KNOWLEDGE ECONOMY INDICATORS

Workpackage 4

State-of-the-Art Report on Developing New KBE Indicators

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1. Introduction

The KEI report *State-of-the-art of a Knowledge Based Economy* (Report WP1.1) describes the main characteristics and output measures of a knowledge based economy (KBE). The report identifies five main characteristics or drivers; ICT and other generic technologies, human resources and skills, knowledge production, entrepreneurship and creative destruction, and organisational change, and two output categories: economic performance and social impacts. Work Package 2 of the KEI project summarized the types of data that are currently available for defining the characteristics of a KBE, identifying the drivers of growth in a KBE, and measuring the performance and output of a KBE. This WP is supplemented by a dataset of available KBE indicators.

This report (WP 4.1) explores the state-of-the-art on indicator development regarding key indicators for a KBE that are incomplete, unsatisfactory, or entirely missing.

Incomplete indicators are only available for a few target countries or for only one year, making it impossible to evaluate trends over time. As an example, we often lack complete coverage for all 25 EU member states, with many important indicators only available for the EU-15, while others are only available for a limited number of EU countries with highly developed national statistical systems (typically the U.K., France, Germany, Netherlands, Belgium, Italy and the Scandinavian countries).

Even the more 'successful' indicators, in terms of scope and coverage, are not available for several countries. For example, relevant indicators for several important policy areas are available for the EU-15, but the statistical systems in the new member states have not yet caught up. Examples of existing indicators that are largely limited to the EU-15 include R&D spending of affiliates as a percent of total BERD, the percentage of total business R&D funded from abroad, co-patenting by individuals in different countries, and the co-authorship share for international scientific articles.

Similarly, information on the inflow of knowledge workers is scant in many countries and limited by public policy sensitivities surrounding the immigration of foreign talent. For Germany and the Nordic countries, immigration information can be used to develop indicators on foreign skilled workers. For countries like the Netherlands, the information exists but is protected by confidentiality restrictions that make it difficult, if not impossible, to develop indicators on the number of foreign scientists and engineers working in the Netherlands. In other countries, relevant data are simply not collected (immigration data are not disaggregated by qualifications or expertise).

Incomplete indicators can be quickly identified by evaluating the dataset of available KBE indicators. Table 1 is an example of a set of incomplete indicators where time series or country coverage is not complete. Missing cells are shaded.

Table 1. ICT expenditures expressed as a share of GDP, EU-25 and selected countries, 2000 to 2004						
Indicator A1a4		Year				
		2000	2001	2002	2003	2004
		% of GDP				
EU25	EU-25 countries		5.6			6.4
EU15	EU-15 countries	6.5	6.3	6.6	6.4	6.3
AT	Austria	6.2	6.3	6.5	6.4	6.4
BE	Belgium	6.7	7	6.7	6.4	6.4
BG	Bulgaria	8.7	8.5			8.6
CY	Cyprus					
CZ	Czech Republic	8.8	8.3			7.1
DK	Denmark	7	6.8	6.8	6.7	6.7
EE	Estonia	13.1	9.5			8.6
FI	Finland	6.9	6.6	7.1	7	7.1
FR	France	5.9	6.1	6.2	5.9	6
EL	Greece	5.7	5.5	5.6	5.3	5.1
HU	Hungary	9.6	8.9			7.1
IE	Ireland	5.7	5.1	5.9	5.3	5.4
IT	Italy	5.1	5.2	5.4	5.3	5.3
LV	Latvia	9.6	7.8			7.6
LT	Lithuania	6.3	6.3			5.8
LU	Luxembourg	7.3	7.4	6.8		
MT	Malta					
NL	Netherlands	7.6	7.2	7.8	7.4	7.5
PL	Poland	6.7	5.9			7.2
PT	Portugal	6.6	6.7	7.2	7.1	7.1
SI	Slovenia	7.3	5.4			5.2
SK	Slovakia	7.3	7.3			6
ES	Spain	5.5	5.2	5.6	5.4	5.2
SE	Sweden	8.5	8.5	9.2	8.8	8.7
UK	United Kingdom	7.6	7.4	8.6	8	7.9
IS	Iceland					
IL	Israel					
NO	Norway	5.4	5.7	6.1	6.2	6.2
RO	Romania	8.6	4.9			1.5
CH	Switzerland		7.6	7.3	6.9	7.8
TR	Turkey	13.1	5.6	4.1	3.2	
JP	Japan	5.2	7.5	7.8	7.8	8
US	United States	6.7	8.6	8.1	7.9	7.8
Source: NewCronos						

Annex Table 1 provides an overview of the incomplete indicators. No further discussion of incomplete indicators is provided in this report.

A more difficult challenge is how to identify key unsatisfactory or 'missing' indicators. We use one criterion, which is the importance of specific types of information for policy. Both policy analysis and planning are constrained by the availability of indicators to measure the KBE, especially timely indicators of relevance to a range of dynamic economic and social interactions that are expected to change, sometimes substantially, over the coming decade.

Unsatisfactory indicators partly address a characteristic, driver, or outcome, but are often proxies for the underlying phenomenon that we would like to measure, or the available data do not cover many important aspects of the phenomenon. There are probably more areas where indicators are unsatisfactory than there are areas where indicators are entirely missing.

Our ability to assess sector and national innovation performance in the KBE is curtailed by a limited number of indicators on important facets of innovation activities, including the diffusion of productivity-enhancing technologies, entrepreneurship, organisational innovation and demand conditions. Both the supplementary thematic country reports to the 2004 National Innovation Systems (NIS) project and Trend Chart's 2004 An Exploratory Approach to Innovation Scoreboards (EXIS) highlight the role of demand for innovative products and processes and the social and cultural factors that support innovation.

There are other elements receiving increasing policy interest (and some might argue well past due), including the commercialisation of publicly funded research and skilled worker mobility. Both are areas where the United States seems to be more successful than Europe, but we can't fully assess these issues without more complete data. Many of the claims for the superiority of American performance are based on anecdotes, case studies, or proxy indicators, rather than indicators that measure these two phenomena. For Europe, indicators on human mobility are needed to consider the effects of occupation, sector, and geography (both regional and international) on mobility, although one might argue that the main concern rests with flows of skilled workers in and out of Europe.

Another example of unsatisfactory indicator coverage is for knowledge production, such as e-learning and the certification of skills that are not currently reflected in existing systems of formal recognition of qualifications. The recent Aho report (2006) for the Spring European Council emphasizes that 'turning knowledge into growth' will require a key and growing role for education systems and e-education. Education is, in fact, an area where there are an enormous number of indicators, but many of them are imperfectly adapted to the needs of a knowledge economy, often because they are imperfect proxies for what we would like to measure. Education indicators need to be evaluated in terms of knowledge and creativity capabilities and also as a stimulator for changing European attitudes to innovation and entrepreneurship.

In order to fulfil the European Union's goal of creating a 'European Research Area' (ERA), as part of meeting the global challenges of a KBE, we also need to improve and expand indicators for measuring the industry-science relationship. 'Industry-

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science relations (ISR) are one important node in the national innovation system.'[1] Relevant indicators include measures of R&D cooperation and knowledge exchange, both between firms and between firms and the public research sector. There is a need to provide accurate and timely measures of innovation drivers in EU member states.

Missing indicators simply don't exist, although we can imagine how to collect the necessary data. There are three areas where there is a near total lack of useful indicators: for entrepreneurship and creative destruction (we only have a few proxies), organisational innovation, and for social impacts. In respect to the latter, there are very few indicators on the ways and means of how citizens adapt to the KBE. There are also major gaps in indicators for environment and sustainable development. Other examples, which are more difficult to define, include indicators for measuring how businesses react to the increasing competitiveness and potential for growth in the KBE, and how citizens are tackling the challenges and exploiting the advantages of living and working in a KBE.

Statistical systems are based on developing national data to meet gaps in indicator needs, either for overcoming problems with unsatisfactory coverage or missing indicators. However, non-national data can sometimes be used to provide new indicators of relevance to policy. Again, we can use the example of highly skilled scientists and engineers. The numbers of scientists and engineers lost to a country through emigration are often best examined according to the receptor country immigration files, and for Europe as well as other regions in the world. Canadian population and immigration data tells us that the UK remains a strong contributor to skilled workers for Canada consistently ranking among the top ten source countries. However it is the U.S. that draws upon talent from global sources and American data sources are key. We know that in 2004, one quarter of the highly skilled workers admitted to the U.S. were from the EU-25. We need to consider how and where we are willing and justified in going to develop European indicators. Can we rely upon external data sources for critical indicators? Perhaps the globalization of business means also the globalization of indicator development.

There are also problems of comparability because of differences in definition. This is readily illustrated by the problems of indicators for human resources and skills. New indicators must provide for international comparability both for 'in-house' EU policy and for external trading and competition on a global scale.

The next sections of this report evaluate unsatisfactory and missing indicators for each of the five main characteristics of a KBE and the two main outcomes. Of note, this report only identifies the areas of incomplete, unsatisfactory or missing indicators. The task of making recommendations on how to fix the problems and how to address some of the data gaps and weakness in indicator development falls to Report WP 4.2.

[1] Graversen E.K., The interplay and interfaces between private firms and public research organizations (2004)

2. Identifying unsatisfactory and missing key indicators

Indicators for the KBE can be classified according to five groups of characteristics or drivers:

- The influence of the production and diffusion of ICTs;
- The crucial role of human resources;
- The change in knowledge production and diffusion;
- Innovation and entrepreneurship and; and,
- Structural change.

The role or focus that policy puts on these five groups of drivers may vary but they are essential to examining and understanding change and growth in the KBE. All five will need indicators to meet European policy and planning needs. Within each of the five groups, the policy interest on certain characteristics of the KBE may vary from time to time and this inconsistency in policy interest and support for data and indicator development is what sometimes contributes to the situation of unsatisfactory and missing key indicators. Keeping the main policy interests, for each of the key five groups, we now describe some of the unsatisfactory or missing key indicators for the KBE.

2.1. Production and diffusion of ICTs

We need to remind no one of the policy priority given to ICTs, given their crucial role in the competitiveness of businesses in the KBE and their ever growing importance in the working conditions and social activities of Europeans. ICTs play a crucial role in regional and national economic and social well-being. European policy needs timely and qualitative indicators on the factors of production and diffusion of ICTs to ensure Europe's competitiveness and growth.

Part of the problem is that we are trying to identify indicator needs in an area where agreement has yet to be reached on definitions. This is illustrated below using the example of IT and ICT workers.

The IT worker can be defined by education and skills (e.g. qualification) or by occupation or by firm (sector). This tells us that we need more indicators on non-formal qualifications (e.g. professional certification). According to a RAND Europe report *The Supply and Demand of E-Skills in Europe* prepared for the European Commission (2005), the share of IT and ICT practitioners that acquired their skills through higher education within the field of computing was low. Other fields and training indicators need to be developed. The IT workforce can also be measured based on occupations and here a lot of national sources rely upon the IT community to provide information that can be used to define IT workers in order to estimate the number of ICT workers.

We need to develop composite indicators that can be used to produce a clearer picture of IT and ICT workers in the labour force. Table 2 shows the ranking of the top seven sectors according to IT versus ICT 'jobs'.

Table 2. Ranking of industry divisions according to highest stock of IT and ICT skilled workers

IT defined as: ISCO 213 (computing professionals) ISCO 312 (computer associate professionals		ICT defined as including: ISCO 213 (computer professionals) ISCO 312 (computer associate professionals) ISCO 313 (optical and electronic equipment operators) ISCO 724 (electrical and electronic equipment mechanics and fitters))	
Ranking	**ISCO occupation**	**Ranking**	**ISCO occupation**
1	72 Computer and related activities	**1**	72 Computer and related activities
2	74 Other business activities	**2**	45 Construction
3	75 Public administration, printing and reproduction of recorded material	**3**	74 Other business activities
4	65 Financial intermediation, except insurance and pension funding	**4**	64 Postal and telecommunications
5	64 Postal and telecommunications	**5**	52 Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
6	80 Education	**6**	75 Public administration, printing, and reproduction of recorded material
7	51 Wholesale trade and commission trade, except of motor vehicles and motor cycles	**7**	40 Electricity, gas, steam and hot water supply

Source: this information is based on Table 2, page 34 of RAND Europe report *The Supply and Demand of E-Skills in Europe* prepared for the European Commission (2005)

The shading on the table is used to illustrate the number of sectors within the top seven industries that are the same regardless of occupation definition. However, the table clearly shows how the ranking and types of industries changes when one compares IT occupations and ICT occupations. The RAND study estimates, when all industries are considered, 58% of IT practitioners and 77% of ICT practitioners are employed outside of the core IT industry sector (NACE 72). The OECD notes the problem of making a link between ICT workers and IT jobs (OECD 2002). Lack of composite indicators on IT and ICT employment and employees will undermine the development of useful supply and demand scenarios for policy.

From meeting firms' labour needs for domestic supply, to putting immigration policy in place to facilitate mobility of ICT workers, to the education system priorities to respond to supply demands, the need for indicator development in this area is clear. Given the problem with linking ICT workers and ICT occupations and labour markets, supply-demand analysis may prove to be a liability for policy makers. Recently, emphasis on e-business skills is growing and calls for service contracts to provide indicators and forecasts for Europe's needs for ICT skills are increasing (e.g. work generated from the e-Skills for Europe forum).

2.2. Human resources, skills and creativity

Human resources, from the persons that create new knowledge to those who diffuse the knowledge to those who apply the knowledge come under the policy interests for human resources. Human resource indicators are of central importance to economic and social and health policy and for the public and private sector policy planners and decision makers alike. Skills and knowledge are central to innovation and economic growth. Skills and the life-long learning are important for all citizens in the KBE. We need indicators on the creators of knowledge and on the ability of society to adopt and adapt to new technologies and organizational systems.

For the KBE, we need to expand the scope of indicators on human resources, including the stock and flow of people who create and apply knowledge. And, while there is a pressing need for indicators on the stock and flow of R&D performers, the human resources responsible for creativity and innovation, we also need indicators on human resources that form the rest of the 'team', from the undergraduate engineer to the technical assistant.

In *e-Skills for Europe: Towards 2010 and Beyond* (2004) the need for a long-term strategy and improvement of data and indicators on the ICT labour market is identified. We also need to expand our understanding of the absorption capacity of our population at large — their ability to use new technologies such as automatic teller machines, accessing government information and records on-line, or taking education courses to upgrade their skills.

General education indicators

Education indicators have been, are and will continue to be important for policy. Policy needs to know of the domestic supply of talent for the economy but also about the 'educational health' of its population at large. Policy needs to know if students continue to shy away from the fields of expertise that will help them grow and benefit in the KBE. Policy needs to know of changes in attitudes towards science and engineering education and how this differs for men and women. EU policy needs to know where weakness in Europe's education pipeline may develop in order to put in place measures to address them. Literacy and math scores vary across Europe just as the attraction of science and technology courses for students varies across Europe.

There are a range of indicators available on 'traditional' education pipelines (e.g. ISCED). For the most part these indicators are well provided for, at least compared with other education indicators needed for the KBE. There is information on foreign students, but comparable indicators on characteristics of those who earn degrees are sketchy for the EU-25.

Apart from some national efforts and some special surveys, there are no EU-25 indicators on aspects of education and innovation systems. Vocational and on-the-job training indicators are weak. Historically, training indicators have been difficult to develop because of issues of definition and 'interpretation' of training on the part of firms. Today, when software and manuals distributed to employees may represent 'training' and may or may not form a critical phase of employees' upgrading of skills, it is important to have indicators on in-house and employee-motivated up-skilling and training. We need indicators of trends in non-traditional learning such as might be measured by professional certification and private sector e-learning. We also need indicators that discriminate from 'business as usual' training to creativity and innovation motivated learning.

Perhaps one of the reasons Americans are so successful is that they have been quick to recognize the essential role of education and systemic weaknesses. For example, their policies are 'friendly' to the import of foreign students. A clear message has been sent about the U.S. views on education and innovation in the KBE — a 2003 report to the President's Council (Washington), on a review of technology transfer policies, recommended that 'education' be part of the Department of Commerce technology transfer mandate. The U.S. has extensive indicators on education and R&D and continues to improve its S&T taxonomy and indicator development[2]. Europe needs to have indicators on the extent to which policy is progressing for national needs and interests in key areas for growth in the KBE such as knowledge workers, at every stage. We need to build indicators on the potential creative capacity of the ERA from the early stages (e.g. pre graduate). How is ERA doing in courting foreign youth for scientific, engineering and technical training?

Creativity indicators

Here we focus on our skilled human capital, our researchers and skilled workers with high levels of expertise. Despite the recognition of the importance of human capital to economic and social growth and well being in the KBE, creativity indicators remain some of the least developed. A harsh review might suggest that there has been little done to measure human capital and skilled workers beyond the traditional educational rankings (e.g. level of education) at the EU level. Economists continue to focus on 'highly-skilled' jobs without even considering the role of the 'mix' of skills required in specific sectors or occupations. Indicator development continues to be driven by the traditional low-medium-high skill measures promoted by organizations such as the OECD and followed by the EU for many years.

[2] Other countries are moving to make the lives of foreign students, easier but policies differ across the EU and around the world. Recently, Canadian policy has changed the limitations on foreign students and they may now work outside of the university environment. This not only provides the foreign students additional income opportunities but of course networking and other employment considerations.

Very few indicators have been developed that consider the role of human beings and their skills for the challenges of European MNEs operating in a global market. That is not to say there are no lights on the horizon. For example, the OECD and Eurostat are developing a survey to follow the careers of skilled workers, although again they focus on the small percentile – the PhD graduates. There is no argument that PhD-qualified researchers are critical for innovation, technology and science for economic, health and social life, but indicators on all levels of trained workers are badly needed. NewCronos has information on training that for the most part seems to predate 2000. There are a few limited indicators on life-long learning, such as the measures introduced to the LFS.

Mobility indicators

The mobility of scientists and engineers – between firms, countries and between firms and the public research sector – is commonly believed to diffuse knowledge and consequently support innovative capabilities, but indicator development remains weak. There are two dimensions to the policy interest in mobility. There are policies to promote mobility where the situation is seen as win-win, benefiting all parties. Examples include programmes to encourage mobility within Europe and hence knowledge exchange, or programmes to facilitate public sector and private sector exchanges to encourage knowledge diffusion. Government-university interchanges encourage networking and knowledge exchange. European policy has identified the need to improve the commercialization of R&D and so policies that encourage and enable commercialization are important. Then there is mobility that benefits one party but may cost the other party(s). Flows from public research to private research due to lack of R&D support may undermine public research needs. A key policy interest concerns skilled researchers moving abroad (e.g. outside of ERA) to carry out their research and the apparent lack of attraction ERA has for highly skilled foreign researchers. Much of the indicators are based on anecdotal evidence and ad hoc surveys. Mobility indicators are critical for R&D policy needs from education to immigration to R&D investment.

Inter-occupation

It is important to discriminate when it comes to occupation indicators. There are the readily available indicators from surveys like the LFS that tell of general occupation shifts and for the most part they can provide information on level of education, broad field of specialization and characteristics of age and gender. There are no EU-wide occupation indicators on the types of skills within occupations or how this has been changing over time. There are difficulties with international comparability because different countries apply different edits on their occupation categorization. For example, the occupation of engineer may include a variety of fields and a variety of skill levels. One has only to imagine what might be included in the occupation ‘computer specialist’ to get an idea of the types and levels of skills these occupations use and the challenge of providing comparable indicators. The traditional practice is to group occupations according to high, medium and low skilled, which is rather tenuous when sector variation is considered. Occupations in management in one R&D sector may have a rather different human resources profile in another. One may even find that in one sector it is considered medium skill level and in another high skill level; international differences exacerbate the situation.

We can also suggest the need to identify indicators that are weak or missing at the occupation level because the skills and education of workers are factors of mobility, just as mobility enhances the skills mix a worker can bring to bear on a task. For example, new work practices such as smaller and goal oriented teams ask for versatility, judgement and cognitive and social competences (see Arnal et al, 2001). As recently as the 1980s, concerns about the need for engineers to have more than technical skills was expressed as a challenge in a business environment that asked employees to have a set of different skills and most importantly, the ability to communicate. In the KBE, the skills 'mix' and adaptability of knowledge workers is critical. The report of Arnal et al. speaks of the new approach to production processes as needing to be 'lean' and more responsive to market changes. Today, researchers can be expected to bring together a research team, carry out research, train members of the research team and also have financial and management responsibilities. Occupation indicators, beyond the more traditional indicators grouped around high, medium and low skilled occupations, are extremely limited and available for only a limited number of EU member countries.

<u>Inter-sector</u>

Mobility between firms is a method of knowledge diffusion. Labour needs to be mobile to exploit new technologies, in some cases moving from 'sunsetting' activities to areas of growth and for being able to adapt to organizational change at the firm level. The LFS can provide general information on job to job mobility (e.g. country trends, tenure trends). New Cronos does provide an indicator for the job-to-job mobility of persons employed in science and technology but few characteristics about the persons are known and indicators for factors of mobility are basically non-existent (e.g. salaries could be used for composite indicators but salary is not necessarily the primary factor of scientists' and engineers' mobility).

Indicators on knowledge flows between the public research sector and firms are a key area for development. For ERA goals and needs, indicators on R&D cooperation, knowledge exchange and societal impact have become more and more important to assess the efficiency of innovation systems.

Knowledge flows between public research organizations and private enterprises can occur in different ways, one of which is the movement of research staff to positions in private firms. We could find few indicators on flows between public research institutes and firms.

Another area where we lack indicators is on the physical movement of skilled workers including the timing and duration (e.g. how much does the actual physical movement of skilled workers matter and what are the time periods; do they tend and/or need to be short-term, medium-term or long-term?). A Danish study suggests that employment growth in firms with industry-science relations (ISR) is higher than in firms with no ISR interactions — a 2003 survey by the Danish Centre for Research and Research Policy shows that growth in employment was more than double for those with ISR interactions compared with those for no ISR interactions (figures compared 2000-2002 employment averages to 1999.

There are a number of routes for knowledge to flow between the research sector and firms including open science, temporary exchanges and informal contacts during conferences. Again, the Danish work provides us with an example of the type of indicators we need to explore. Firms may participate in several types of ISRs and how knowledge flows from the public research sector to firms brings about different types of interactions that in themselves serve to encourage knowledge flows. Indicators that consider the impact of 'human' knowledge flows between public sector research and private firms are not available for most EU countries.

International

Mobility is stressed by the Aho report, which sets a target for 10% of scientists and engineers moving in each year. 2006 has been designated as *The European Year of Workers' Mobility* (http://europa.eu.int/comm/employment_social). Yet mobility can have a negative impact: highly skilled people can leave a country, or too much mobility could be economically inefficient.

There are some indicators available at the EU level (e.g. New Cronos on cross-border mobility), but they are limited to students and not graduates. Moreover, there are no data to develop indicators according to the area of specialization of training of the students (e.g. science, engineering, humanities). There is no information to develop indicators on international mobility because these files do not track where the students end up after graduation (e.g. stay in the country or leave).

From the LFS we have limited indicators on country to country mobility such as how few EU-25 citizens live and work in a country other than their country of origin — a mere 1.5%. As in the case of freshly trained researchers, indicators on characteristics and factors of international mobility are scarce. Those that are available are typically from ad hoc surveys in some of the member states with the largest contingents of human resources in science and technology. These countries have a vested interest in tracking this small but critical segment of their labour force.

For the EU, there is little information on where the student goes after graduation. The indicator for all tertiary foreign students includes data on the country of origin, so students from other EU countries can be identified. The disadvantage of these two indicators is that 1) they refer to all tertiary or all PhD students, rather than specifically to S&E students, and 2) there is no information on whether or not the students remain in the country after graduation. US policy makers can rely upon indicators of the National Science Foundation that not only tell of the post-graduate plans of their PhD science and engineering graduates including the sector they plan to work in, but they also have these indicators for Europeans who earn their PhD in the United States. Do the Europeans plan to stay and work in the U.S. or do they plan to leave? Policy has key information on an important factor of supply.

A study in France suggests researchers are leaving because of an absence of adequate opportunities in France. Another study suggests students tend to stay and work in the country where they obtained their PhD or are less likely to return to their native country after studying abroad (see MERIT, Brain Drain Study 2003). Results of a MERIT study show that factors of international mobility are different for Europeans when compared with their American or Asian colleagues.

There is another dimension to the discussion of international mobility and that is of course that researchers need to explore opportunities to acquire skills and experience in their most productive years of their career and so working abroad is good for science and good for the scientist. At the same time, Europe could profit from its researchers abroad by having ongoing relationships and creating networks of access and knowledge exchange. We can find no indicators for the EU (except for ad hoc or special surveys) on the factors that drive or attract (they may not be the same) European talent abroad or the factors that might influence foreign talent to come to work in Europe. This is critical information for a range of policy, from R&D to immigration. It would be wrong to assume immigration policy can be flexed as quickly or be as successful in the future, with global pressures for talent as it was even a few decades ago.

2.3. Knowledge production and diffusion

Knowledge production is a key focus of science and technology policy. Relevant policies include support for the public research infrastructure, including the training of students at all levels up to doctorates, subsidies for R&D conducted by firms, and institutional programmes for intellectual property protection, such as the patent, design, and copyright systems. The diffusion of knowledge (in contrast to the diffusion of innovations) is supported by public programmes to encourage the commercialisation of public sector research, including funding of technology transfer offices (TTOs) at universities and government research institutes, changes to legislation to encourage the patenting of publicly-funded inventions, and a variety of policies to encourage knowledge sharing among firms, ranging from Framework Programmes to support collaborative research to more ambiguous programmes to support industry clusters.

There are three main types of indicators for knowledge production; R&D, patents and bibliometrics, and a set of indicators for knowledge flows.

R&D, patents and bibliometrics

The family of indicators for R&D, patents and bibliometrics have been under development for several decades and are consequently highly developed, with only a few areas where the indicators are unsatisfactory. The three main problems concern R&D[3].

Indicators for public sector expenditures by field are insufficient, with current data based on dividing GBAORD data (Gross budget appropriations or outlays for R&D) among major NAB categories (Nomenclature for the analysis of science budgets), such as ‘industrial production and technology’ or ‘protection and improvement of human health’. These categories are not detailed enough to permit an estimate of the amount of public R&D expenditures for key generic technologies such as ICT or biotechnology. Furthermore, comparability in how governments classify outlays for health R&D is required. Young (2001) notes that many countries assign health R&D to different NAB categories, rendering international comparisons meaningless.

A related problem also applies to the data for business sector R&D (BERD). Comparable data for biotechnology are not yet widely available, although the situation is rapidly improving, with 14 OECD countries including a question on biotechnology R&D expenditures in their official R&D survey.

Another problem for international comparisons is the quality of data for R&D in the business services sector. Many service sector firms, such as in NACE 73 (R&D services) or even in wholesale and retail trade perform R&D, but the purpose of the R&D is to develop new and improved manufactured products. In some countries the R&D surveys collect data on the purpose of the service sector R&D and assign R&D conducted under NACE 73 on pharmaceuticals, for instance, to the pharmaceutical manufacturing sector. Other countries, including the United States, assign all R&D to a firm’s principal economic activity, which is determined by the sector of the largest share of employees. Using this definition, a major computer manufacturer can be assigned to wholesale services if it has more employees in wholesale than in manufacturing. These differences partly explain why the United States appears to perform much more service sector R&D than many European countries. Business sector data on R&D would be both more accurate and more comparable if all countries used the product-based approach instead of the principal activity approach. Other methods of disaggregating R&D data by region or firm size would also assist policies, such as those that support regional clusters or SMEs.

The third problem with R&D data is that it does not adequately cover the continuous globalisation of R&D. R&D statistics are currently based on national jurisdictions,

[3] For a more extensive discussion of R&D indicator improvements, see Arundel et al, 2006.

whereas large multinational firms can conduct a substantial share of their R&D in other countries. In terms of the firm, its global R&D expenditures are more relevant, in terms of its R&D intensity or innovative success, than its domestic R&D expenditures alone.

Patent data have several well-known limitations: not all innovations are patented, many patents have no economic value, and the number of patents per innovation is highly variable. The first two problems can partly be overcome by using 'triadic' patents, or patents for the same invention that are applied for or granted in the world's three major patent jurisdictions, the European Patent Office, the US Patent and Trademark Office, and the Japanese Patent Office. Unfortunately, triadic patent data has a lag time of four to five years before it is available. For instance, the most recent triadic patent data in late 2005 was for 2001.

Knowledge flows

Indicators for knowledge flows are a fairly new area. Most indicators to date are based on the European Union's Community Innovation Survey (CIS) and cover links with public research institutes and collaboration. A problem with many of these indicators is that they provide no information on the type of knowledge that is obtained, or on its purpose. This could particularly important when firms are part of a value-added chain. Their innovation strategies can be determined by the requirements of their suppliers or customers.

A key requirement is an indicator on the role of knowledge diffusion in the development of innovations. For instance, firms can develop an innovation entirely within house or in collaboration with other firms or with public research institutions. Surprisingly, we don't have such an indicator, although it would be possible to construct one using the CIS questions on 'who' developed both product and process innovations. This could provide a measure of the share of firms that rely on the diffusion of knowledge for their innovations.

Indicators for knowledge flows between firms and the public research sector can be constructed using, co-patenting, co-publishing, or the CIS data. A drawback is that all of these indicators only measure formal knowledge exchange. They completely fail to capture the role of 'public science', such as open publication and dissemination of knowledge by university academics.

Knowledge flows from the public to the private sector can also occur through spin-offs and licensing. We are not aware of any internationally comparable data for these two methods for European Union countries. Although several projects have been conducted in the EU to gather data on spin-offs and licensing by universities and research institutes, none have gathered consistent data for a majority of EU member states. The OECD ran a pilot survey in 2001 to gather such data, but there was no follow-up and only eight EU countries participated in the 2001 study (OECD, 2003).

Even then, not all of the eight countries used the standard model questionnaire developed by the OECD. In the spring of 2006, the Association of Science and Technology Professionals (ASTP) ran a survey of its members to replicate data obtained on a regular basis by the AUTM for the United States. The survey results show that it is feasible to obtain data on spin-offs at a relatively low cost, but the ASTP membership does not include the majority of European universities and research institutes. The ASTP results permit the calculation of an indicator of the number of spin-offs and licenses per million Euros of R&D expenditures, which can be directly compared to equivalent AUTM data.

2.4 Innovation, entrepreneurship and creative destruction

Innovation is widely believed to be central to European economic competitiveness and is consequently featured in a range of policy documents, both at the national level and from the European Commission. Many pro-innovation policies are based on subsidizing knowledge production, either directly or through fiscal benefits for R&D, but innovation is also supported through manufacturing extension services to promote the adoption of productivity enhancing technologies such as Advanced Manufacturing Technology (AMT) or ICT, other information services, and subsidies to SMEs for hiring scientists and engineers or acquiring new technology. A few countries also provide government support for innovative start-ups, such as venture capital. Entrepreneurship is difficult to support, but there is widespread discussion about including courses on entrepreneurship and patenting in the syllabus for science and engineering students. Entrepreneurship is also supported directly through government provision of grants, loans and early-stage financing to small innovative firms and indirectly through tax relief to investors in venture capital firms.

Technical Innovation

Innovation indicators for innovation expenditures, the sales share of innovative products, and the percentage of firms that innovate are available from the CIS. The main problem is that there is a need for disaggregated indicators on how firms aggregate.

In addition to creative in-house innovation (which can be captured by the percentage of firms that perform R&D), firms can also innovate through the uptake and successful adoption of new technology by developed by other firms or the public sector (embodied technology diffusion). Currently, an indicator for ‘adoptive’ innovators is not available, but it would be simple to construct from CIS data.

A second missing indicator is on the effects of process innovation, such as amount of cost savings that are due to process innovation. Germany has included a relevant question in its version of the CIS (Aschhoff et al, 2006), but similar questions have not been adopted in other EU countries.

Organisational innovation

Organisational innovation can be a key factor in both productivity growth (Brynjolfsson and Hitt, 2000; Murphy, 2002) and the ability of firms to profit from product and process innovation. The fourth CIS provides new options for constructing indicators on organizational innovation on 1) knowledge management, 2) organization of work, and 3) relationships with other firms or public institutions. CIS-4 also asks about four types of outputs of organizational innovation, so it is possible to determine which of the three types of organizational innovation have the greatest impacts on quality or production costs. A main limitation for CIS indicators on organizational innovation is the lack of time series.

Research on the KBE shows that work reorganization is one of the main organizational changes in today's workplaces. So far, it has been difficult to find timely and comparable indicators on new work practices. Surveys tend to be carried out on an ad hoc basis and at national levels. A 1996 survey of European managers in ten EU countries found that workplaces with direct participation in management outperformed those without direct employee participation in management. Due to its potential impact on firm performance and employment, we need indicators on the level of responsibility given to employees. Low levels of responsibility are correlated, at the national level, with poor innovation performance. An intriguing possibility is that low responsibility could also be responsible for possible European weaknesses in commercialization and mobility.

Entrepreneurship

Entrepreneurship is possibly one of the most important drivers of innovation and one of the most difficult to measure. It involves individual attitudes to risk, opportunities that reduce risk, receptiveness to new ideas, and access to capital. Most indicators of entrepreneurship either measure individual attitudes, such as the Flash Eurobarometer measure of attitudes to starting a financially risky business, or attitudes to self-employment.

There are virtually no indicators for entrepreneurship within existing firms, such as the rate of formation of new spin-off firms or the rate of introduction of new products (the latter would require a question on the number of significantly new products that were marketed, which might not produce reliable responses). In addition, indicators of individual attitudes to entrepreneurship do not differentiate between establishing a 'mom and pop' shop and establishing a firm with an innovative business strategy.

In addition to the role of entrepreneurship in establishing firms, the policy goal is for these firms to succeed and grow rapidly. While the CIS is a possible source of data that can identify innovative fast-growing firms, the difficulty is to define 'highly innovative SMEs'. Indicators are still limited to fast-growing SMEs with very high R&D intensities (above 5% and above 10%). There are no indicators for different types of fast growing innovative firms such as those that score high on the efficient adoption of new technology. These missing indicators are crucial because depending on national conditions, the fastest growing SMEs may not be R&D intensive, but technology adopters, or possibly firms that rely heavily of knowledge diffusion over in-house creative activities.

Venture capitalists and technology transfer officers at universities and research institutes frequently complain that the problem in Europe is not a lack of ideas for the formation of innovative new firms, but a lack of experienced managers who can guide the development of an invention through to commercialization. We are not aware of any indicators that cover the availability or quality of such managers. There are indicators for managers (e.g. by formal education and by occupation) but they do not provide for breakdowns for targeted groups to link to commercialization.

Entrepreneurship not only depends on the ability to establish new firms, but on the replacement of older less efficient firms. This is part of creative destruction, or the continual entry of new firms and the exit of established firms that no longer provide competitive advantages - or what is called ‘churn’. This process assists productivity growth and increases value-added from product innovation Blanchard (2004). Firm exit is often dependent on the regulatory environment, which can reduce churn and thereby discourage entrepreneurs from entering a market. Currently, the necessary data to calculate churn are only available for a limited number of EU countries[4].

Demand for innovative products

The risk of innovation, and hence the willingness of established firms to invest in innovation or entrepreneurs to set up a new innovative firm, crucially depends on the expected market demand for innovative products (goods and services). Nevertheless, there are few relevant indicators for demand, even though demand can be influenced by both regulatory policy and by public procurement.

A substantive body of literature, starting with Porter in the early 1990s, argues that sophisticated *domestic* demand for innovative products is an essential driver of innovation. This theme was most recently restated in the Aho Report. Where domestic demand is inadequate, firms can also develop international markets. The problem for Europe might lie more in encouraging innovative firms to enter global markets than a lack of domestic demand. Conversely, local demand conditions could be essential to firms that do not innovate. This gap in innovation demand indicators must be addressed.

Government forms a major buyer of products and services. This creates a potentially important role, noted by the Aho Report, for government procurement policies to encourage innovation. However, there are no indicators for governmental demand for

[4] An indicator for churn can be created from two New Cronos indicators: er081 for new enterprise establishments and er082 for enterprise exits. The total can be standardized by dividing by GDP in millions of Euros.

innovation, which could be particularly important for countries that are not at the leading edge of consumer innovation demand. We have no indicators on how governments' demand for innovation relates to the national average demand. This leaves policy without measures of how government is setting the example (e.g. as in the case of ICT adoption for some countries) or not, and how government adoption compares with national demand.

A potential aggregate measure of demand by businesses is gross fixed capital formation (GFCF), defined as the acquisition less disposals of buildings, structures, machinery and equipment, mineral exploration, computer software, literary or artistic originals and major improvements to land such as the clearance of forests. The value of GFCF as a measure of demand depends on the reasonable assumption that almost all new capital equipment will contain technical improvements over existing stock. The disadvantage of GFCF is that it includes expenditures that are not related to innovation, particularly land and buildings (although new buildings might contain innovative, productivity-enhancing features) and improvements to land. It would be much more useful to have an indicator for GFCF that is limited to capital equipment.

2.5 Economic and Social Outputs

Available economic indicators include national production (GDP), productivity, and employment, plus value-added and productivity indicators at the sector level. All are generally acceptable for measuring the output of a KBE.

There is also a wide range of available indicators for social performance, including environmental indicators, employment and welfare, and quality of life indicators. The most serious problem concerns the latter. The available quality of life indicators measure aspects such as life expectancy, accidents, or living conditions that do not get to the heart of social satisfaction. One option is to use indicators for happiness, which are available for many countries, both within Europe and abroad from the World Values Surveys. However, economic research is still resistant to using such indicators, although an economics course on happiness is accordingly one of the most popular courses on offer at Harvard. An alternative approach is to improve the usefulness of monetary measures such as GDP as a measure of well-being.

The OECD (2006) recently evaluated several alternative versions of GDP that seek to overcome several of the limitations of the indicator: GDP assigns leisure a zero value, does not accurately measure income available to household consumption, makes no allowance for income distribution, and does not consider negative externalities. Possible adjustments to GDP include its replacement with Gross National Income (GNI), which measures actual domestic income (this change has a significant negative effect for Luxembourg and Ireland and positive effect for Switzerland), weighting methods to adjust for income inequality, or an adjustment that assigns a monetary value to leisure time.

Environmental innovation

Although there are many indicators for environmental impacts (CO_2 production, air pollutants, etc), there are very few indicators for environmental innovation. Patent data are difficult to use for this purpose because environmental innovations are very difficult to identify, requiring pain-staking analysis. The primary requirement is for indicators on the effect of environmental innovation on production costs.

The KBE and the Citizen

There are very few indicators that measure the direct effect of the concept of the KBE on individual citizens.

One example is the effect of tele-working, which has several relevant socio-economic dimensions, including human resources and ICTs. Tele-working can be considered part of a KBE because it is made possible by ICT and by other organizational changes, such as giving greater responsibility to employees. Tele-working has potential social benefits for the environment, by reducing transport pollution, and it could have quality of life benefits (or costs).

There are few official indicators on tele-working. Research on tele-working tends to be at the national level, and/or on an ad hoc basis, and the definitions vary. Indicators on tele-working should assess the benefits and costs to citizens and firms. Is tele-work something to be encouraged, benefiting both citizens and firms, or would indicators point to benefits going to mainly one party, the citizen or the firm? These are important indicators for policy for reasons beyond productivity and workplace change. For example, does tele-working present wider job opportunities or is it evolving into a practice used by firms to outsource repetitive functions and limit the employee's advancement and skills' upgrading? Does tele-working represent a positive development for families allowing for more flexibility, or does tele-working mean office work is now officially brought home and the line between work and family life is increasingly blurred?

2.6 Other Challenges: Public sector Innovation and Globalisation

Two other areas where current indicators are unsatisfactory or missing are for innovation in the public sector and the cross-cutting issue of globalization.

Public sector innovation

Governments are both a major purchaser of innovations and a major provider of services that can benefit from adopting technological or organizational innovations. Nevertheless, there are almost no comparable indicators for innovation in the public sector, with the exception of indicators for the e-economy, such as the provision of public services on-line. For instance, there are comparable indicators for whether or not citizens can file taxes or download government application forms over the internet. Given the economic importance of the public sector, the development of indicators for public sector innovation should be a very high priority in Europe.

As almost all public sector organizations are large, there are enormous opportunities for productivity gains through organisational innovation and technology adoption. Canada has experimented with gathering data on both types of innovation (Earl, 2004), but we are not aware of any equivalent research in Europe.

We would also benefit from indicators of the benefits or success of innovation in the public sector. It may well be easier for a segment of the population to download government documents via the Internet but this presupposes a certain level of education and access to the Internet. To what extent this has made life easier for citizens at large, or has life been made less productive and more complicated? Does public ICT innovation mean that a service office in a rural community is lost resulting in loss of jobs and expanding the digital divide from urban to rural or perhaps, does the on-line library service mean access and education where before there was none?

Globalisation

Innovation activities are increasingly global as firms perform more of their innovation activities in foreign countries. Existing indicators such as R&D spending of affiliates as a percent of total BERD, the percentage of total business R&D funded from abroad, co-patenting by individuals in different countries and co-authorship share for international scientific articles are generally limited to the EU-15. Moreover, these indicators share a common problem: the degree of internationalization is positively correlated to the size of the domestic economy. Small countries have higher levels of co-patenting and co-authorship than large countries because there are fewer opportunities to find a co-author or co-inventor in the domestic market. So while there are some indicators for globalization, they are weak and additional sources for indicators need to be developed.

3. Summary

This state-of-the-art report identifies where key knowledge economy indicators are unsatisfactory or entirely lacking for the EU-25. We have considered existing data sources at the national and EU levels (e.g. Eurostat, CIS) and ad hoc surveys in member countries (e.g. the Danish survey, the MERIT survey). This report is not meant to be an all encompassing ‘inventory’ of data and indicator gaps. Rather, the aim of this report is to identify key unsatisfactory and missing indicators for current policy priorities (e.g. targeting science, technology and innovation as part of ERA) and secondly, information needs for future policy development in a KBE driven by scientific and technological developments. Here we consider key missing indicators such as those that affect life, work and governance.

The results of this overview are summarized in three Annex tables. Annex Table 1 provides a summary of incomplete indicators that are missing for the EU-15, EU-25 or individual countries for the main KEI indicators. Annex Table 2 suggests areas of unsatisfactory key indicator coverage, while Annex Table 3 identifies areas where key indicators are largely missing.

In addition to the problem of data gaps in specific EU member states or over time, many indicators suffer from poor comparability across countries (or sectors and regions), due to inconsistent definitions and/or survey methodology. The task of suggesting remedies for these weaknesses and filling the KBE indicator gaps for the short and long term needs of policy and decision makers will be addressed in WP 4.2.

4. Annex Tables

Annex Table 1. Incomplete Indicators

Annex Table 2. Unsatisfactory Indicators

Annex Table 3. Missing Indicators.

Annex Table 1. Incomplete Indicators.

Indicator	EU-25 series × missing ✓ complete	EU-15 series × missing ✓ complete	Selected countries or selected years in the time series × missing ✓ complete
Production and diffusion of ICTs			
Economic Impact of ICT sector			
ICT expenditure expressed as a share of GDP, 2000 to 2004.	×	×	× for selected countries × for selected years
Number of patent applications to the EPO in ICT patent classes (priority year) per million population, 1981 to 2002.	✓	✓	× for selected years
Number of patents granted at the USPTO in ICT patent classes (priority year) per million population, 1981 to 1999.	✓	✓	× for selected years
Internet use by firms			
Businesses receiving orders over the Internet, 2003 to 2005.	×	✓	× for selected years
Percent of individuals making use of the Internet by age, 2003 to 2005.	×	✓	× for selected years
Broadband penetration rate (number of broadband lines per 100 population), 2002 to 2005	×	✓	× for selected countries × for selected years
Government ICT Production and diffusion of ICTs			
Percentage of individuals using the Internet for interacting with public authorities broken down by purpose, 2000 to 2005.	×	×	× for selected years
Human resources, skills and creativity			
General Education Indicators			
Science and technology graduates - Tertiary graduates in science and technology per 1000 of population aged 20-29, 1993 to 2004.	×	×	× for selected years
HRST education indicators			

	EU-25 series × missing ✓ complete	EU-15 series × missing ✓ complete	Selected countries or selected years in the time series × missing ✓ complete
Total HRST as a percentage of total employment by age cohort, 1993 to 2004.	×	×	× for selected countries × for selected years
Skills			
Hours in CVT courses per 1000 hours worked (all enterprises), by NACE, 1999.	✓	✓	✓
Participation in life-long learning per working age population (25-64), 1994 to 2005.	×	×	× for selected years
Mobility			
Annual data on job-to-job mobility of highly qualified personnel (employed HRST) aged 25-64 at the national level by gender, 1994 to 2004.	×	×	× for selected countries × for selected years
Knowledge production and diffusion			
R&D family			
GERD expenditure as a share of GDP, 1981 to 2005.	×	×	× for selected countries × for selected years
GERD per capita population (current PPP$), 1981 to 2005.	×	×	× for selected countries × for selected years
Estimated civil GERD as a percentage of GDP, 1981 to 2005.	×	×	× for selected countries × for selected years
GOVERD and HERD as a percentage of GDP, 1981 to 2005.	×	×	× for selected years
BERD as a percentage of GDP, 1981 to 2004.	×	×	× for selected years
BERD as a percentage of value added in industry, 1981 to 2004.	×	×	× for selected years
Patents			
EPO patent applications, 1977 to 2004.	×	×	× for selected years
EPO high tech patent applications by priority year per million population, 1977 to 2004.	×	×	× for selected years
USPTO high tech patent grants per million population, 1977 to 2004.	×	×	× for selected years
USPTO high tech patent grants per million population, 1977 to 2004.	×	×	× for selected years
Triadic patent families by priority year per million population, 1981 to 2005.	×	×	× for selected years

	EU-25 series ✗ missing ✓ complete	EU-15 series ✗ missing ✓ complete	Selected countries or selected years in the time series ✗ missing ✓ complete
Bibliometrics			
Knowledge flows			
Share of all firms reporting public research as a high value information source, 2000.	✗	✗	✓
Share of all firms reporting public research as a cooperation partner, 2000.	✗	✗	✗ for selected countries
Share of SMEs collaborating on innovation, 2000.	✗	✗	✗ for selected countries
Total investment in intangibles			
Innovation, Entrepreneurship and creative destruction			
Entrepreneurship			
Firm entries - real enterprise births of year n, as a percentage of the population of active enterprises of year n, 1997 to 2003.	✗	✗	✗ for selected countries ✗ for selected years
Firm exits, 1997 to 2003.	✗	✗	✗ for selected countries ✗ for selected years
Demand for innovative products			
GFCF as a percentage of GDP, 2003 to 2005.	✓	✓	✗ for selected countries ✗ for selected years
Firm level technology absorption,	✗	✗	✓
Market innovation outputs			
Share of firms introducing new to market products, 2000.	✗	✗	✗ for selected countries

	EU-25 series × missing ✓ complete	EU-15 series × missing ✓ complete	Selected countries or selected years in the time series × missing ✓ complete
Share of total sales from new to market products, 1998 to 2004.	×	×	× for selected countries × for selected years
Share of firms introducing new to firm products, 1998 to 2004.	×	×	× for selected countries × for selected years
Share of total sales from new to firm products, 2000.	×	×	× for selected countries
Community design registrations per million population, 2002 to 2004.	✓	✓	× for selected countries × for selected years
Organisational indicators			
Percent of SMEs reporting non technological change, 2000.	×	×	× for selected countries
Economic outputs			
Income			
GDP per capita in PPS, 1995 to 2007	✓	✓	✓
Real GDP growth rate, 1995 to 2007.	×	×	× for selected years
Productivity			
Labour productivity per hour worked	✓	✓	× for selected years
Gross fixed capital formation – current prices – millions of euro – as a percentage of GDP, 2001 to 2005.	✓	✓	× for selected years
Employment			
Total employment growth, 1992 to 2004.	×	×	× for selected years
Total employment rate, 1992 to 2004.	×	×	× for selected years
Environment			
Energy intensity of the economy, 1991 to 2003.	×	×	× for selected years

	EU-25 series ✗ missing ✓ complete	EU-15 series ✗ missing ✓ complete	Selected countries or selected years in the time series ✗ missing ✓ complete
Employment and economic welfare			
Employment rate of older workers, 1992 to 2002.	✗	✗	✗ for selected years
Long term unemployment rate, 1992 to 2002.	✗	✗	✗ for selected years
Inequality of income distribution, 1995 to 2004.	✗	✗	✗ for selected years
Quality of life indicators			
Internationalisation			
Trade			
High tech exports as a share of total exports, 1990 to 2004.	✗	✗	✗ for selected countries ✗ for selected years
Direct inward investment flows as percent of GDP, 1993 to 2004.	✗	✓	✗ for selected countries ✗ for selected years
Knowledge production and diffusion of knowledge			
R&D spending of affiliates as a share of total BERD, 1982 to 2005.	✗	✗	✗ for selected countries ✗ for selected years
Share of R&D funded from abroad, 1981 to 2005.			
Economic structure			
FDI intensity, 1993 to 2004.	✗	✗	✗ for selected years
Human resources			
Number of foreign students (non-EU) in tertiary education ISCED 5 as a percentage of tertiary education ISCED 5, 1998 to 2003.	✗	✗	✗ for selected countries ✗ for selected years
Number of foreign students (EU) in tertiary education ISCED 5 as a percentage of all tertiary education, ISCED 5, 1998 to 2003.	✗	✗	✗ for selected countries ✗ for selected years

Annex Table 2. Identification of key unsatisfactory indicators	
Indicator group	**Key missing indicators**
Production and diffusion of ICT	**Non formal versus formal qualifications**
Human resources, skills and creativity	▶ General education: ▪ non-traditional learning ▶ HRST: ▪ employment outcomes of graduates (e.g. occupation, sector) ▪ in-house training ▪ multi-tasking of researchers (e.g. activities and skills needed) ▶ Mobility: ▪ firm to firm
Knowledge production and diffusion	▶ R&D: ▪ public sector expenditures by field insufficient (e.g. do not provide for estimate for key generic technologies); ▪ business sector R&D (e.g. product-based approach); ▪ global R&D expenditures. ▶ Patents: ▪ not all innovations captured in patent data; ▪ lack of economic value for some patents. ▶ Knowledge flows: ▪ industry-science relations (e.g. impact on firm growth, employment growth); ▪ existing indicators limited to 'formal' knowledge exchange – ignore role of public science (e.g. missing publication and dissemination of academics' knowledge)

Innovation, entrepreneurship and creative destruction	► Entrepreneurship indicators: ▪ measures of entrepreneurship within existing firms — ability to discriminate between entrepreneurship oriented to an innovative business strategy or one without (e.g. corner store); ► Demand for innovative products: ▪ indicators for demand for innovations; ▪ indicators for regional, domestic, international demand (e.g. responding to local, national or international demand). ► Financing of innovation: ▪ total venture capital indicator does not provide for effect at various stages (e.g. start-up, availability during growth stages).
Economic indicators	GDP measures that value leisure time, income distributions, and negative externalities.
Globalisation	► human resources indicators: ▪ number and type (e.g. specialization) of foreign-born HRST, broken down by level (e.g. technical, bachelor, PhD); ▪ source of foreign-born HRST (country of origin, country of degree); ▪ sector of employment of foreign-born HRST (e.g. public or private sector demand); ▪ occupation of foreign-born HRST (e.g. public or private sector; e.g. basic or applied research); ▪ socio-economic characteristics need to be collected for all indicators in particular gender and age (e.g. demographic pressure on supply; women and science policy); ▪ scholarships/financial support for foreign students vs nationals; indicators on satisfaction with international posting. ► Improved measures of globalised R&D,

Annex Table 3. Identification of key missing indicators	
Indicator group	**Key missing indicators**
Production and diffusion of ICT	▶ Economic impact of ICT sector: ▪ share of firms with portals (by NACE)
Human resources, skills and creativity	▶ General education indicators: ▪ non-traditional certification; ▪ e-skills. ▪ creative capacity of the population (e.g. pre-graduation) ▶ Skill indicators: ▪ non-traditional training systems (e.g. firm level; profession level); ▪ ICT skills for ICT producer versus ICT user industries; ▪ life-long learning — training and upskilling by occupation, by education (e.g. upskilling variance by level of formal qualification and field and economic activity). ▶ Creativity indicators: ▪ skills for adopting new technologies skills mix within occupations (e.g. occupation ≠ skills); ▪ skills composition of research teams (e.g. formal qualifications (level and field), non-formal (e.g. professional training). ▶ Mobility: ▪ sector: duration, frequency ▪ occupation: duration, frequency.

Knowledge production and diffusion	Knowledge flows: ▪ indicators on type of knowledge obtained from industry-university collaboration ▪ role of knowledge diffusion in innovation development.
Innovation, entrepreneurship and creative destruction	Entrepreneurship: ▪ measures of entrepreneurship within existing firms — rate of formation of new spin-off firms; ▪ measures of entrepreneurship within existing firms — rate of introduction of new products. ▪ indicators on availability or quality of managers (e.g. needed for commercialization). Demand for innovative products: ▪ government adoption of technology Financing of innovation: ▪ indicators for pre-seed, seed, and business angels. Organisational indicators: ▪ indicators on share of employees affected by organizational innovation; impact on employee duties and activities (e.g. increase or drop in responsibilities, skill needs); ▪ organizational innovation in the public sector.
Economic indicators	Employment: ▪ IT and ICT employment for ICT producer versus ICT user industries Quality of life: ▪ confidence indicators (e.g. ability to prosper in the KBE — national, personal); ▪ ranking of individual response to change (e.g. go beyond a 'happiness' scale type indicator).
Internationalisation	Knowledge production and diffusion of knowledge: ▪ diasporas (e.g. number, frequency Human resources: ▪ factors driving ERA HRST abroad; ▪ factors drawing foreign HRST to ERA

5. References

Aho report. *Creating an innovative Europe: Report of the Independent Expert Group on R&D and Innovation*, appointed following the Hampton Court Summit, January 2006, http://europa.eu.int/invest-in-research/.

Arnal E., Ok W. and Torres R., *Knowledge, Work Organisation and Economic Growth*, OECD Occassional Paper No 50 DEELSA/ELSA/WD(2001)3, 2001.

Arundel A, and Hollanders H. *EXIS: An Exploratory Approach to Innovation Scoreboards*, TrendChart, DG Enterprise, March 2005.

Arundel A, Colecchia A, Wyckoff A. Rethinking science and technology indicators for innovation policy in the 21st century. In Gault F and Earl L (Eds), *Innovation and Impacts: The Next Decade,* pp 167-197, McGill-Queen's University Press, Kingston, 2006.

Aschhoff B, Doherr T, Ebersberger B, Peters B, Rammer C, Schmidt T. Results of the German Innovation Survey 2005, ZEW, Mannheim, March 2006.

Blanchard, O. The Economic Future of Europe, *NBER Working Paper 10310*, NBER, Cambridge Mass., February 2004.

Brynjolfsson E, and Hitt LM. *Beyond computation: information technology, organizational transformation and business performance*. Journal of Economic Perspectives 14:23-48, 2000.

European Commission (2003), Communication from the Commission *The Role of Universities in the Europe of Knowledge*, COM (2003), Commission of the European Communities, Luxembourg.

European Commission (2001), Communication from the Commission *The Regional Dimension of the European Research Area*, COM (2002), Commission of the European Communities, Luxembourg.

European Committee for Standardization *European ICT Skills Meta-Framework – State-of-the-Art Review, clarification of realities, and recommendations for next steps*, CEN Workshop, February 2006. Ref.No.:CWA 15515:2006:E.

Graversen E.K., *The interplay and interfaces between private firms and public research organizations — why personnel mobility is an important indicator*, November 2004 (1st draft presented at European Network on Human Mobility, Oslo September 2003).

Earl, L. *Technological change in the public sector 2000* – 2002. Statistics Canada working paper, 88F0006XIE No 8, Statistics Canada, Ottawa, March 2004.

Harloe M. and Perry B., *Rethinking or Hollowing out the University? External Engagement and Internal Transformation in the Knowledge Economy*, Higher Education Management and Policy, Volume 17, No.2 ISSN 1682-3451.

Murphy M. *Organisational change and firm performance*. STI Working Paper 2002/14, OECD, Paris, April 2002.

Lopez-Bassols V., , *ICT Skills and Employment,*Working Paper 110543273678, DSTI (2002)10.

OECD. *Turning Science into Business: Patenting and Licensing at* Public *Research Organisations*, Paris, OECD, 2003.

OECD. Economic Policy Reforms: Going for Growth 2006, OECD, Paris, 2006.

OSTP, The President's Council of Advisors on Science and Technology *Report on technology transfer of federally funded R&D, Findings and Proposed Actions*, Washington, 2003.

RAND Europe, *The Supply and Demand of E-Skills In Europe*, a report prepared for the European Commission, September 2005.

Salazar M, Holbrook A. *A debate on innovation surveys*. Science and Public Policy, 31, 2004.

Young A. An assessment of national and international practices for compiling data on health-related research and development. In *Measuring Expenditure on Health Related R&D*, pp 11-22, OECD, Paris.

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