



Workpackage 8
An Overview of the KEI
Achievements

Deliverable 8.2

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CIS8-CT-2004-502529 KEI

The project is supported by European Commission by funding from the Sixth Framework Programme for Research.

http://europa.eu.int/comm/research/index_en.cfm

http://europa.eu.int/comm/research/fp6/ssp/kei_en.htm

http://www.cordis.lu/citizens/kick_off3.htm

<http://kei.publicstatistics.net/>



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Chapter 1

Introduction

In the context of the Sixth Framework Programme of the European Commission the project KEI (Knowledge Economy Indicators: Development of Innovative and Reliable Indicator Systems) started on September 2004. The KEI project was part of priority 8 of the policy orientated research under the Framework Programme.

The project's aim was to develop and improve indicators for the knowledge economy, including the analysis of aggregation issues and the use of composite indicators. The project has covered indicators from 25 European countries (the EU-25) and two non-European countries (the US and Japan).

The KEI project has reviewed existing concepts and definitions of the knowledge-based economy and its key components. Further, it has developed main thematic areas in relation to the Lisbon and Barcelona objectives. KEI has then used these themes to classify existing indicators and thoroughly explore data and indicator quality issues. Gaps have been identified and the way forward has been mapped, identifying innovative approaches to improve our understanding and appraisal of the knowledge economy.

Composite indicators have been analysed in detail using both statistical and participatory approaches, including the use of multi-criteria methods, aggregation and weighting techniques, decomposition methods, and an evaluation of analytical and presentational techniques. Simulation methods have been employed extensively to investigate the robustness of indicators and the conclusions based on them. The study has evaluated the quality and accuracy of indicators and the underlying data and has assessed the innovative use of additional information to improve indicator quality.

The state-of-the-art analysis, as provided by KEI for the knowledge-based economy, will benefit other policy objectives of the European Union and Commission Services. It will contribute to a methodological framework for building effective measurements of interdisciplinary issues such as sustainability, employment, social cohesion, and economic disparities. KEI will also make recommendations for the design and use of statistical reference systems.

The following chapters will give an overview of the achievements of the KEI project. The main focus is laid on the knowledge economy composite indicator which is based on a large dataset developed in workpackage 2. Due to a large amount of missing values,

this dataset was imputed using a multiple imputation approach which was developed under workpackage 3. Finally it was used in workpackages 5 and 7 and especially for the Knowledge Economy composite indicator to which an overview is given in Chapter 6. In addition to this report, an overview to the political impact of the project is depicted within deliverable 8.1.

Chapter 2

Knowledge Economy Indicators

2.1 Defining the Knowledge-Based Economy

Workpackage 1 (WP1), defining the knowledge-based economy, identified potential indicators for measuring the drivers, characteristics and key outputs of a knowledge based economy (KBE). Building on the literature, KBE indicators are classified into five main groups: 1) ICT investment and use, 2) human resources, 3) knowledge production, 4) entrepreneurship and creative destruction, and 5) structural and organisational change. In addition, the project identified two main groups of performance measures: 1) economic growth and productivity and 2) social impacts.

In most research, ICT is seen as a principal driver of a techno-economic shift towards a KBE. This occurs not through the ICT hardware sector but through the application of ICT across all economic sectors, including the public sector. Human resources and skills have long been recognised as essential, but current approaches based on occupation or formal educational attainment are inadequate for capturing abilities. Knowledge production is essential, but it is insufficient unless several types of knowledge, including entrepreneurial skills, are developed so that individuals and firms are capable of applying knowledge in an economically useful way. Organisational change in workplace systems, business practices and networking can be as important as technical knowledge in improving productivity. WP1 discusses the need to develop these indicators not only for the business sector, but also for the public sector and the volunteer non-profit sector.

The key economic measures are economic growth and productivity, which are identified in most of the literature on a KBE, but social impacts are of growing importance to policy. These include the impacts of shifts in the knowledge intensity of economies on income dispersion, happiness, social cohesion, equality, and the environment.

The development of a statistical system for the KBE needs to be relevant to major trends that will influence policy needs over the future. WP1 identifies five main challenges: 1) global production chains, 2) the changing environment for innovation strategies, such as increasing research activity in China and India, 3) demographic change and its effect on demand for innovative products and conflicts over resources, 4) the supply of human capital and 5) technology shifts.

Three scenarios are developed that focus on three of these five future economic challenges: the supply of researchers in Europe, demand for innovation, and technology shifts. The purpose of the scenarios is to identify key indicators for tracking developments over time that will be of value for policy.

The scenario for innovation demand identifies 18 key indicators, of which 13 can be constructed from currently available data. Examples include the intensity of local competition, buyer sophistication, the youth share of the population, the breadth of foreign markets, and government procurement policy. The disadvantage of many of the available indicators is that most of them are based on the subjective opinions of firm managers.

The scenario for the supply of human capital evaluated over 100 indicators and identified eight key indicators for tracking the ability of the EU to increase the supply of scientists and engineers to meet the 3% R&D target. Five indicators determine 90% of the supply of scientists and engineers in a series of simulations: actual average retirement ages of scientists and engineers, the proportion of students choosing science and engineering studies, the proportion of science and engineering graduates that are employed in research occupations, in-migration of scientists and engineers, and the proportion of women studying science and engineering.

The third scenario evaluated eco-innovation, which provides an example of both a potential technology shift and is directly relevant to the environmental aspect of social outcomes. Forty-five potential indicators were investigated and assigned to five main types: indicators of social or policy pressure for environmental innovation, facilitators (organisational or management changes), inputs (R&D or investment in eco-innovation), outputs (sales or trade in innovative products), and measures of environmental effects. A major problem is that many of the 14 key available indicators concern the Environmental Goods and Services Sectors (EGSS), which misses eco-innovation activities in many other services and manufacturing sectors.

The final section of this WP evaluated policies for a KBE. Original results were obtained from interviews with 40 policy analysts to assess policy and user needs for KBE indicators and to identify new and improved indicators for emerging policy challenges. The interview results showed that the main drawback with currently available indicators concerned timeliness (indicators were often several years out of date), a lack of data at the sector level, and poor international comparability. The interviews identified several areas where policy analysts would like new indicators: flow of innovations, including diffusion, economic impacts, collaboration, social impacts and the role of consumers (innovation demand).

2.2 Indicators for the KBE

Workpackage 2, indicators for the KBE, constructs a database of current indicators of the five main characteristics of a KBE plus the two types of performance outcomes. The purpose of the database is to provide a source of statistics for the methodological research on constructing composite indicators for a KBE. This required each indicator to be available for the majority of EU countries. Consequently, the database is very conservative, with few subjective indicators (other than those drawn from the Community Innovation Survey) or experimental indicators that are only available for a single year or for a few

countries. Conversely, there are many 'traditional' indicators based on patents (7 indicators) or drawn from the R&D family of indicators (11 indicators). The economic output indicators include GDP (two indicators), productivity (two indicators), and employment (two indicators). Largely due to data availability issues, the database is not able to capture many of the recommendations for KBE indicators covered in WP1. This highlights the need for further work to expand the quality and national coverage of KBE indicators. There is also a pressing need to develop both current and new indicators at the sector level.

2.3 The Way Forward: Innovative Use of KBE Indicators

Workpackage 4, the way forward, focuses on identifying the 'gaps' in indicators for a knowledge economy and developing proposals for how these gaps could be filled. As a first step, WP4 develops a framework for identifying incomplete, unsatisfactory, and missing indicators.

Incomplete indicators are only available for a few target countries or only for one year, making it impossible to evaluate trends over time. However, they present few conceptual problems because the indicators have usually been thoroughly tested in other countries or during one year. Examples include the R&D spending of affiliates as a percent of total BERD, or data on the inflow of knowledge workers.

Unsatisfactory indicators address a characteristic, driver or outcome of the KBE, but are either proxies for the underlying phenomena that we would like to observe or the available data do not cover important aspects of the phenomenon. Examples include the diffusion of productivity enhancing technology or the commercialisation of public research.

Missing indicators simply do not exist, nor are there available proxies. There are two areas where there is an almost total lack of indicators: entrepreneurship and creative destruction and the social impacts of a KBE. A third area of organisational innovation was identified at the start of the KEI project, but since then questions on organisational innovation have been added to the CIS.

As a second step, WP4 examines each of the five main characteristics of a KBE plus the economic and social impacts and identifies insufficient and missing indicators. The third step is developing solutions to missing indicators. Instead of providing an overview of this problem, four areas are evaluated in depth: human resources, organisational innovation, knowledge transfer between the public research sector and firms, and better indicators for how firms innovate. The in-depth research looks at three options for improved indicators: linking data in order to obtain new insights, creating entirely new indicators, and creating new indicators by imaginative ways of analysing existing data.

Two examples of the benefits of data linking are provided. The first example links R&D data at the sector level with the number of PhDs in science and technology working in specific sectors. The results show that technological output depends, across all sectors, on both PhDs and R&D expenditures. The conclusion is that lower level training (Masters or engineers) is not adequate to reap the full benefits of R&D expenditures. The second study

links data on work organisation with how firms innovate and finds a positive relationship between the level of responsibility given to workers and innovative capabilities¹.

The third in-depth study shows how new comparable indicators of knowledge transfer could be created for Europe by a relatively low cost survey of Technology Transfer Offices (TTOs)². This work has since been taken up by an expert group struck by DG Research to construct a database containing seven knowledge transfer indicators using TTO surveys.

The fourth in-depth study³ shows how CIS data could be used to create indicators for how firms innovate. The goal is to meet a major policy need for better indicators for firms that innovate without performing R&D (approximately half of all innovative firms within the EU). The study proposes six new indicators. This work has been included in an OECD project on developing new CIS indicators.

¹Arundel A, Lorenz E, Lundvall B-A, Valeyre, A. How Europe's economies learn: a comparison of work organization and innovation mode for the EU-15, *Industrial and Corporate Change*, 16:1175-1210, 2007.

²Arundel A, Bordoy C. Developing internationally comparable indicators for the commercialization of publicly-funded research, MERIT, University of Maastricht, 2008.

³Arundel A. Innovation survey indicators: What impact on innovation policy? *In Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*. OECD, Paris, pp 49-64, 2007.

Chapter 3

Role of Multinational Enterprises for Information on R&D

3.1 Introduction

This chapter describes the results of work within KEI WP6. Globalisation of R&D is a phenomenon attending more and more policy interest in these days. Indicators on globalisation of R&D exist in some countries, but mainly as results from ad hoc studies in deliverable 6.1.

The aim of the work has been to develop and test new indicators on the role of multinational companies for R&D. The main research topic, however, has been to develop and improve relevant indicators on outward R&D (R&D in foreign affiliates of domestic companies) and inward R&D (R&D in affiliates of foreign companies), which could be produced on a regular level at a relatively low cost.

We start with a discussion of the policy context and user needs for development of indicators on the globalisation of R&D. Various available methodological options for how to go further are discussed next. The focus is on the measurement of outward R&D where the gaps are the biggest. Several survey approaches are discussed as well as matching data from R&D surveys and company records. In the conclusions some ideas are presented for ways to go further in the development of indicators on R&D globalisation.

3.2 Policy issues and measurement needs

The policy measures with respect to R&D globalisation could be divided into three groups

- policies towards attracting R&D units from abroad
- government measures to link domestic firms to knowledge from abroad
- policies towards the mobility of human resources

Policies of attracting R&D units from abroad relate to measures aimed at strengthening the scientific and technological capabilities of a country and non-discrimination of foreign firms compared with domestic enterprises. Technology programs in a country may serve as platforms for attracting international experts and foreign firms.

Measures to link domestic firms to knowledge from abroad may include financial support for R&D abroad. Up to now this has been used rather seldom. Various measures of promoting international and national networking are more common as well as giving services for establishing international contacts.

There are a lot of policies aiming at stimulating import of foreign talent. These relate to releasing barriers to immigration, income taxation, accreditation of foreign qualification, improving legislation on S&T and lessening cultural and structural barriers.

To monitor progress in these policy fields several indicators; both traditional as well as new ones especially focused on globalisation issues are needed. Indicators of relevance for monitoring these policy fields are among others general statistics on foreign direct investments, indicators on the qualification structure of the population and the mobility of qualified personnel. The basic questions on which countries are net recipient countries of foreign R&D and which countries are net sources of foreign R&D are not enough illuminated by statistics and most of this report is devoted to a discussion of the possibilities on improving indicators on these issues.

3.3 Methodological issues

In this section we go deeper into various methodological issues. Existing R&D statistics according to the Frascati Manual relates to activities of units within national boundaries. Therefore the possibilities of ordinary R&D statistics to describe the process of R&D globalisation are rather limited but there are variables shedding some light on R&D globalisation.

Inward R&D investments consist of R&D activities by affiliates of foreign companies in reporting countries (the ultimate beneficiary owner is foreign). These can be created from nothing as green field investments or obtained through acquisition of an existing company or relocation of an existing R&D unit abroad. The most common indicator is perhaps R&D expenditures but also R&D personnel or number of researchers could be used. These indicators can be derived from existing R&D statistics if combined with information on which firm is foreign owned. This can be taken from various registers.

These registers could be of various kind:

- the usual official business register of the country (if the information on foreign ownership is included)
- special registers on foreign affiliates

R&D surveys or innovation surveys having the information on foreign ownership may also be used as sources.

Outward R&D investment means R&D activities by affiliates of national companies abroad (the ultimate beneficiary owner is from the reporting country). Also these can be created from nothing or obtained through acquisition of an existing company or relocation of an existing R&D unit in the country to a location abroad.

In principle there are two different approaches for the measurement of outward R&D. It is possible to get the information from various kinds of surveys but it is also possible to make estimations on the basis of comparisons of global figures from company accounts and figures on the national level based on surveys.

Basically there are four different kinds of survey approaches:

- (i) One option is including one or two questions on R&D in regular R&D surveys.
- (ii) Detailed special surveys inquire data on the level of the foreign subsidiary or at least by country.
- (iii) An alternative to the previous approach is a small survey directed to only big companies with just a few questions on R&D abroad by country. This approach has been tested within the work package.
- (iv) R&D could be included as a variable in general surveys of foreign direct investments.

If sufficient resources are available to investigate outward R&D, option (ii) seems to be the best one as it is widest in details. If a more limited amount of resources is available, options (iii) and (iv) might be good alternatives taking into account the results of the testing described in the following chapter.

The EU R&D Industrial Investment Scoreboards include annual information on R&D financing on the group level. The use for the purpose of measuring outward R&D is focused on the lists by country of the biggest R&D performing companies in EU with information on their global R&D investments taken mainly from annual reports. Information on total funding of R&D (intramural R&D + extramural R&D – external funding of R&D) from the R&D survey can be matched with the global amount of R&D expressed in the scoreboard. The difference gives an indication of R&D financing of the company not directly attributable to the national part of the company reporting in the national R&D survey.

3.4 Collecting data on R&D globalisation

Statistics Finland undertook a survey within deliverable 6.2 on R&D globalisation in the major Finnish corporations in order to test its feasibility as a source of information and to obtain new figures on the extent of outward R&D. R&D expenditure and personnel data was completed by further information on motives for conducting R&D overseas. Additionally, questions concerning problems, reliability, easiness and confidentiality related to the given information were requested. Another essential thing in focus was the motives for conducting research and development abroad. Respondents were asked to estimate a

general view on the importance of different reasons in conducting R&D activities in the host countries.

Overall, the survey can be considered rather straightforward from companies' point of view, since only a couple of them specified problems in providing the R&D data. Confidentiality of the data and response burden may sometimes set a limit in replying. Difficulties in breaking down R&D resources between various countries can be difficult, because companies' monitoring is often based on business units instead of geographical regions. A key to locate R&D expenditure between these sub-units around the world is sometimes simply missing. Problems involved in reporting came up in a few answers. One corporation gave only numbers for R&D personnel divided by country of location and another company only the distribution of R&D expenditures, respectively.

Along with the objective to test the feasibility of the survey as a source of data and to produce some real estimations on outward R&D, another aim in our exercise was to match external sources on multinationals' global R&D with the national R&D survey data. Therefore the target was to find out and describe the usefulness of the EU R&D Scoreboard as an alternative way of providing data on R&D globalisation.

3.5 Conclusions and recommendations

The results given in deliverable 6.3 of the piloting exercises explained above show that it is possible to improve the information on globalisation of R&D by integrating the aspect of measuring outward R&D in several ways to existing statistics. A lot of experience is already available in countries and it is now an issue on further harmonisation of the data.

It is possible to develop a simple survey instrument to be used in connection with the R&D survey to collect information on outward R&D. Maybe it could also be possible to only add some questions on outward R&D in existing R&D surveys. This can be done for both R&D expenditures and personnel. Some details about country or country group breakdowns and some simple questions on reasons for having R&D abroad could also be included.

A matching between the company data of the EU R&D Investment Scoreboard and the corresponding company data from the R&D surveys is also feasible and can be done with rather limited resources (a few days work). This does not give the same result as the survey, but gives indication of the order of magnitude. Only outward R&D expenditures can be estimated in that way. Neither breakdown by country or motives for globalisation is possible to be evaluated.

Both for information on outward and inward R&D, it is very important to ensure the quality of the information on ownership. Multiple sources for information on the UBO ownership including special questions in surveys could be used to check the information.

As the activities of the multinational companies are becoming more and more global and a split of activities between various countries will be more and more difficult, perhaps in the future data collection on R&D and other variables will be on the group level, and less on the enterprise level, which is now the standard practise. Some exploratory work

in that direction has already started in a joint ECE, OECD and EU project lead by Statistics Canada. The EU plans to establish a register over enterprise groups in EU also contributes to this.

Indicators on the globalisation of R&D is a new field, which need development within the next years. It is important to know how globalisation is influencing our knowledge based economies. Work package 6 has contributed to a kick off of discussions both within EU and the OECD on how these indicators can be developed in the future.

Chapter 4

Statistical Analysis of KBE Indicators

Workpackage 3, statistical analysis of KBE indicators, focuses on three aspects for indicator methodology. The first deliverable contains data quality concepts and the code of practice. Some follow-up report, data quality for knowledge economy indicators, is covered within the deliverable 3.3. Deliverable 3.4 deals with special estimation methods and accuracy measurement for composite indicators. Finally, one special problem of data quality, missing values and their treatment is discussed in deliverable 3.2. The main emphasis is put on proper inferences from the imputation process of missing values via multiple imputation.

4.1 Quality Concepts and Quality of Indicators

When using data, e.g. for economic and policy recommendations, adequate data from reliable sources should be used. In general, the whole data production process has to be considered or should at least meet the requirements of a sound methodology. In order to facilitate appropriate data dissemination and use, many different institutions have developed specific quality reporting recommendations.

Deliverable 3.1 gives an overview of several important developments of quality reporting in recent years. First, after giving a short introduction to metadata and data quality reports in general as well as on quality management, recommendations of the Leadership Expert Group in Statistics, led by Lars Lyberg, Statistics Sweden, and the Commission of the European Communities are presented. The main emphasis is put on the presentation of the different data quality concepts from selected institutions:

International Organizations

- Eurostat
- International Monetary Fund (IMF)
- Organisation for Economic Co-operation and Development (OECD)

National Statistical institutes

- Office for national Statistics (ONS)
- Statistics Canada
- Statistics Finland
- Statistics Sweden
- U.S. Bureau of the Census

The importance of this topic can be drawn from the fact, that rapid improvements currently take place. These improvements cover the basics but especially also the implementation of quality reporting.

As a follow-up of the general quality framework, deliverable 3.3 focuses on specific recommendations for knowledge economy indicators as well as of corresponding composite indicators. The major difficulty for knowledge economy indicators follows from the fact that data are drawn from many different sources such as sample surveys conducted in different years and time periods or national accounts. Further, the concepts of data gathering and processing are highly different between the countries. When communicating comparisons of regions with the help of indicators or development of indicators in certain regions, many diverse aspects of data quality have to be considered.

Within this deliverable, special aspects of data quality for indicators are depicted. These cover the different sources of the knowledge economy data on the one hand, their usage and applications to composite indicators, on the other hand. The KEI dataset, developed within WP2, was building the base for gathering quality information. The information of interest covered many different data sources from all relevant countries. Finally it turned out, that the availability of necessary quality indicators in practice and the theoretical requirements are still different. For an end-user it was still difficult to access detailed country specific information, although comparative information should already be available. The above mentioned developments will surely help to provide the necessary information in order to facilitate the process to more comparative studies at least within the ESS.

4.2 Accuracy Measurement of Composite Indicators

One important goal in statistics is surely the accuracy of information, especially in the context of sample surveys. Following the general quality reports within deliverables 3.1 and 3.3, little information on accuracy is available for the different indicators in general as well as in detail for the different countries and indicator variables.

Within the deliverable 3.4, the question arose whether detailed accuracy information for all indicator variables and countries would enable to report the accuracy of composite indicators. In order to elaborate this research task, a specific less sophisticated micro dataset was used within a simulation study. It turned out that even in simple cases, the lack of covariance information yields a severely biased estimation of the overall accuracy of composite indicators.

4.3 Treatment of Missing Values

The major problem when dealing with indicators on an aggregate level is the fact that especially in the context of longitudinal studies many missing values impede a proper economic analysis. Hence, adequate compensation methods which overcome the missingness have to be applied. In general, simple or even heuristic methods such as last value carried forward are applied for simplicity reasons. However, these methods do not consider the data structure and possible interdependencies between the variables or the more sophisticated dependency over time. Therefore, it seems more convenient and appropriate to apply the so-called imputation methods. With the help of statistical and numerical rules, missing values are filled in with the most *sensible* values. The term sensible certainly covers many facets such as possible values and values which fulfil statistical properties.

In order to account for the structure of the data on the one hand, as well as of the inference coming from the imputation process on the other hand, a multiple imputation method is proposed in deliverable 3.2. The deliverable gives a thorough overview to multiple imputation focusing on the KEI dataset from WP2. The multiply imputed dataset facilitates the sensitivity analysis with respect to missing values performed on composite indicators as shown in Chapter 6.

Chapter 5

The Benefit-of-the-Doubt Approach

One of purposes of KEI's WP 5 was described as the 'construction and testing of new composite indicators', where 'additional methods of aggregation will be applied following recent critiques of the existing aggregation procedures.' The development and further refinement of the 'benefit of the doubt' (BoD) -methodology (on which, see e.g. deliverables 5.1 and 5.3) can be seen as a direct contribution to this particular aspect of the KEI-project. The essence of Bod is the selection of (partially) endogenous weights to be used in the aggregation of sub-indicators, in circumstances where information about the true weights is lacking, or, conceivably more realistic, where experts agree only to a limited degree on the possible values that such weights may take. BoD should not be mistaken for a technique that renders each country a benchmark performer per definition. On the contrary, for units (such as countries) that are demonstrably outperformed when their most favourable weighting scheme is applied to another unit's sub-indicator values, discussions can no longer center around an ad hoc choice of weights. Thus, the focus shifts from 'methodological' to arguably more relevant 'data-oriented' discussions. Recognizing that composite indicators are often used to summarize the results of national policies, the core idea that one size need not fit all, even in the field of composite indicator construction, is evidently reminiscent of the subsidiarity principle.

During the KEI program, the work has been extended to cope with intertemporal analysis (recognizing that an adequate measurement of performance changes requires taking stock of both changes relative to benchmark countries as well as changes within these benchmarks), and with missing data. In the latter case, the inspiration for a satisfactory solution was directly driven by the work undertaken in WP 4. Conversely, the Bod was one of the methodologies that was used in the sensitivity analysis of the composite indicator for the knowledge based economy (see chapter 6 of this deliverable). Next to its instrumental value within the KEI program, one major purpose of this particular workpackage has been the dissemination of methodological advances to the scientific community. This objective has been achieved, as witnessed by the articles that appeared in scientific journals.

Chapter 6

The Knowledge Economy Composite Indicator

In the KEI conceptual framework of the knowledge economy, a total of 115 individual indicators have been selected to measure the sub-dimensions of the KBE. The number of indicators per sub-dimensions varies between 1 and 12. The high number of individual indicators raises the issue of robustness of the ranking obtained by their aggregation into one composite measure. To tackle this issue a sensitivity analysis is a fundamental step of the KEI composite indicator. In particular, in building the KEI composite an innovative methodological assumption has been made, i.e. it is considered as the final composite index the frequency of all rankings obtained by means of all the simulations carried out. This allows us to deal with the criticism, often made to composite indicators that rankings are presented as they were under conditions of certainty while it is well known that this is not true in general terms. Most practitioners compute a composite indicator by a simple weighted summation mathematical model. Sometimes it is acknowledged that the ranking obtained is subject to some uncertainty, but this issue is treated as a kind of mathematical appendix for technical readers, and all policy suggestions are derived under the assumption of the linear aggregation model. Here the ranking presented is the one derived by considering the whole spectrum of uncertainty. It is important to note that this is a peculiar characteristic of the KEI composite.

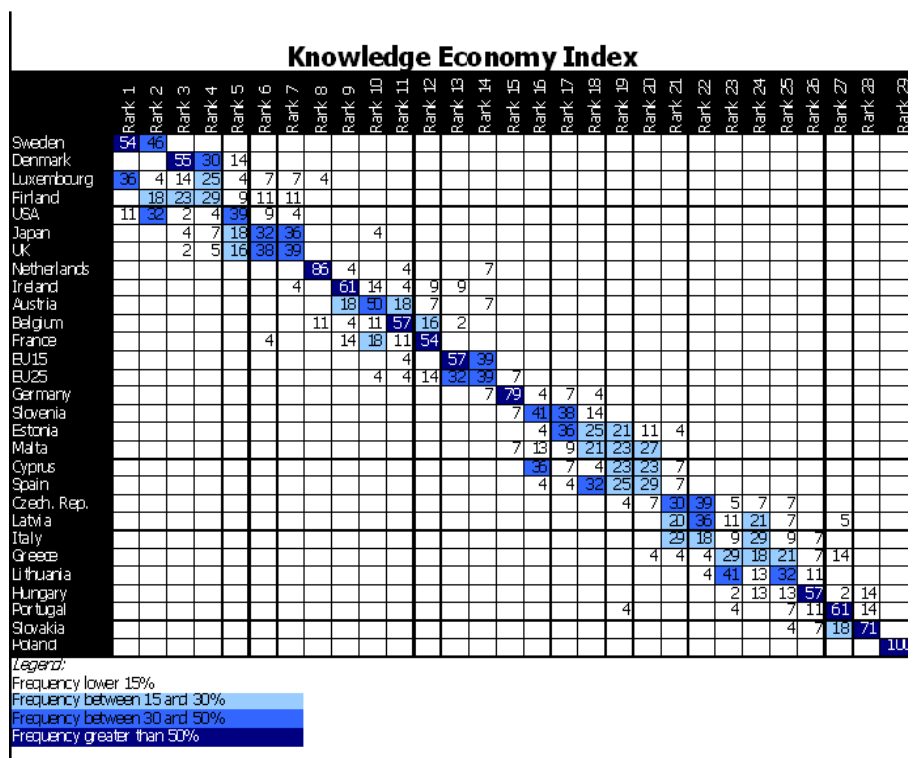
The scenarios, simulations and indicators developed by the JRC team answer five main research questions:

1. Is it possible to measure the knowledge economy?
2. What are the drivers of the knowledge economy?
3. How does knowledge economy relate to other complex dimensions?
4. Is it possible to reduce the total number of individual indicators of KEI conceptual framework without losing any relevant information?
5. Are rankings useful at all for deriving policy suggestions?

1.) A multi-modelling approach was applied to weight and further aggregate the sub-dimensions scores into dimensions and finally into a composite indicator. The approach consisted of about 2,000 simulations (saturated sampling) based on combinations of the:

- imputation method (dataset deriving from either splines or multiple imputation),
- number of sub-dimensions (all 29 sub-dimensions included or one-at-time excluded)
- number of dimensions (all seven dimensions included or one-at-time excluded)
- normalisation of the 29 sub-dimensions scores (z-scores or min-max),
- structure relating the sub-dimensions to the dimensions (preserved or not),
- weighting method (factor analysis, equal weighting, data envelopment analysis),
- aggregation rule (additive, multiplicative, non-compensatory multi-criteria analysis).

Although, this analysis may look very technical in nature, in reality a social component is also present. In fact to consider or not a given dimension, normally has behind a long story of social, political and scientific controversy. Thus to include or exclude a given dimension or a set of indicators means to deal or not with peculiar social concerns and social actors. The frequency matrix of a country's rank in each of the seven dimensions and the overall KEI was calculated across the 2,000 scenarios. Besides the *frequency matrix*, the median rank per country was selected for further analysis of the associations between KEI and its main dimensions, or other complex concepts, such as human development. The KEI composite indicator results are the following:



This is a novel approach to the presentation of results of a composite indicator. Our objective here is to synthesize and make explicit the uncertainty contained in the country ranking. For each country it is indicated the percentage of times it was in a given rank in all the 2,000 simulations, one can see that e.g. Poland was 100% of times in the last position, and Sweden 54% of times in the first position and 46% in the second.

A first consideration is that the overall ranking is very stable; in fact considering the whole 2,000 simulations, all countries are clustered unambiguously. No doubt the top performing countries are Sweden, Denmark Luxembourg, Finland and the USA. Then it follows the group Japan, United Kingdom, Netherlands and Ireland (where Japan and UK are slightly better than the other two). Austria, Belgium, France and Germany form the next group (where Germany is slightly worst than all the other three). All the rest of countries can be considered with a bad performance with respect to a knowledge based economy. However, we could still split this class into two subsets: a first one including Slovenia, Estonia, Malta, Cyprus, Spain, the Czech Republic, Latvia, Italy, Greece and Lithuania is a bit better than the worst performing group including Hungary, Portugal, Slovakia and Poland. An interesting result is also that overall both USA and Japan have a better performance than EU 15 and EU 25.

To better understand the influence of the conceptual model used to derive these results, we have computed country rankings by using the subset of individual indicators belonging to each one of the seven dimensions, thus other seven rankings have been obtained. The objective of this analysis is to check if in some single dimensions, poor performing countries might present an improvement or vice versa, good performance countries a worsening. Of course rankings are obtained again by

considering the whole spectrum of uncertainty related to the computations.

Overall, dimensions A1(Production and diffusion of ICT), A2 (Human resources, skills and creativity) and A3 (knowledge production and diffusion) supply rankings correlated with the KEI composite indicator highly. In these three dimensions Finland is always the top country, but Sweden is always very close to it. In the bottom of the ranking we can find both Cyprus and Portugal, but Poland is never too far from the last position. On dimension A1 Italy has a net improvement but it is still far from the top performing countries. The grouping of countries is very similar to the one of the KEI composite (with all the seven dimensions). On the contrary, A4, B1, B2 and C1 produce country rankings with bigger differences. On dimension A4 (Innovation, entrepreneurship and creative destruction), Italy ranks as the bottom country with a very high degree of credibility (frequency= 11% rank 27, 32% rank 28 and 57% rank 29). Also countries like The Netherlands, Belgium, Austria and Germany show a very poor performance. Finland is closer to medium performance countries than to top countries. Spain improves its rank position considerably. Sweden is still a top performing country. Poland improves its performance surely, but it is very volatile (it occupies positions in the range from the 7-th to the 24-th and the frequency it is never higher than 14% in any position).

Taking into account dimension B1 (Economic outputs) only, big surprises exist. Although the bottom countries are very similar to the ones supplied by other dimensions, Greece (5-th position) and Spain (4-th position) are extremely well performing. Cyprus is also improving considerably. Denmark, Finland and Sweden are instead much worse, since they perform as medium countries. The same argument applies to dimension C1 (Internationalisation). The bottom countries are quite robust a part from Cyprus which is performing around the 7-th and 8-th positions. Portugal is in a better position than Finland (which is very volatile but never above the 17-th rank). Denmark and Sweden are between positions 11 and 13. Top performing countries are Luxembourg, Belgium, Austria and the USA. On dimension B2 (Social performance), top countries are Denmark, Sweden, Austria and the Netherlands. Particularly strong is the worsening of Finland which is around the 13-th position. Germany is also performing very badly (frequencies are clustered around positions 22 and 23). Improvements are shown by Hungary, Italy, Portugal and Spain which perform as middle ranked countries.

- 2.) The internal consistency of KEI conceptual framework is synthesised by computing the relationship between the KEI overall ranking and the dimensions and sub-dimensions considered through the Spearman rank correlation coefficients. As a rough first conclusion we could state that overall all dimensions play a role but surely the less influential seems to be the innovation, entrepreneurship and creative destruction dimension. This conclusion is corroborated by a more sophisticated tool i.e. Path Analysis. By using path analysis, the influence of each single dimension on the total ranking can be computed (this influence is divided into a direct effect and an indirect one). Results of the path analysis conclude that all dimensions seem to have a more or less equal impact (the range is between 12 and 18) on the KEI ranking (please note that here only the linear aggregation is used, since path analysis cannot be carried out for the non-compensatory aggregation rule) except dimension A4 (Innovation, entrepreneurship and creative destruction, whose score

is 8). The variability is much higher if one looks at the sub-dimension levels (e.g. very low scores can be found for knowledge flows (7) or organizational indicators (2)). We can expect an even higher variability at the individual indicator level; this is potentially very relevant if one desires reducing the set of indicators of the KEI conceptual framework. The rankings derived by a linear aggregation rule and a non-compensatory one (under the equal weighting within dimension assumption) are highly correlated, although the non-compensatory one appears more stable. Compensability might be an issue for Finland whose position in the non-compensatory ranking is definitely worse than the ones of Sweden, Denmark, Luxembourg, United Kingdom and Japan. The bottom countries are very stable in both rankings. Useful information is also coming from the comparison between the KEI median ranking and the ranking derived by using data envelopment analysis weights. Since these weights are beneficial for the bottom countries, we can state quite safely that even with endogenous weights the bottom countries are no doubt very stable, thus they are very far from being knowledge based economy countries. Regarding the top countries, it is noteworthy the strong top position of Sweden and the fact that Finland, even with its best set of weights, is still worse than Luxembourg, Japan and Denmark. A final observation is about Ireland. This country belongs to the set of more or less good performance countries, but it is never a real top country, even with its best set of weights, we could thus conclude that according to the KEI conceptual framework and its statistical elaboration, the common perception that Finland and Ireland are the most relevant success stories of knowledge based economies is somewhat misleading.

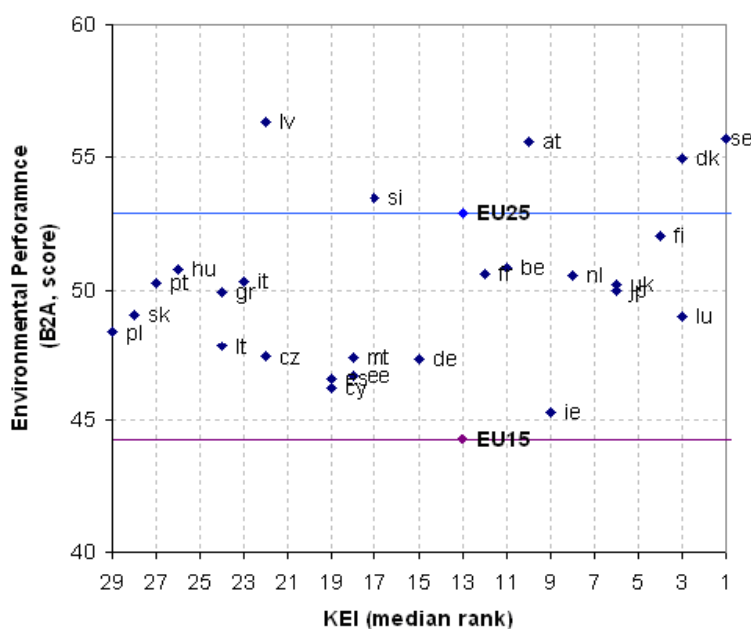
- 3.) Economic theory tries to take technological change into account by two main theories: *Human capital theory* (whose main foundational principle is the recognition of the role of education and importance of skills people has) and *endogenous growth* (whose main idea is the Schumpeterian concept of accumulation of knowledge due to research and innovation in leading private firms). First of all, let us try to understand if to be a knowledge based economy is relevant at all for a good overall economic performance. By looking at the relationship between GDP and the KEI median ranking the answer is YES. Except Germany, Italy and Spain which have a high level of GDP per capita without any particular good performance on a KBE, all the other high level GDP countries seem to perform well in the KEI composite (where Luxembourg can be considered an extreme case -probably an outlier-).

As we already know at the level of dimensions considered in the KEI framework, they all seem to have an influence on the knowledge based economies, thus both economic theories seem to have an influence (since roughly both theoretical models are conceptualized). However, a first result was that the Innovation, entrepreneurship and creative destruction dimension appears not to be very relevant; thus starting challenging the Schumpeterian model. Let us then start by checking if the human capital theory is more relevant in the case of the KEI composite, for doing so we go deeper than the dimensional hierarchical level. The following conclusions can be drawn from our analysis. While the number of Ph.Ds seems to play a role in explaining the success of a knowledge based economy (all countries with an high number of Ph.Ds, except Portugal, are top countries in the KEI median ranking), the same result does not apply to percentage of working population with a tertiary education (very clear the case of Italy where the number of working population with a tertiary

education is extremely high, but the number of Ph.Ds is small). Participation to life long learning seems also to be a success factor, although not for all top countries. In sum, we could state that the human capital theory seems to be corroborated by the KEI results roughly.

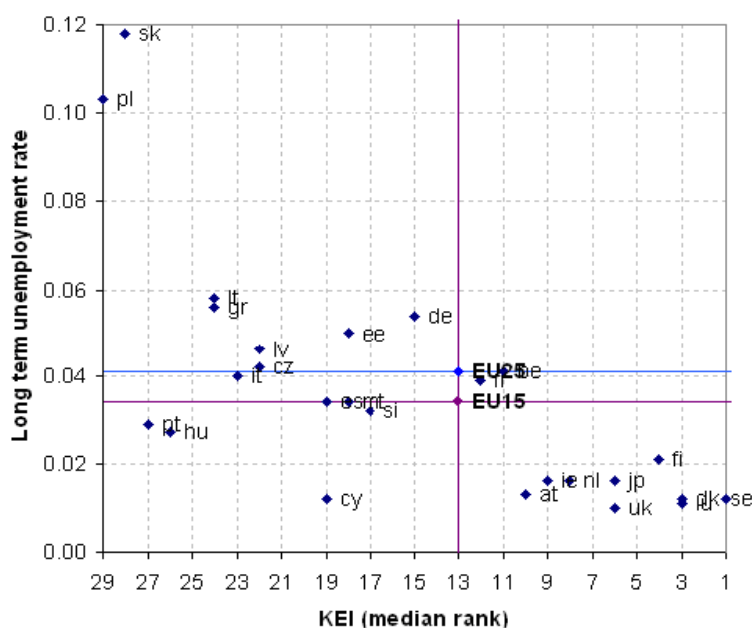
However, if one considers, what probably is the most important Schumpeterian indicator, i.e. Gross domestic expenditure on research and experimental development, the relationship with the KEI median is a clear cut one: countries which invest in research are top countries in a KBE. Research is a key driver for a KBE surely, thus the endogenous growth idea seems also corroborated.

Let us now look at other concepts embedded in the idea of a knowledge economy. A popular one is *eco-efficiency*. i.e. the idea that advanced economies, such as knowledge based economies, are more environmental friendly since they use less material goods and are more energy efficient in productive activities. Unfortunately, the *Jevons' paradox* teaches us that an increase in efficiency in using a resource leads, in the medium to long term, to an increased consumption of that resource (rather than a decrease). This is a classic example of the co-existence of opposite causal links emerging when considering the same process at different (spatial, temporal) scales. Trade-offs also emerge when considering different attributes of performance or when adopting different disciplinary analyses. Sustainability literature clearly emphasizes that environmental preservation has an economic cost and economic growth has an environmental cost, no escapes from this conflict exists. These arguments seem corroborated by the KEI measure. In fact, as one can see, no clear relationship between environmental performance and a KBE exists.



Another interesting aspect of a KBE is unemployment. Job creation can be successfully increased in the short term, by a slowdown of the rate of technological progress. As noted by the Kok report, this is exactly what has recently happened inside the

European Union. But in a longer time horizon, this strategy may easily cause the collapse of the economy given that non-specialized low productivity jobs can easily be substituted by lower wage labour in other parts of the world. Thus, in the short term technological progress and job creation are conflicting objectives but they might be compatible in the long period if a right balance (i.e. compromise) between flexibility and employment security is found. If the relationship between long term unemployment rate and the KEI median ranking is displayed, this compatibility between technological progress and job creation seems to be true. All top countries in the KEI measure are presenting an extremely low long term unemployment rate. This aspect of a KBE seems extremely interesting and encouraging.

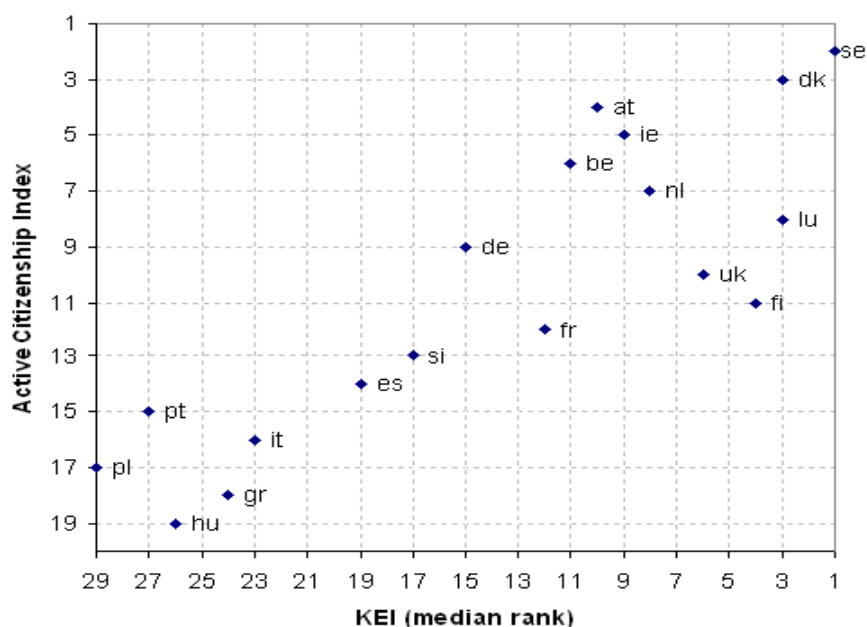
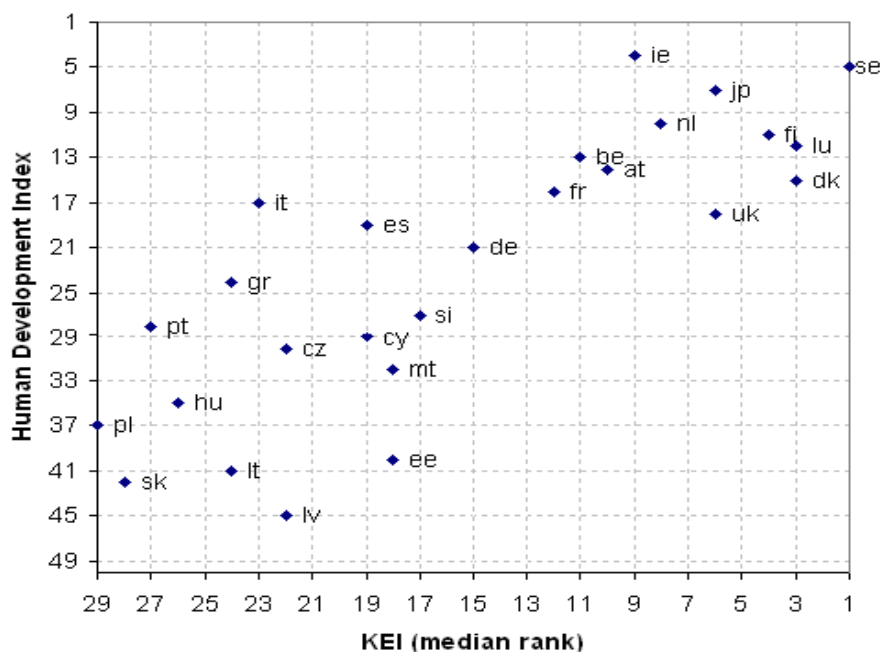


Another common statement about a KBE is that income distribution inequalities are reduced. This statement appears difficult to corroborate by examining the relationship between the KEI measure and the income distribution inequality. No precise relationship exists and when it seems to exist, in reality might simply be a corroboration of the classical Kuznets curve model, where income distribution inequality is supposed to decrease when GDP increases (one should not forget that KEI and GDP are correlated).

As an external benchmark, we look at the relationship between the KEI composite and the Human Development Index. The relationship found seems again a corroboration of the human capital theories, in fact the correlation between KEI and the HDI is extremely high. A peculiar behaviour is the one of Italy and Spain whose HDI is high but the KEI performance is poor.

In this context a relevant index to use as a final external benchmark might be the Active Citizenship Index. This index produced at JRC by CRELL (Centre for Research on Lifelong Learning) is an attempt to measure a component of the social capital, and thus can be considered as complementary to the human capital measu-

rements, which look more at individual skills. It is interesting to note that this index correlates very much with the KEI median ranking, thus it might open interesting research questions on the importance of the social component in a knowledge based economy.



- 4.) To reduce the number of individual indicators, we first undertook both forward and backward stepwise regression, so as to identify those indicators within a KEI dimen-

Production and diffusion of ICT (A1)
ICT value-added (% of total business sector value added) SMEs ordering over the Internet (% of total SMEs) Individuals using the internet for banking (% total)
Human resources, skills and creativity (A2)
Pisa reading literacy of 15y (average score) Total researchers (per 1000 labour force in FTE) Participation in lifelong learning (% of working 25-64y) Employed in creative occupations (% total)
Knowledge production and diffusion (A3)
BERD performed in service industries (%) EPO high tech patent applications (per million pop.) Triadic patent families (per million pop.)
Innovation, entrepreneurship and creative production (A4)
Firm entries (birth rate) GDP (per capita) Early-stage venture capital (% GDP) SMEs reporting non technological change (%)
Economic outputs (B1)
GDP per capita (in PPS) Real GDP growth rate Total employment growth
Social performance (B2)
Long term unemployment rate Hampered in daily activities because of chronic conditions Rooms per person by tenure status and type of housing
Internationalisation (C1)
Technology balance of payments (% GERD) Co authorship share on international S&E articles Foreign PhD students (% total PhD enrolment)

sion that represent (in a linear fashion) the dimension. We also applied forward/s-stepwise regression to choose those indicators that represent best the overall KEI rank. We finally crosschecked, using canonical analysis, whether the subset of indicators describes reliably the set of the seven KEI dimensions and the overall KEI. The following 23 indicators (from a total of 115) are proven sufficient to describe 97.4% of the variation in the overall set (KEI and its seven dimensions).

- 5.) A nasty question at this point might be: *is all this effort we have done of any use?* Even if we have very reliable rankings, which is the policy utility of knowing that a country is overall better than another one or vice versa? This kind of criticism is often put to composite indicators, thus it is worthy to tackle this issue.

Indeed we have already seen that rankings are already giving very interesting information for policy purposes. For example, in the KEI framework, we succeeded to find out clear success stories, i.e. top performance countries, and clear policy drivers. However, one should note that for the majority of indicators used in any assessment exercises no clear reference point is available, for instance, when GDP

is used nobody knows the ideal value of a Country GDP, thus it is quite common to compare with other Countries GDP, e.g. the USA one. In general to get a set of reference values to be used as benchmarks, two options exist:

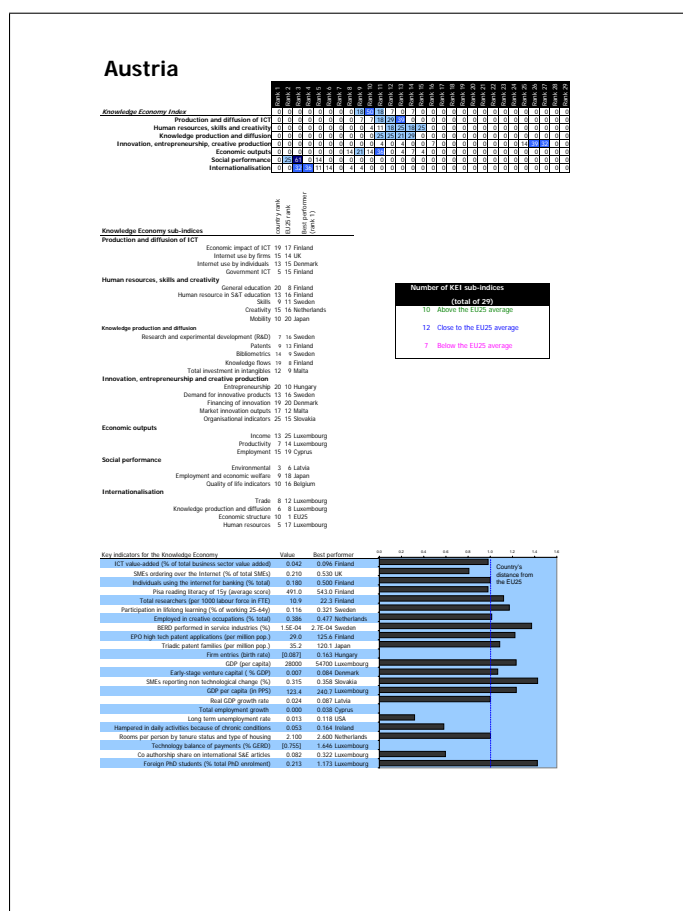
- To compare any country performance with a relevant average (in our case EU15 or EU25).
- To construct an „ideal point“ defined by choosing the best values reached in any single individual indicator by a country. This is a well established technique in multi-criteria evaluation literature and has the advantage of indicating „real world ideal values“.

In KEI both approaches were followed. The performance of each single country is synthesized by comparing its scores on dimensions and sub-dimensions with the EU25 average. Later on country profiles are shown in details, where both EU25 average and the idea of a best performing country are used for deriving policy priorities.

By looking at the following Table, we have both synthetic and analytic information on single country performance. In fact we know the total numbers of sub-dimensions which are above (+), close (0) or below (-) the EU25 average, thus allowing a quick scoring of countries; but at the same time, it is also possible to derive policy suggestions since all the sub-dimensions are scored. To give some illustrative examples, Finland is clearly a top performing country since it is above or close to the EU25 average for the majority of sub-dimensions. The only plausible policy priorities since the performance is below the average are Entrepreneurship, Organizational indicators, Knowledge production and diffusion and Economic Structure. Entrepreneurship, Organizational indicators and Economic Structure seem problematic for another top performing country, Sweden. For Sweden, Mobility and Knowledge flows also offer space for improvement. On the other side, if one examines the performance of countries such as Italy (above in the average only in Government ICT and Organizational indicators), Portugal (+ only in Financing of innovation and employment and economic welfare) or Greece (+ only in Economic impact of ICT, Income and Employment) it is clear that the space for improvement is enormous, but of course this does not necessarily mean that their governments wish to pursue the objective of being a KBE, it is important to remember that a KBE is one of the possible models that a country may choose and the fact that a poor performance exists might simply mean that this scope is not a policy objective for that country. An interesting result is that EU 15 is NOT always equal or superior to the average of EU25. It is actually below EU25 average in three sub-dimensions: Organizational indicators, Environment and Economic structure; in these areas the enlargement has then lead to an improvement of the average EU performance.

Dimension	Sub-dimension	AT	BE	CY	CZ	DE	DK	EE	ES	EU15	FI	FR	GR	HU	IE	IT	JP	LT	LU	LV	MT	NL	PL	PT	SE	SI	SK	UK	USA
Production and diffusion of ICT	Economic impact of ICT	0	0	-	0	0	+	+	-	0	+	0	+	0	+	0	+	-	0	+	-	+	-	+	-	-	+	+	+
	Internet use by firms	0	0	-	-	+	+	-	-	0	+	+	-	-	+	-	+	-	0	-	+	0	-	-	+	0	-	+	+
	Internet use by individuals	0	0	-	-	+	+	+	-	+	+	+	-	-	-	-	+	-	+	-	-	+	-	-	+	-	-	+	+
	Government ICT	+	0	-	-	0	+	+	0	0	+	+	-	-	0	+	+	-	+	-	0	0	-	-	+	-	-	-	+
Human resources, skills and creativity	General education	-	0	0	-	0	-	-	-	0	+	0	-	-	+	-	-	0	-	-	-	0	-	-	+	-	-	0	0
	Human resource in S&T education	0	0	0	-	0	+	+	0	0	+	+	-	-	+	-	+	0	+	0	-	-	-	-	+	-	0	0	+
	Skills	0	0	0	-	-	+	-	-	0	+	-	-	-	-	-	+	-	0	0	-	-	-	-	+	+	-	+	+
	Creativity	0	+	-	0	+	+	0	-	0	+	0	-	-	+	0	+	-	+	-	-	-	+	-	+	-	-	+	+
Knowledge production and diffusion	Mobility	+	0	+	-	0	+	+	+	0	+	+	0	-	+	-	+	+	-	+	0	+	-	0	-	+	-	+	+
	R&D	+	0	+	-	+	+	0	-	0	+	+	-	-	-	-	+	0	0	0	0	0	-	-	+	0	-	0	+
	Patents	+	0	0	-	+	+	-	-	0	+	0	-	-	-	-	+	-	+	-	-	+	-	-	+	-	-	0	+
	Bibliometrics	-	0	-	-	0	+	-	-	0	+	0	-	-	-	-	+	-	-	-	0	+	-	-	+	-	-	+	+
Innovation, entrepreneurship and creative diffusion	Knowledge flows	-	-	-	-	-	-	-	-	0	+	-	-	-	-	-	0	-	-	+	-	-	-	0	0	+	+	-	-
	Total investment in intangibles	-	-	0	-	-	-	-	-	0	0	0	-	+	+	-	+	-	+	-	+	0	-	-	-	-	-	+	+
	Entrepreneurship	-	0	-	-	+	-	0	0	0	-	0	-	+	-	-	0	0	0	0	-	-	0	-	-	-	0	+	-
	Demand for innovative products	0	-	0	0	0	+	+	0	0	0	0	0	0	+	-	0	0	+	0	-	0	-	-	+	0	+	+	0
Economic outputs	Financing of innovation	0	+	+	-	+	+	+	0	+	+	+	0	-	+	0	+	+	+	+	0	0	-	+	+	0	0	+	+
	Market innovation outputs	0	-	-	0	-	0	0	-	0	0	-	0	-	0	-	+	-	+	-	+	0	-	-	0	+	0	+	0
	Organisational indicators	-	-	0	+	-	-	-	+	-	-	+	0	+	-	+	0	+	-	0	+	+	+	0	-	+	+	-	-
	Income	+	+	+	0	0	0	+	0	0	+	0	+	0	+	-	0	+	+	+	-	0	0	-	+	+	0	+	+
Social performance	Productivity	+	+	-	-	0	0	0	+	0	0	+	0	-	+	0	+	-	+	-	-	0	-	-	0	0	-	0	+
	Employment	0	-	+	0	0	+	-	+	0	+	-	+	-	+	-	+	-	+	0	-	0	-	0	+	0	-	+	+
	Environmental	+	0	-	-	-	0	-	-	-	0	0	-	0	-	0	-	-	-	+	-	0	-	-	+	0	-	-	0
	Employment and economic welfare	+	0	+	0	0	+	-	0	0	0	0	-	+	+	0	+	-	+	0	+	+	-	+	+	+	+	-	+
Internationalisation	Quality of life indicators	+	+	+	-	0	+	-	+	0	0	0	0	-	+	0	0	-	+	-	0	+	-	-	+	-	-	-	+
	Trade	0	+	0	0	0	0	-	0	0	+	0	-	0	+	0	0	-	+	-	0	+	0	-	+	0	0	0	0
	Knowledge production and diffusion	0	+	0	-	-	-	-	0	+	-	0	-	-	0	-	-	-	+	-	0	0	-	-	0	-	-	+	0
	Economic structure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of sub-dimensions	Human resources	+	+	+	0	+	+	-	0	0	0	+	0	-	+	-	+	-	+	-	0	+	-	0	0	-	-	+	+
	Above the EU25	10	8	8	1	8	17	8	5	3	17	10	3	4	16	2	18	4	17	6	5	12	1	2	19	7	3	17	19
	Close to the EU25	12	14	9	9	13	5	5	10	23	8	14	8	5	3	8	7	5	5	8	9	13	3	5	5	8	6	6	6
Below the EU25	7	7	12	19	8	7	16	14	3	4	5	18	20	10	19	4	20	7	15	15	4	25	22	5	14	20	6	4	

To understand the country profiles presented, the following explanations are useful.



The Country Profiles present a compilation of selected data and statistics for each individual country included in the Knowledge Economy Index. The European Union countries included are: Austria, Belgium, Cyprus, Czech. Rep., Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom. The EU15 and EU25 are also included. Finally, two non-European countries are used for benchmarking purposes: Japan and the United States of America.

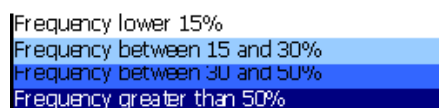
1. Knowledge Economy Index (KEI) and its seven main dimensions

The first section presents the frequency distribution (%) of a country's rank in KEI and in each of the seven dimensions (Production and diffusion of ICT; Human resources, skills

and creativity, etc.). These frequencies are estimated over 2000 scenarios in the development of the KEI depending on:

- imputation method (dataset deriving from either splines or multiple imputation),
- number of sub-dimensions (all 29 sub-dimensions included or one-at-time excluded)
- number of dimensions (all seven dimensions included or one-at-time excluded)
- normalisation of the 29 sub-dimensions scores (z-scores or min-max),
- structure relating the sub-dimensions to the dimensions (preserved or not),
- weighting method (factor analysis, equal weighting, data envelopment analysis),
- aggregation rule (additive, multiplicative, non-compensatory multi-criteria analysis)

For example, Austria has a frequency value 50 under rank 10, which implies that Austria was ranked 10th (total of 29 positions) in the KEI in 50% of the scenarios. A colour code summarizes the frequencies as follows:



2. Knowledge Economy Index sub-indices The second section presents the country rank in each of the 29 sub-indices (grouped under the seven main dimensions). For comparative purposes, the EU25 rank and the best performing country in each sub-dimension are also shown. A summary table provides the number of sub-dimensions that are above, close to, or below the EU25 score. A country's performance was deemed to be close to the EU25 performance if the country score is in the range .

3. Key indicators for the Knowledge Economy The third section offers the raw data values for a country across 23 indicators, which were selected from the dataset of 115 indicators underlying the Knowledge Economy Index. The 23 indicators were originally grouped (together with the rest 92 indicators) under the seven main dimensions as follows:

Production and diffusion of ICT: ICT value-added (% of total business sector value added); SMEs ordering over the Internet (% of total SMEs); Individuals using the internet for banking (% total)

Human Resources, skills and creativity: Pisa reading literacy of 15y (average score); Total researchers (per 1000 labour force in FTE); Participation in lifelong learning (% of working 25-64y); Employed in creative occupations (% total)

Knowledge production and diffusion: BERD performed in service industries (%); EPO high tech patent applications (per million pop.); Triadic patent families (per million pop.)

Innovation, entrepreneurship, creative production: Firm entries (birth rate); GDP (per capita); Early-stage venture capital (% GDP); SMEs reporting non technological change (%)

Economic outputs: GDP per capita (in PPS); Real GDP growth rate; Total employment growth

Social performance: Long term unemployment rate; Hampered in daily activities because of chronic conditions; Rooms per person by tenure status and type of housing

Internationalisation: Technology balance of payments (% GERD); Co authorship share on international S&E articles; Foreign PhD students (% total PhD enrolment)

In case a country missed data for a given indicator, the missing datum was estimated by multiple imputation. Estimates are included in brackets and report the mean value based on the multiple imputation. For comparative purposes, the best performing country and score are shown. A graph complements the information provided in this section by displaying the relative distance of the country score from the respective EU25 value. Estimated values are not displayed in the graph. For the EU25 profile, this last graph shows the distance of the EU25 from the best performing country in the KEI dataset.

Overview of the KEI Workpackages and Deliverables

WP1: Defining the Knowledge-Based Economy

WP1 spans both indicators and policy. The first phase will develop a theoretical framework for the project, building on previous research, in order to identify the main characteristics and drivers of a KBE for all economic sectors: high technology manufacturing, low and medium technology manufacturing, private services, and public services. The second phase will identify forward-looking policies that can promote a knowledge economy, meet other European goals, and adjust for new social and technological developments. The final phase will combine indicator and policy analysis through a series of short (less than five years) and mid-term (five to ten year) scenarios to evaluate the impacts of alternative policies on indicator outcomes.

D1.1 State-of-the-Art on the Knowledge-Based Economy

D1.2 Future Challenges for a Knowledge-Based Economy

D1.3 Policies for a Knowledge-Based Economy

D1.3a Indicators for a KBE: Interviews with policy analysts

D1.4 Policy scenarios:

1. Supply of scientists and engineers
2. Environmental innovation
3. Demand for innovation

D1.4a Policy scenarios Supply of scientists and engineers

D1.4b Policy scenarios Environmental innovation

D1.4c Policy scenarios Demand for innovation

D1.5 Defining the Knowledge-Based Economy: Final Synthesis Report

WP2: Indicators for the KBE

WP2 will identify and evaluate potential indicators for measuring the drivers, characteristics, and key outputs of a knowledge economy and for meeting policy and user needs. The

indicators will be assigned to logical categories within two major classifications of input and output indicators. The categories will be used in WP3 and WP5 to develop composite indicators. WP2 will collect data and supplementary information for each indicator and identify missing indicators for important phenomena.

D2.3 Summary of selected KBE indicators and categories Data Annex

D2.5 Indicators for the Knowledge-Based Economy: Summary Report

WP3: Statistical Analysis of KBE Indicators

The objective of this work package is to analyse key aspects of the quality of data for use with KBE indicators of interest. Since many sources of data for indicators are based on survey samples, special emphasis will be laid on the accuracy and statistical reliability of indicator values. The main purpose of the data quality analysis is to identify areas of indicator weakness and guide the selection of indicators. Further emphasis will be paid on the analysis of erroneous data and their influence on the reliability of the indicators for the KBE. Furthermore, it is intended to investigate indicator performance in respect to their analytical and statistical properties. The work on this work package will be split into two parts: Phase I will summarise the current methodology in this area whereas phase II will elaborate the methodology and tools needed for new developments in this area. Special emphasis will be laid on the influence of non-response to the reliability of indicator values and the accuracy of regional sub-indicators.

D3.1 Quality Concepts: State-of-the-Art

D3.2 Imputation of Knowledge Economy Indicators

D3.3 Quality of Knowledge Economy Indicators and its Composites

D3.4 Accuracy Measurement of Composite Indicators

WP4: The Way Forward: Innovative Use of KBE Indicators

WP4 focuses on the innovative use of indicators, either through finding solutions to missing indicators or identifying indicators that can meet future needs. When no indicators are available, WP4 will identify proxy indicators, alternatives such as new ways of analysing existing survey data, or develop new survey questions. WP4 will identify long-term indicators that measure fundamental inputs into a knowledge economy, such as some education indicators, and identify possible developments (either technological or social) within a knowledge economy that will require new or improved indicators in the short-term future. This may require changes to some indicators or the identification of alternative indicators that can cover future data needs.

D4.1 State-of-the-Art Report on Developing New KBE Indicators

D4.2 Solutions for Missing Indicators

D4.4 Summary Report on the Way Forward: Innovative Use of KBE Indicators

WP5: Composite Indicators for the KBE

After a summary of the state-of-the-art in developing composite indicators, this WP deals with the construction and testing of new composite indicators, suggesting improvement for the existing ones. Additional methodologies of aggregation will be applied following recent critiques of the existing aggregation procedures. Various approaches to extend user involvement will be tested and presentational issues and visualisation tools will be recommended based on feedback from users.

D5.1 State-of-the-Art Report on Composite Indicators for the Knowledge-based Economy

D5.3 ‘Benefit of the doubt’ composite indicators

D5.5 Applied Sensitivity Analysis of Composite Indicators with R

D4.3 and 5.7 Time Series Modeling with Busy

D5.4, 5.6, 5.8, 7.2, and 7.3 Final Report on Simulation Results for Indicators

WP6: Role of Multinationals for Information on R&D

National indicators on R&D efforts are somewhat distorted by world-wide R&D activities by multinational companies. The aim of the work package is to develop and test new indicators on the role of multinational companies in national indicators on R&D efforts in order to estimate the effects on national figures. The results may assist in evaluating how far the 3.0 percent target of R&D expenditure on GDP is reached. The intention is to form an expert group with 4 or 5 interested countries with access to enterprise level official R&D data. Depending on the countries, a representative set of multinationals will be chosen. Publicly available information on the R&D in these companies will first be analysed as well as what is available from national R&D statistical publications. Then a paper with possible approaches will be produced for discussion in a small workshop with the chosen countries. The aim of the workshop is to agree on a common approach for data extraction. On the basis of the results the final report will suggest some methodologies for further dissemination and use.

D6.1 State-of-the-Art Report on the Role of Multinational Enterprises for Information on R&D

D6.2 Indicators on the Globalisation of R&D, Some Methodological Issues

D6.3 Role of Multinational Enterprises for Information on R&D

WP7: Simulation Study

A set of simulations will test the accuracy and reliability of the indicators in a practical environment under different realistic assumptions and data quality standards. This WP will address the robustness of the composite indicators to various policy scenarios, data quality and weighting/scaling approaches. The robustness assessment will be done on various inferences, such as leaders and laggards, middle-of-the-road performers, and on “status” versus progress performances.

D7.1 State-of-the-Art Report on Simulation and Indicators

WP8: Final Report

The final report will be split into two different reports. The first report will draw together policy-relevant results from all seven research WPs. The report will present and interpret the set of composite indicators developed in WP5, discuss their use in policy applications, and make recommendations for policy. The report will be written for a general audience and will be fully illustrated with charts and graphs of the results for all countries. The report will also include an annex with complete details on the data, including sources, and dates. The second report will focus on technical and methodological issues and provide a detailed overview of the project methodology and results from the project.

D8.1 Policy Analysis of Knowledge Economy Indicators

D8.2 An Overview of the KEI Achievements

Remark: Some of the deliverables have been provisional or internal only. However, all final results are covered within the above reports.