science and Math Education (1-7), 2008	5.10	8.64
Quality of Management Schools (1-7), 2008	3.80	4.00
15-year-olds' math literacy (PISA), 2006	415.00	2.22
15-year-olds' science literacy (PISA), 2006	418.00	1.85

The evaluation for KAM Labour - Romania 2009

Table 3

Labor	Romania	
	actual	normalized
Unemployment Rate (% of labor force), 2007	6.00	5.74
Employment in Industry (%), 2005	30.00	8.80
Employment in Services (%), 2005	38.00	1.50
Prof. and Tech. Workers as % of Labor Force, 2007	18.53	4.57
Extent of Staff Training (1-7), 2008	4.10	6.00
Brain Drain (1-7), 2008	2.60	2.56
Cooperation in labor-employer relations(1-7), 2008	3.70	1.36
Flexibility of wage determination(1-7), 2008	4.90	4.16
Pay and productivity(1-7), 2008	4.20	5.20
Reliance on professional management(1-7), 2008	4.50	4.48
Local availability of specialized research and training services (1-7), 2008	4.00	5.36
Difficulty of Hiring Index, 2009	67.00	1.50
Rigidity of Hours Index,2009	80.00	0.57
Difficulty of Firing Index,2009	40.00	4.57
Firing costs (weeks of wages), 2009	8.00	9.20
Labor tax and contributions (%), 2009	35.50	1.00
Employment to population ratio, 15+ (%), 2007	50.00	1.97
Employment to population ratio, ages 15-24(%), 2007	24.00	1.20
Share of unemployment with tertiary education , 2007	6.00	1.61
Share of unemployment with secondary education, 2007	66.00	9.14
Labor force participation rate, 2007	61.00	1.97
Labor force with tertiary education (% of total), 2005	12.00	1.52
Labor force with secondary education (% of total), 2005	62.00	8.62
Firms offering formal training (% of firms), 2007	33.00	4.40

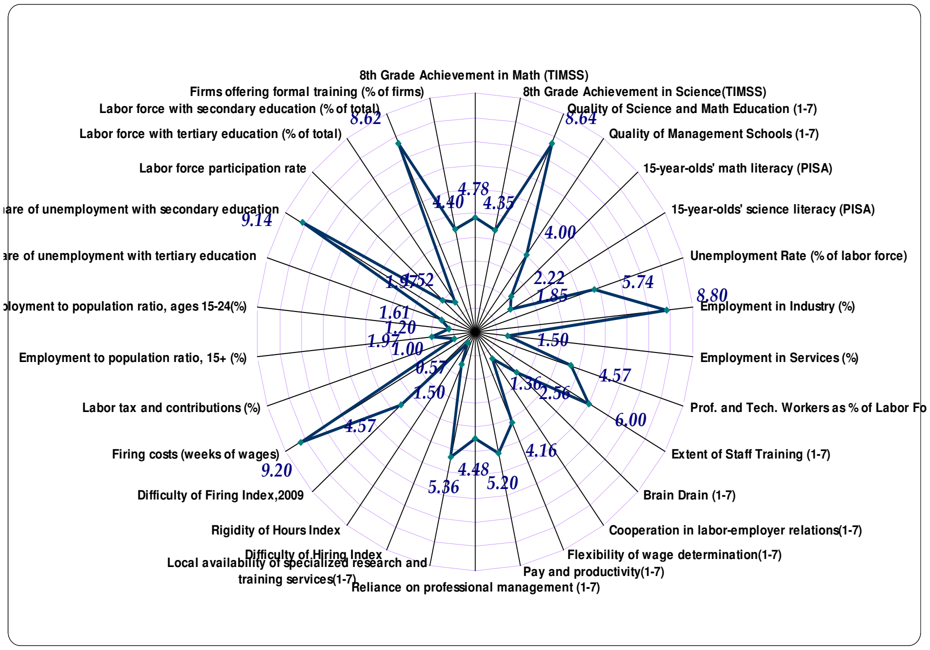

Figure 2. The "spider" representation of Romania Education and Labour 2009

The evaluation for KAM ITC - Romania 2009

Table 4

ICT	Romania	
	actual	normalized
Total Telephones per 1000 People, 2007	1,260.00	6.78
Main Telephone Lines per 1000 People, 2007	200.00	5.52
Mobile Phones per 1000 People, 2007	1,060.00	7.47
Computers per 1000 People, 2007	190.00	7.18
Households with Television (%), 2006	90.00	5.79
Daily Newspapers per 1,000 People, 2004	70.00	4.55
International Internet Bandwidth (bits per person), 2007	2,945.00	7.31
Internet Users per 1000 People, 2007	240.00	5.68
Price Basket for Internet (US$ per month), 2006	16.96	5.52
Availability of e-Government Services (1-7), 2008	3.16	3.36
Extent of Business Internet Use (1-7), 2006	3.40	3.56
ICT Expenditure as % of GDP, 2007"	5.00	3.20

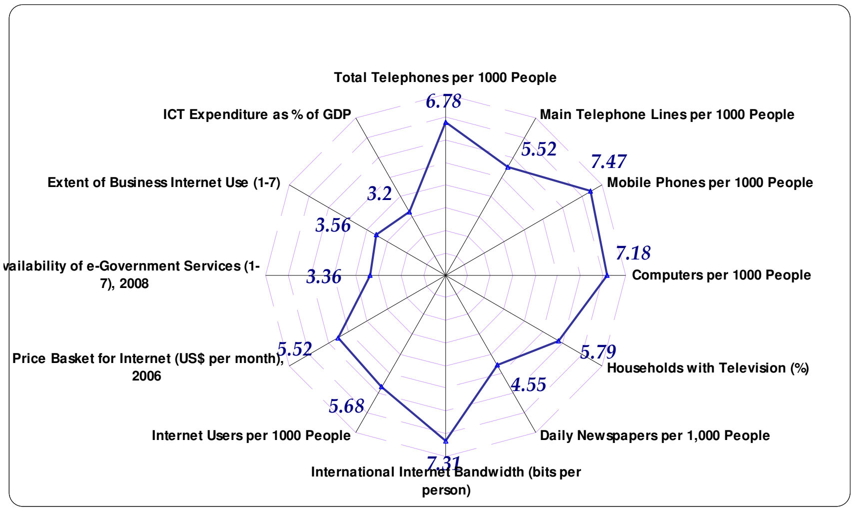

Figure 3. The "spider" representation of Romania ICT 2009

Conclusions

It is very clear that innovation consists of a set of complex and qualitative interrelations meaning that it cannot be 'measured' in a simple way within an innovative national environment.

Innovation today is inherently complex and dynamic, requiring alignment across the organization. Efforts to implement a systemic innovative capability must compete for "*disseminate* or *share of mind*" with continuing pressures for top – ranked performance: lower costs, higher quality, and improved customer service. More than any other single tool available to managers, well-applied metrics can cut through the impreciseness and, very clearly, signal to the organization a desired direction and strategic priorities.

Metrics can drive change throughout an organization - and specifically boost innovation capability - by: signaling strategic intent and providing incentives to align activity with the organization's goals; monitoring progress and guiding corrective action; allowing the evaluation of people, objectives, programs, and projects to optimize resource allocation.

Rather than using a disaggregated menu of individual indicators, aggregated composites supposedly allow for analysis of interrelated performance or policy areas. They are popular in benchmarking exercises where countries wish to measure their performance relative to other countries and identify general areas where national performance is below expectations. Benchmarking with the aid of composites is often used to identify general trends, determine performance targets and set policy priorities.

It is critical to create methods to gauge innovation performance - while also providing live guidance to help the organization build its capacity to innovate systemically.

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