A Composite Indicator for Knowledge Transfer

Report from the European Commission's Expert Group on Knowledge Transfer Indicators

Håkon Finne, Adrian Day, Andrea Piccaluga, André Spithoven, Patricia Walter, Dorien Wellen

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FOREWORD

This report is the result of a task commissioned by the European Commission, Directorate General for Research and Innovation, Directorate C – Research and Innovation, Unit C.6 – Economic analysis and indicators, to a group of independent experts to develop a composite indicator for knowledge transfer from the research sector to other sectors, following the need to support ERAC's work on indicators on knowledge transfer and on the implementation of the IP recommendation (C(2008)1329) endorsed by the Council of the European Union. The group has previously delivered a report assessing two candidates for headline indicators for knowledge transfer (Finne *et al.*, 2010).

The immediate background for the task is lined up in chapter 1. Chapter 2 reports the group's understanding of knowledge transfer; important additional material can be found in Annex 2. In chapters 3 and 4 we develop the composite indicator and illustrate it with available data in chapter 5; see particularly Table 9 on page 31. Conclusions and recommendations are found in chapter 6. Readers mainly interested in a shorter version should read the Executive summary on page 3 and look at the chart in Figure 2 on page 27.

The group has met six times between June 2010 and May 2011 and has also consulted with a number of other individuals and institutions, particularly in the search for data not readily available from published sources. Acknowledgements are found in Annex 1 but we would like to take this opportunity to thank the Commission for entrusting us with a stimulating and rewarding task.

Trondheim, October 2011

Håkon Finne
Chair

EXECUTIVE SUMMARY

Background

Effective transfer of knowledge from the research sector (higher education institutions (HEIs) and public research organisations (PROs)) to other sectors for economic, cultural, social and personal value is of increasing importance throughout the world. In order to work towards optimal exploitation of this knowledge resource, which to a great extent is funded by public sources, a systematic policy focus on suitable indicators is needed. The European Commission's IP recommendation

What is knowledge transfer?

The Expert Group has adopted a broad concept in which knowledge transfer encompasses all functions that may lead to improved use of knowledge developed and held in the research sector for the benefit of society and its individuals. A model shown in Figure 1 on page 10 (Holi *et al.*, 2008) places knowledge transfer activities *between* activities to produce knowledge (research) and economic activities in which knowledge is converted to value. This model acknowledges different sets of actors with different skills, goals, responsibilities, and inclinations for each of the three sets of activities. The outputs of research – including new knowledge and more knowledgeable researchers – are candidates for transfer to the economic sphere to enter into economic processes along with a host of other factors required to generate economic value. Knowledge transfer activities undertaken by knowledge transfer offices (KTOs) and others, including establishing new firms based on new knowledge, licensing, collaborative and contract research (which are not knowledge transfer in themselves but facilitate it), consultancy, etc, are essential in improving the knowledge flows. They come in addition to, and intertwined with, those transfers that usually take place with less intervention, e.g. when new graduates, people going back to university for continued professional development, or even experienced researchers go out to work with innovation in established firms. Of course, networks between researchers and potential users of research are essential in that they facilitate not only contact but also actual knowledge flows.

Methodological considerations for a composite indicator

The Expert Group has chosen to develop indicators for three main sets of transfer mechanisms: through **people**, through **co-operation**, and through **commercialisation** (to use the shortest possible terms). Unfortunately, indicators for **networks** do not seem feasible at this time. Within each of these three overlapping areas, a number of component indicators are selected in order to capture a wide array of relevant activities and in order to produce a robust composite.

A composite indicator consists of a number of component indicators "added up" to a single number. In the case of knowledge transfer, this composite clearly give a better overall picture of status and development than any headline indicator available. At the same time the range of component indicators is wide enough to support the monitoring of a wide variety of national strategies in this field.

Table 1: Proposed component indicators for knowledge transfer

Knowledge transfer through trained people	Institutional co-operation in R&D and other phases of innovation	Commercialisation of research
1.1. Stock of HEI graduates employed in business enterprise sector	2.1. Number of R&D contracts in HEIs/PROs with firms and other users	3.1 Invention disclosures from HEI/PRO employees
1.2 Stock of doctorate holders employed in business enterprise sector	2.2. Number of consultancy contracts in HEIs/PROs with firms and other users	3.2 Priority patent applications submitted from HEIs/PROs
1.3. Continuing professional development revenue for HEIs	2.3. Revenue to HEIs/PROs from R&D contracts with firms and other users	3.3 Patent applications submitted from public sector actors to EPO
1.4 Employed adults (age 25-64) engaged in university level training or education	2.4. Revenue to HEIs/PROs from consultancy contracts with firms and other users	3.4. Patents granted to HEIs and PROs
1.5 Teaching in HEIs performed by people with their primary job outside the HEI/PRO sector	2.5. Firms co-operating with HEIs	3.5. New licensing agreements
1.6. Entrepreneurship propensity among HEI students	2.6. Firms co-operating with PROs	3.6. Licensing revenue to HEIs and PROs
	2.7. R&D in HEIs/PROs funded by business	3.7. International licensing trade from HEIs and PROs
	2.8. Co-publications between private and public authors	3.8. Number of new spin-offs

For a picture of the composite, please turn to Figure 2 on page 27.

Current and future data availability

Much of the data required for the proposed component indicators is collected and published in most European countries on a regular basis and made available as consistent data sets through international sources. In some of these cases, normalisations will have to be calculated using other published data. For commercialisation of research, data exist for many countries but in the majority of cases they cannot currently be aggregated to national estimates.

Conclusions and recommendations

The Expert Group has shown that it is possible to construct a reasonable composite indicator for knowledge transfer at the national level in Europe. In order to be able to publish data on an annual basis, there are three sets of tasks that need to be undertaken, listed in order of priority:

- To generate more and better data on commercialisation at the national level (task 1)
- To collect and collate data from the various sources and integrate them in a published composite indicator system (task 2)
- To improve data for other component indicators (task 3).

The Expert Group recommends for the European Commission, in suitable collaboration with ERAC and its member states, to initiate tasks 1 and 2 as one undertaking, with a single, strong project manager to secure sufficient quality, progress, and impact in both tasks. The Expert Group also recommends that the European Commission liaise with owners of on-going surveys of knowledge transfer offices (KTOs) in order to improve data availability where it is most needed, *i.e.* under the heading of commercialisation.

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1 BACKGROUND

1.1 Introduction

Vast amounts of knowledge are produced and maintained in higher education institutions (HEIs) and public research organisations (PROs). Effective transfer of this knowledge from the research sector to other sectors for use in the creation of economic, cultural, social, and personal value in society as a whole is essential in order to benefit more from the rapidly accumulating research efforts and results. Many actors are concerned that Europe may not be achieving an optimal exploitation of this knowledge resource, which to a great extent is funded by public sources. They are advocating a more systematic policy focus on knowledge transfer in order to improve it and the development of suitable indicators for monitoring progress. This report is about the latter. In the following chapters we will

- conceptualise knowledge transfer (chapter 2)
- select appropriate indicators for its monitoring (chapter 3)
- combine them into a composite indicator (chapter 4)
- illustrate the indicators with sample data (chapter 5)
- recommend a monitoring scheme that will facilitate a more accurate discussion of progress in the field (chapter 6).

But first we will trace some important developments that led to this report.

1.2 The European Commission's IP recommendation

An effective management of intellectual property (IP) may be crucial for the exploitation of research results, particularly when there is a potential for economic gain.[1] IP practices that follow the same principles across the single European market are expected to enhance and increase the exploitation of research results. The European Commission has adopted a Recommendation on the management of intellectual property in knowledge transfer activities with a Code of Practice for universities (including public research organisations) in order to promote policies at member state level and principles for their application at research institution level. At the level of individual research organisations, this IP recommendation (C(2008)1329) covers policies under the headings of intellectual property, knowledge transfer, and collaborative and contract research, but a broader range of activities "facilitating the circulation and use of ideas in a dynamic knowledge society" (p. 2) is also acknowledged. At the level of relevant public authorities, one of the issues raised concerns the need to monitor the progress made in knowledge transfer and in implementing the IP recommendation, particularly at the national level.

1.3 The ERAC Working Group on Knowledge Transfer

The Council of the European Union has endorsed the IP recommendation through its resolution of 30 May 2008. As a follow-up, Member States and the European Commission have created a Working Group on Knowledge Transfer to, *i.a.*, define and use common indicators to monitor the implementation and impact of the IP recommenda-

[1] The French term *valorisation* is gaining in usage also in English for characterising this type of exploitation, emphasising the purpose of adding value. Commercialisation is another term that is frequently used, although knowledge can also be exploited non-commercially. We will use these three terms interchangeably.

tion. This task was subsequently strengthened by the establishment of a sub-group dedicated to indicator development. The Working Group was set up by the European Research Area Committee (ERAC; then CREST) in 2009 and its work should be seen in the context of ERAC's effort to develop a comprehensive monitoring scheme for the progress of a European Research Area (EUR 24171, 2009).

1.4 The European Commission's Expert Group on Knowledge Transfer Indicators and its mandate

As a support for the ERAC Working Group on Knowledge Transfer and its subgroup on indicator development, particularly in the area of monitoring the impact of the IP recommendation, the European Commission has established an Expert Group on Knowledge Transfer Indicators, which has authored the present report. The objective of the group is twofold:

- To validate two given proposals for headline indicators for knowledge transfer
- To elaborate a proposal for a composite indicator describing different dimensions of knowledge transfer.

The Expert Group has earlier delivered a report related to its first objective (Finne *et al.*, 2010); the present report relates entirely to the composite indicator. The mandate further specifies to use the report of an Expert Group[2] on Knowledge Transfer Metrics established by the European Commission in 2008 (EUR 23894, 2009) as a starting point, to select a set of indicators, to test and develop normalised scores for the components and composite indicators using sample data, and take into account the availability of data over a ten year time period.

[2] There is also an overlap in membership between the expert groups on metrics and indicators. For membership of the present group, see Annex 1.

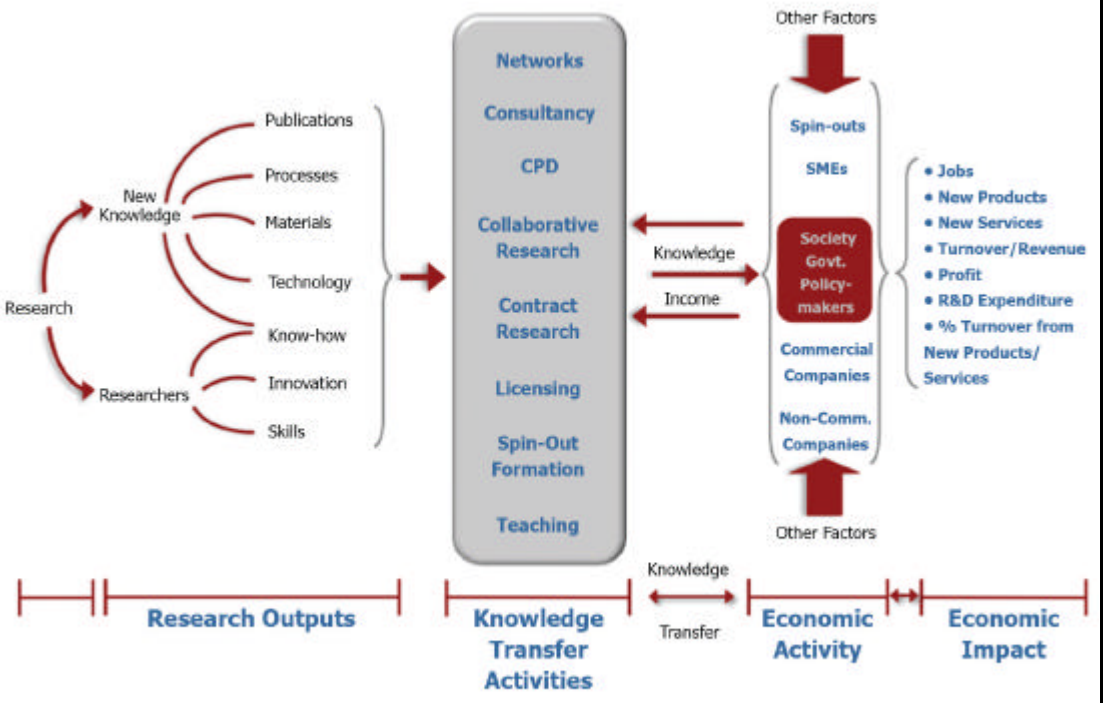
2 WHAT IS KNOWLEDGE TRANSFER, AND HOW CAN IT BE MONITORED?

2.1 Main types of knowledge transfer activity

2.1.1 Introduction

The OECD (2003) has defined technology transfer (TT) as IP management, focussing on patenting and licensing – services frequently provided by technology transfer offices (TTOs). Knowledge transfer is a broader concept that also encompasses TT, acknowledging the many forms, activities, processes, and actors involved in making knowledge from the research sector available for creating benefits throughout society. There is clearly agreement now that knowledge transfer is broader than IP management. There is also a wide array of approaches to conceptualising, classifying, and measuring it.

The Expert Group decided not to stick with a narrow concept of knowledge transfer – in which it is essentially the right to apply a certain body of knowledge that is transferred, usually in return for payment – but to move towards a broader concept, in which knowledge transfer encompasses all functions that may lead to improved use of knowledge developed and held in the research sector, for the benefit of society and its individuals. An instructive review of how some important stakeholders have expanded their views of what aspects of knowledge transfer are worth monitoring, is shown in Annex 3. The Expert Group has considered these carefully. Among the many contributions to conceptualise knowledge transfer, the group has chosen as its first source of inspiration an understanding presented in a PraxisUnico report (Holi *et al.*, 2008) that has also served as an important direct source of inspiration for the views expressed by AUTM ([2010]) and the Knowledge Transfer Metrics Expert Group (EUR 23894, 2009), and indirectly also for the ERAC Working Group on Knowledge Transfer (2010). The illustration in Figure 1 below epitomises this concept of knowledge transfer.



Source: (Holi *et al.*, 2008 p. 2; attributed to Kevin Cullen of Glasgow University).

Figure 1: Model of knowledge transfer within the innovation ecosystem

In this concept, there are three distinct types of **activities**: **research** activities, **knowledge transfer** activities, and **economic** activities; performed in principle by different sets of actors with different skills, goals, responsibilities, and inclinations. The **outputs** of research – including new **knowledge** and more knowledgeable **researchers** – are candidates for transfer to the economic sphere to enter into economic processes along with a host of other factors. The **knowledge transfer activities** in the illustration are not a complete set; nor are they mutually exclusive. Equally important, while many of the activities involve transfer of ready made knowledge or knowledgeable people, others include the joint creation and transfer of new knowledge tailored to the needs of economic actors, thus involving actors in both academia and industry. **Networks** between researchers and potential users of research facilitate not only contact but also actual knowledge flows. **Consultancy** provides existing knowledge collated by experts in universities to target clients' specific problems or opportunities. In **collaborative and contract research**, knowledge transfer goes hand in hand with knowledge production, since clients play an important role in defining the research agenda in both cases. The knowledge generation itself may on average be more jointly performed in the former case. **Licensing** of the university's intellectual property, usually to existing companies, and the formation of new companies (here called **spin-outs**) to commercialise research results, are classical technology transfer activities. Finally, **teaching** and **continued professional development** (CPD) refer to the training of people who then carry the new knowledge with them into society.[3]

[3] Obviously not all that is taught in HEIs is the result of *new* research, or even research performed in the HEI itself (since research results are disseminated globally), but research based knowledge accumu-

In a simplified image one may distinguish between knowledge transfer activities as differently weighted towards **input** (*i.e.* generation of knowledge), **throughput** (*i.e.* making knowledge ready for external use) and **output** (*i.e.* use of knowledge) of the knowledge transfer functions. To accurately attribute socio-economic impact to the original knowledge that was originally transferred, or to the quality of the transfer activities, is difficult because of the multitude of other factors. Furthermore, the heterogeneity of the model attests to its heuristic character; it cannot be said to embody a specific theory of knowledge transfer. Nevertheless, it helps clarify the width of activities that can be said to involve knowledge transfer and gives an excellent point of departure for developing new indicators and their metrics.

Bearing these developments in the KT communities in mind, and also other relevant literature and experience, the Expert Group has decided to consider intertwining knowledge transfer activities and processes from the research sector to the economic sector under the following four main headings or perspectives:

- **networks** where knowledge travels
- transfer of knowledgeable **people**
- **institutional co-operation** in solving problems and opening opportunities
- **IP management** to facilitate exploitation of research results.

These four will be considered briefly below and three of them in greater detail in chapter 3.

2.1.2 Network activities that enable and facilitate knowledge transfer

Networks between researchers and economic actors are essential for successful knowledge transfer in all phases. They have three main functions: to convey relevant information in a timely and selective manner; to give privileged or semi-privileged access to relevant resources; and to embed transactions of information and resources in relations of trust that reduce the risks associated with these transactions. Networks underpin and intertwine with all phases of knowledge transfer and can be considered enablers as well as transfer channels.

Activities to build and use networks for knowledge transfer abound. They span from informal and formal dissemination events to the bonding between university classmates that later go to both sides of the science/industry divide. Many of these networks are built by researchers and industrialists directly and on a personal basis without the intervention of intermediaries. Others are built formally with conscious effort by higher education institutions and other actors. However, the Expert Group has found it difficult to identify valid indicators of network activities that distinguish good from poor performance for the purpose of knowledge transfer which are at the same time sufficiently general to capture typical activities and can be aggregated to national level.[4] The recommendation to leave out networking from the proposed indicator set at this time is related to difficulties of appropriate definition and measurement and does in no way imply a devaluing of the importance of good networks.

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lated throughout the research sector over time. This does not diminish the importance of teaching in knowledge transfer, but its role is different from the targeted transfer of specific new discoveries.

[4] This is supported by the results of a recent study commissioned by HEFCE to explore the possibility of developing appropriate metrics for network activities (unpublished work by Bruce Cronin of Greenwich University) as proposed by the PraxisUnico study (Holi *et al*., 2008).

2.1.3 Knowledge transfer through the mobility of people educated or trained in or by the research sector

It is often said that the most important knowledge transfer activity of universities and other HEIs is to turn students into graduates and let them carry their newly won knowledge to society through the labour market. Recent studies also suggest that firms consider recruitment of qualified employees as their primary source of knowledge for R&D and innovation (EUR 24891, 2011); these employees may of course come from all sectors. The transfer of experienced researchers to the economic sphere can be an important knowledge transfer mechanism, even though it occurs at a much lower frequency. What researchers learn when performing research can be considered a highly relevant on-the-job training in this context. Education and training prepares for, and culminates in, knowledge transfer when people move out of the HEI/PRO[5] sector; it also results in strengthening of networks between HEIs/PROs and sectors outside research. Indicators for the transfer of people with education and training in the research sector as discussed here can be considered input and throughput indicators of knowledge transfer.

These activities and possible indicators, metrics and data sources are discussed in chapter 3.2.

2.1.4 Knowledge transfer through institutional co-operation in R&D and other phases of innovation

Co-operation between HEIs/PROs and economic actors in producing new knowledge, or in making known knowledge bear on problems and opportunities for exploitation, gives direction to research towards issues considered important outside the scientific disciplines themselves. This is important in itself for improving the uptake of new knowledge. Depending on the mode of operation and co-operation in the individual project, the new knowledge may be made available directly to the client even as it is created but at least at the end of the project. While only a part of such co-operation can be said to involve knowledge transfer to identified partners (the rest being R&D), it is nevertheless a form of R&D where the transfer of results is usually much more direct than in researcher initiated projects. R&D co-operation prepares for – and leads up to – knowledge transfer, and measurements of this can be considered indicators of input and throughput of knowledge transfer processes.

R&D co-operation typically falls in the categories of contract research and collaborative research, although a number of different terms are used in different contexts. An interesting case is consultancy, which by definition is not R&D because it does not aim to create new knowledge or resolve uncertainty. It is, however, an important way of making knowledge held in HEIs/PROs bear directly on problems and opportunities in innovation processes in firms.

A detailing of these activities and possible indicators, metrics and data sources are discussed in chapter 3.3.

[5] Public research organisations come in many forms and sizes and their functions in the innovation system varies between countries. Private not-for-profit research institutions may also belong here.

2.1.5 Knowledge transfer through IP transfer, mostly commercialisation of research results

Commercialisation, valorisation or exploitation of research results corresponds more or less to the classical understanding of technology transfer where the right to use discoveries and inventions made in the academic institutions is transferred to economic actors. These obviously focus on generating economic benefits. Not only patenting and licensing is involved, but also formation of – and follow-up of – spin-off and other start-up companies to convert knowledge into value.[6] The longer commercialisation process begins with preparing the ground for IP transfer and aims to follow into the realm of actually producing value. Commercialisation indicators can therefore be considered throughput and output indicators of knowledge transfer.

These activities and possible indicators, metrics and data sources are discussed in chapter 3.4.

2.2 Methodological considerations for a composite indicator

Knowledge transfer is a complex phenomenon and is best measured through a number of indicators that portray different aspects of this complexity. The Expert Group has chosen – in line with the deliberations above – to develop indicators for knowledge transfer taking place through three main sets of mechanisms: through **people**, through **co-operation**, and through **commercialisation** (to use the shortest possible terms). Unfortunately, indicators for networks do not seem feasible at this time. Within each of these three areas, a number of component indicators are selected in order to capture a wide array of relevant activities.

A composite indicator consists of a number of component indicators "added up" to a single number. The underlying components are interpretable in their own right as measurements of various dimensions of knowledge transfer. The main advantage of adding them together is to get a simple understanding of a complex phenomenon. In cases where different countries may prioritise differently, there is an additional advantage in that it gives an overall picture of performance across the various underlying dimensions. In complex cases such as KT, a composite indicator is also usually favourable to a single headline indicator, which only measures one dimension.

In order for the composite to be a valid representation of knowledge transfer, the components need to be shown not only by theory or reasoning but also by means of statistical analysis to be indicators of the same phenomenon and at the same time to be sufficiently different from each other to warrant inclusion precisely as different dimensions. For this purpose we have followed the advice of the OECD/JRC handbook on construction of composite indicators (OECD, 2008) as closely as possible and also looked to the Innovation Union Scoreboard (Hollanders and Tarantola, 2011; UNU-MERIT and EC DG JRC G3, 2011) for a practical example.

Even when the statistical properties of a composite indicator are in order, the numbers for each country need interpretation in light of the national innovation system, poli-

[6] All new firms are obviously start-ups; what is spun off in the case of university spin-offs is by our definition centred around a specific 'piece' of knowledge in which the university or one of its employees has full or partial ownership. Others have called these firms spin-outs; we will not alter their terminology when quoting them, but these are essentially what we call spin-offs, following the standard set by (EUR 23894, 2009).

cies, cultural differences, etc. It is beyond the scope of the work of this Expert Group to give any details about this interpretation. Suffice it to say that similar interpretation exercises already take place around *e.g.* the Innovation Union Scoreboard and that the description of national knowledge transfer policies and practices, including the implementation of the IP recommendation, could serve as important resources in such an interpretation. As is often the case, such numbers are better suited for comparison within and between time series than for direct comparison between a cross section of countries. Furthermore, the Expert Group supports the view that "composite indicators are better regarded as invitations to look more closely at the various components that underlie them" (Stiglitz *et al.*, 2009 p. 65), both individually and in the light of national differences as described above. Of course, the collection of components into a composite also helps determining which components are the most relevant ones to consider.

For example, a country may decide that it is currently more important for improved knowledge transfer to increase the number of spin-off companies from HEIs than it is to increase the number of consultancy contracts between PROs and private firms. In that case, it will be more interesting to consider its performance over time on total number of spin-offs per capita and compare it with the development over time of the same indicator in other countries. Is that component indicator growing faster than in comparable countries? Or a country may decide that because of its industrial and demographic structure, extra emphasis should be placed on increasing the number of employees taking evening classes at a university. The range of component indicators should make it possible to monitor the effects of many policy mixes for enhanced knowledge transfer

In this exercise, indicators are provided at the level of individual countries. For many but not all the component indicators, data are generated by adding up numbers generated at the individual HEI or PRO. Much of the data, particularly on exploitation or commercialisation, rely on collection from specialised knowledge transfer offices (KTOs)[7]. For all indicators, raw scores are aggregated to the national level and then normalised by dividing by a measure of the size of the research sector or other relevant population, or the size of the nation's economy, as appropriate for each component indicator. Unless otherwise indicated, each measure designates the flow during one year, preferably a calendar year. Then, in order to make it possible to join all the component indicators into one composite indicator, they are normalised against each other as explained in chapter 4.

The Expert Group has applied the following criteria in selecting component indicators and recommendations for a monitoring scheme:

- Indicators should capture a broad range of knowledge transfer activities (and processes) and together give a representative understanding of knowledge transfer
- Indicators should be valid measurements of the different aspects of knowledge transfer (discussed as pros and cons)

[7] KTOs usually have broader responsibilities than TTOs, but there is no uniform definition, and here it is an all-inclusive term that also includes TTOs proper. Each actor (KTO, HEI, PRO) may also wish to generate data about its own knowledge transfer activities that may be more important to the actor itself rather than as an input to indicators at the national level. This will be particularly clear in the case of KTOs.

- Data should preferably already be available as internationally comparable national scores, published or accessible through statistics agencies or others
- For data not already available, it should be feasible to generate them at the level of each HEI or PRO (or other relevant unit of observation) for aggregation to national level
- Cost and burden of generating new data should be kept at an acceptable level in HEIs/PROs etc. and at national level
- It should be organisationally feasible to collect and collate new data from different national sources, opening *i.a.* for other channels than those usually used in producing official statistics.

Indicators considered and selected are documented in the next chapter. Their combination to a composite indicator, including weighting, is discussed in chapter 4.

3 PROPOSED COMPONENT INDICATORS

3.1 Introduction

In the following three subchapters, we look closer at the three main fields of knowledge transfer through people, through institutional co-operation, and through commercialisation of knowledge. Within each of these we briefly discuss how it relates to knowledge transfer and then identify good candidates for component indicators. We characterise these and discuss their pros and cons and also comment on opportunities and challenges related to obtaining good data. This is all compressed in one table for each main area. We then apply the criteria from the end of chapter 2.2 to select our preferred component indicators and specify their definitions, how they should be normalised for comparability between countries, and data sources. This is done in Table 3, Table 5, and Table 7. Their combination to a composite indicator is documented in chapter 4.

3.2 Indicators for knowledge transfer through people (based on education and training)

Four basic groups of people can be distinguished as regards how they carry knowledge with them from HEIs and PROs to the rest of society. The largest group is students graduating from HEIs. The second group is people coming from their current jobs outside the research sector for shorter or longer training courses (continuing professional development, CPD), and then returning to their current or new jobs afterwards. The third group is people transferring from jobs in the research sector to other sectors and the fourth group is individuals who either have a shorter stay or a part time assignment in HEIs or PROs, such as an industrialist holding an adjunct professorship or a professor serving on the board of a corporation. Indicators for the fourth of these groups could also be considered indicators for networks.

The first two groups are subsets of regular graduates from HEIs and continuing education programs in HEIs, respectively. Obviously knowledge is not transferred until the candidates have entered into jobs (outside the research sector) where their acquired knowledge is relevant. Numbers for training activities are therefore only indicative of knowledge transfer at best. It may therefore better to look at influx of people with a university education into various parts of the economy, even though they do not come directly from university. A main difficulty lies in distinguishing knowledge transfer from education and training in general for these activities.

Potential indicators in a non-normalised form considered by the Expert Group follow in Table 2 below. Pros and cons relate to the validity of the proposed indicators as indicators of knowledge transfer. The considerations in the table are obviously not exhaustive but key issues have been addressed.

Table 2: Potential indicators for knowledge transfer through people transfer

Indicator	Pro	Con	Data opportunities and challenges
Flow of HEI graduates to business enterprise sector (or stock in the sector)	Primary output of HEIs for society	Actual uptake of knowledge depends on match in labour market	Annual stock available from LFS[8], but too inaccurate to calculate net flow
Flow of doctorate holders to business enterprise sector (or stock in the sector)	Transfer of research based knowledge	Depends heavily on the R&D capacity of business enterprise sector	Infrequent stock estimates available from CDH[9], data also on previous employment, theoretically possible to estimate net flow
Continuing professional development revenue for HEIs	Targeted knowledge update for firms	Difficult to distinguish job driven from person driven participation	May be reportable at HEI level
Employed adults (age 25-64) engaged in university level training or education	Measure of knowledge update	Gives equal weight to all types of training and all sectors of employment. May also include PhD students coming directly from their first degree and not from outside the research sector	Requires minor adjustment of LFS
Personnel transfer from HEIs and PROs to private sector	Transfer of research based knowledge. Occasionally critical to success (e.g. where inventors follow their inventions)	Also includes career changes where specialised knowledge is less relevant; such transfer may also be subject to budget changes in research sector	HEIs/PROs may not be allowed to record data about their former employees' new jobs; must rely on register data or surveys. Some surveys exist, but currently not part of IISER[10] indicators of researcher mobility
Researchers holding part time jobs in private sector firms	Concurrent participation in both sectors may be a very smooth channel for continuous knowledge transfer	Difficult to distinguish purely income generating secondary jobs	Difficult to acquire data
Teaching in HEIs performed by people with their primary job outside the HEI/PRO sector	External individuals may give direction to HEI research and bring results back	Very different frameworks for doing this in different countries. Primarily an indicator of private/public knowledge transfer	Would have to be calculated and reported by personnel department of HEIs
Entrepreneurship propensity among HEI students	Measure of willingness to apply acquired knowledge with a commercial orientation	May also reflect lack of interesting job opportunities in existing firms	Requires minor adjustment of GEM[11]

[8] LFS: Labour Force Survey; performed several times a year in a large number of countries.
[9] CDH: Careers of Doctorate Holders; project intermittently undertaken by OECD, UNESCO Institute for Statistics and Eurostat.
[10] IISER: The Integrated Information System on European Researchers; undertaken by the JRC.
[11] GEM: Global Entrepreneurship Monitor, a standing annual survey undertaken in a large number of countries by the GEM consortium.

Indicator	Pro	Con	Data opportunities and challenges
Entrepreneurship orientation among HEI and PRO staff	Orientation towards knowledge transfer	Attitudes may not correlate strongly with actual practice	Some ad hoc surveys exist

Based on criteria set forth in section 2.2, the Expert Group has opted to concentrate on six component indicators as shown in Table 3:

Table 3: Proposed component indicators for knowledge transfer through people

Indicator	Definition	Normalisation	Data sources
1.1. Stock of HEI graduates employed in business enterprise sector	Number of people with a university degree [ISCED 5+] employed in business enterprise sector	Percentage of all people employed in business enterprise sector	LFS
1.2 Stock of doctorate holders employed in business enterprise sector	Number of doctorate holders [with recent degrees] age 25-69 employed in business enterprise sector	Percentage of all doctorate holders [with recent degrees] age 25-69	CDH
1.3. Continuing professional development revenue for HEIs	HEI revenue from continuing education courses	Percentage of GDP	To be integrated in regular official reporting from HEIs
1.4 Employed adults (age 25-64) engaged in university level training or education	Number of employed respondents engaged full or part time in university level courses	Percentage of all employed respondents	LFS
1.5 Teaching in HEIs performed by people with their primary job outside the HEI/PRO sector	FTE adjunct positions in HEIs occupied by people who have their primary job in business enterprise sector	Percentage of total teaching FTEs in HEIs	To be integrated in regular official reporting from HEIs
1.6. Entrepreneurship propensity among HEI students	Total Entrepreneurial Activity as defined by GEM	Pre-normalised as percentage of responding students	GEM

Data availability and suitability will be discussed in chapter 3.5.

3.3 Indicators for knowledge transfer through institutional co-operation in R&D and other phases of innovation

In practice, there are many hybrid forms between various forms of R&D and consultancy. However, all forms are important in considering knowledge transfer because they bring knowledge from HEIs and PROs to bear on problems and opportunities in firms and other producers of social and economic benefits. A proper IP management related to co-operative projects is of course important. The form of co-operation may be of some importance for the knowledge transfer aspect; more so in fact than whether the project creates much new knowledge or not. In projects with a close interaction between the research partner(s) and the clients, knowledge is transferred throughout the project through joint learning processes. In consultancy and contract research projects where R&D tasks are simply outsourced, the knowledge transfer may be limited to a formal report at the end of the project, and some important tacit or contextual knowledge (and even some learning opportunities under way) may be lost

in the process. Still, also in these cases will the knowledge transfer usually be much more to the point for the client in question than in the case of projects initiated from within the research community for the research community.

Potential indicators in a non-normalised form considered by the Expert Group follow in Table 4 below. In all cases the assumption is that contracts relate to private firms or other actors outside the research (HEI/PRO) sector as clients, even though some of the money involved may derive from public funds (research councils, structural funds, annual government allocations, etc.). In other words, pure grants to researchers from research funding agencies, private foundations and the like are excluded. Pros and cons relate to the validity of the proposed indicators as indicators of knowledge transfer. For many of the indicators in question, there are two additional challenges. One is that the data may exist at the level of departments in HEIs but very often no system is in place to aggregate it to the level of the institution, which is the preferred level of reporting for either a census count or a statistically sampled survey. The data situation on this point may be somewhat better on average among PROs. The other one is that many activities, particularly consultancy, may be undertaken by employees on a personal basis (or through their private consultancy firm) rather than through a contract with the HEI (or even PRO). While such cases clearly contribute to knowledge transfer, they are not easily reported through the HEIs, and for the sake of clean indicators, our proposition is to focus on institutional co-operation.[12] The considerations in the table are obviously not exhaustive but key issues have been addressed.

Table 4: Potential indicators for institutional co-operation as a component of knowledge transfer

Indicator	Pro	Con	Data opportunities and challenges
Number of contracts in HEIs/PROs with firms and other users	Simple measure of activity level, one KT relation per contract	Large and small contracts count the same	Available from some surveys but cautions about reliability
Number of clients for HEIs/PROs	Measure of active links, perhaps a form of constituency for direct KT	Clients with large and small portfolios count the same. Possibility of multiple counting when aggregating to national level	HEIs/PROs could collect it from their invoicing systems (but unreliable because of complex money flows)
Number of HEI/PRO personnel involved in contract projects	Measure of exposure to research-external needs and values	May range from marginal to full time contact	May be difficult to collect
Revenue to HEIs/PROs from contracts	Monetary value of activity level	Primarily a measure of R&D with a high probability of KT, not of KT as such. Does not capture payment in kind	Frequently not reported by HEIs/PROs or difficult to collect
Revenue to HEIs/PROs from foreign contracts	Potential measure of quality and relevance of research services	Probably more relevant at the level of individual HEIs/PROs than at national level	Would have to be tagged by HEIs/PROs

[12] Since we are looking for indicators and not necessarily for correct figures, the latter would not be a problem if the proportion of personal business was the same in all countries and every year. However, despite the lack of data on this it is fairly safe to say that this is not the case.

Indicator	Pro	Con	Data opportunities and challenges
Client feedback to HEI/PRO	Measure of quality of service provided	Probably more relevant at the level of individual projects and aggregated to HEIs/PROs than at national level	Costly to collect data uniformly
Repeat business from clients	Measure of quality of co-operation, possible measure of R&D behaviour in clients	A national measure would have to include repeat participation with any HEI/PRO; this would then be a measure of firms' frequency of participation	Operational difficulties in defining data
Longevity of partnerships with clients	Measure of quality of co-operation from both sides	Conservative unless accompanied by a measure of renewal of client portfolio	May be difficult to measure reliably and to aggregate
Firms co-operating with HEIs/PROs	Simple measure of propensity to work with HEIs/PROs	Large and small firms and projects count the same	Available from CIS
R&D in HEIs/PROs funded by business	Monetary measure of the interests of business	No distinction as per degree of co-operation	Available from Eurostat
Publications from co-operative projects	Measure of scientific quality in joint projects	Little different from other scientific publications although they may be more directly relevant	Publications would have to be tagged by HEIs/PROs
Co-publications between private and public authors	Measure of tight research co-operation	Research output, usually co-operation with industry research departments, perhaps little knowledge transfer to firms' innovation processes	Can be mined from publication databases

Based on criteria set forth in section 2.2, the Expert Group has selected to focus on eight component indicators as shown in Table 5:

Table 5: Proposed component indicators for knowledge transfer through co-operation

Indicator	Definition	Normalisation	Data sources
2.1. Number of R&D contracts in HEIs/PROs with firms and other users	All contracts where a firm funds the HEI/PRO to perform research on behalf of the firm, with the results usually provided to the firm. Include collaborative agreements where both partners provide funding and share the results. Exclude cases where the firm funds a research chair or other research of no expected commercial value to the firm. Also exclude consultancy contracts.	Per 1,000 FTEs employed in HEIs and PROs (or per M€ total R&D expenditure)	KT survey or regular reporting from HEIs/PROs to authorities

Indicator	Definition	Normalisation	Data sources
2.2. Number of consultancy contracts in HEIs/PROs with firms and other users	All contracts where a firm funds the HEI/PRO to perform consultancy with the firm	Per 1,000 FTEs employed in HEIs and PROs (or per M€ total R&D expenditure)	KT survey or regular reporting from HEIs/PROs to authorities
2.3. Revenue to HEIs/PROs from R&D contracts with firms and other users	Financial value of service provided from HEI/PRO to client(s) under the contract	Percentage of total R&D expenditure in HEIs and PROs	KT survey or regular reporting from HEIs/PROs to authorities
2.4. Revenue to HEIs/PROs from consultancy contracts with firms and other users	Financial value of service provided from HEI/PRO to client(s) under the contracts	Percentage of total R&D expenditure in HEIs and PROs	KT survey or regular reporting from HEIs/PROs to authorities
2.5. Firms co-operating with HEIs	Firms co-operating with HEIs in innovation some time during last 3 years	Percentage of all firms polled	CIS
2.6. Firms co-operating with PROs	Firms co-operating with government or public research institutions in innovation some time during last 3 years	Percentage of all firms polled	CIS
2.7. R&D in HEIs/PROs funded by business	R&D performed in higher education sector (HERD) and government sector (GOVERD)	Share of (GOVERD + HERD) financed by business enterprise sector	Eurostat
2.8. Co-publications between private and public authors	Scientific publications where at least one author has listed an affiliation with at least one HEI/PRO and a least one other author has listed an affiliation with at least one firm. Recorded in the country of private partner	Per 1,000 FTEs in HEIs/PROs	Science Metrics/ Scopus

Indicator 2.7 is one of the proposed headline indicators previously assessed by the Expert Group. R&D and consultancy are mutually exclusive activities in these indicators. The union of indicators 2.1 and 2.2 (at the level of the firm) and the union of 2.5 and 2.6 (at the level of the HEI/PRO) should in principle correlate strongly. However, by maintaining separate indicators, one will get an understanding of the relative volumes of consultancy and R&D co-operation and of differences in profiles between HEIs and PROs. Similarly, the sum of 2.3 and 2.4 is a subset of 2.7, as the latter also includes non-project funding (such as donations). Over time, interpretations of the empirical results will give input to any revised set of indicators for institutional co-operation in R&D and other phases of innovation.

Data availability and suitability will be discussed in chapter 3.5. For the question of a separate knowledge transfer survey, see also chapter 3.5.

3.4 Indicators for knowledge transfer through exploitation or commercialisation of research results

The three main activities traditionally acknowledged as technology transfer and hence important knowledge transfer activities are patenting (as a strong form of IP protection), licensing in various forms of IP to (mostly) commercial partners, and support for the establishment of new firms based on knowledge and/or people from HEIs and

PROs. Many of these have at their core an invention made by researchers and wholly or partially owned by the researcher and/or the HEI or the PRO, depending on the situation and on the legal regulations in the appropriate jurisdiction. The introduction of routines to disclose such inventions or discoveries to IP staff (typically in KTOs) helps stimulate commercial orientation and also helps define and enumerate the population of ideas on which the IP staff is actually working. The transfer or regulated sharing of ownership or the right to exploit the invention or the exact knowledge in question is then an important activity in IP management. The choice to maintain secrecy, to apply for patenting or to release in the public domain is a strategic choice. KTOs typically log and frequently report patent applications as a leading indicator of technology transfer. However, the high number of denied or withdrawn patent applications reported by patenting authorities attests to the difficulty of using patent applications as a good indicator of knowledge transfer. Even granted applications only vouch for technical uniqueness and thus protectability under patent laws, which may be important for transferring ownership or the right to use, but not necessarily for practical or commercial utility.

Potential indicators in a non-normalised form considered by the Expert Group follow in Table 6 below. Pros and cons relate to the validity of the proposed indicators as indicators of knowledge transfer. The considerations in the table are obviously not exhaustive but key issues have been addressed.

Table 6: Potential indicators for exploitation or commercialisation of research results as a component of knowledge transfer

Indicator	Pro	Con	Data opportunities and challenges
Invention disclosures from HEI/PRO employees	Simple measure of activity level for KTOs	Not all discoveries or inventions are channelled through KTOs. Legal differences between countries may skew the comparison	Available from some surveys[13]
Priority patent applications submitted from HEIs/PROs	Simple measure of activity level	Easily inflated (low application barriers)	Applications submitted from the public sector available from Eurostat. Applications from HEIs/PROs available from some surveys and can also be extracted from public databases
Patents granted to HEIs/PROs	Simple quality-corrected measure of activity level	Reflects technical originality, not necessarily utility potential	Available from some surveys and can also be extracted from public databases

[13] "Some surveys" in this context typically means surveys of KT activities performed regularly by membership organisations such as the ASTP or ProTon Europe or other international or national actors.

Indicator	Pro	Con	Data opportunities and challenges
Number of new licensing agreements	Simple measure of activity level, one KT relation per contract	Large and small agreements count the same. Little information about future economic potential	Available from some surveys
Number of licenses yielding revenue	Measure of current stock of active licensing agreements	Large and small agreements count the same	Available from some surveys
Revenue to HEIs/PROs or their KTOs from licensing agreements	Financial value of knowledge transferred from HEI/PRO to client(s) under the agreements	Pricing may reflect complex relationship management	Available from some surveys
Revenue to HEIs/PROs or their KTOs from licensing agreements with foreign clients	Quality measure reflecting trade specialisation	Complicated by fiscal strategies of multinational firms	Available from some surveys. Possible future availability from TBOP[14]
Number of new spin-offs from HEIs/PROs (based on IP agreement)	Simple measure of activity level	Little information about size and future economic potential. Some spin-offs may be a response to incentives	Available from some surveys
Number of new start-ups (regardless of IP agreements)	Simple measure of activity level	Start-ups without formal IP transfer may also be an indicator of personnel transfer	Available from some surveys, but concerns about reliability
Current stock of existing spin-offs	Measure of current stock of active spin-offs	Many successful spin-offs are merged with existing firms	Available in some ad hoc studies
Current size of spin-offs (employment or turnover)	Measure of economic outcome from knowledge transfer	Many successful spin-offs are merged with existing firms, regardless difficult to enumerate size due to original transfer	Available in some ad hoc studies
Longevity of spin-offs	Quality measure of survival of spin-offs	Many successful spin-offs are merged with existing firms, difficult to establish in the short run	Available in some ad hoc studies

Based on criteria set forth in section 2.2, the Expert Group has opted to concentrate on eight component indicators as shown in Table 7:

[14] TBOP: Technology balance of payments. Dataset of international trade etc. maintained by the OECD.

Table 7: Proposed component indicators for knowledge transfer through exploitation or commercialisation of research results

Indicator	Definition	Normalisation	Data sources
3.1 Invention disclosures from HEI/PRO employees	Inventions or discoveries submitted to KTO staff or equivalent for assessment of commercial application	Per 1,000 FTEs employed in HEIs and PROs (or per M€ total R&D expenditure)	KT survey
3.2 Priority patent applications submitted from HEIs/PROs	New priority patent applications submitted (only one patent jurisdiction counts per technically unique invention)	Per 1,000 FTEs employed in HEIs and PROs (or per M€ total R&D expenditure)	KT survey
3.3 Patent applications submitted from public sector actors to EPO	Patent applications submitted from govemment sector and higher education sector to EPO (by priority year, not necessarily submission year)	Per 1,000,000 population	Eurostat
3.4. Patents granted to HEIs and PROs	Technically unique patents granted (only counted the first year if granted in different years from different jurisdictions)	Per 1,000 FTEs employed in HEIs and PROs (or per M€ total R&D expenditure)	KT survey
3.5. New licensing agreements	All licences, options and assignments for all types of IP. Count multiple (identical) licenses with a value of less than 500 Euros as one license.	Per M€ total R&D expenditure in HEIs and PROs (or per 1,000 FTEs employed in HEIs and PROs)	KT survey
3.6. Licensing revenue to HEIs and PROs	Total income from all types of know-how and IP before disbursement to the inventor or other parties	Percentage of total R&D expenditure in HEIs and PROs (or per 1,000 FTEs employed in HEIs and PROs)	KT survey
3.7. International licensing trade from HEIs and PROs	Total licensing revenue to public sector institutions for export of IP (not including 'cultural' IP)[15]	Percentage of GDP	TBOP
3.8. Number of new spin-offs	Number of new companies expressly established to develop or exploit IP or know-how created by HEI/PRO and with a formal contractual relationship for this IP or know-how, such as a license or equity agreement	Per 1,000 FTEs employed in HEIs and PROs (or per M€ total R&D expenditure)	KT survey

Indicator 3.7 is an enhanced version of one of the proposed headline indicators assessed earlier by this Expert Group. For the question of a separate KT survey, see

[15] See Annex 3 section 11 in the Expert Group's first report (Finne *et al*., 2010) for details.

chapter 3.5. For all the component indicators whose data are to be collected through a KT survey, we have given a preferred and a second choice for normalisation. This is based on the experience from the work of the Expert Group on Knowledge Transfer Metrics that it might be difficult to find data on both R&D expenditure and FTEs in the HEIs and PROs represented in each survey. If a full count is achieved, then these national data can be acquired from official statistics in most countries, but even here, data are incomplete. If not, other approaches are required. For a fuller account, see (EUR 23894, 2009), chapters 4 and 6.

3.5 Current and future data availability

Much of the data required for the proposed component indicators is collected and published in most European countries on a regular basis and made available as consistent data sets through international sources. In some of these cases, normalisations will have to be calculated, again using published data for the denominator. Some of the proposed indicators require minor adjustments that will have to be discussed with the agencies producing the data. Other data, in particular those tagged "KT survey" in the preceding tables, require some effort. A more detailed overview follows in Table 8: Data availability for component indicators. For the availability of data in different countries, Table 9 is indicative.

Table 8: Data availability for component indicators

Indicators	Data source	Data availability
1.1	LFS	Data exist, but do not seem to be published
1.2	CDH	Published data, but infrequently
1.3	(HEIs)	Should be integrated in regular official reporting from HEIs to national authorities if not already done and the further on to Eurostat
1.4	LFS	Published item may include some students, notably PhD students, without a prior full time working experience. This distortion may be improved either by LFS themselves or by estimating PhD student numbers from national sources for correction
1.5	(HEIs)	Should be integrated in regular official reporting from HEIs to national authorities if not already done and the further on to Eurostat
1.6	GEM	GEM data are put in the public domain with a time lag of three years. An agreement with the GEM consortium or a large number of national GEM partners would make data available with a shorter time lag. This particular item includes students and a smaller number of pensioners, distorting the indicator slightly. It will probably be feasible for GEM to make available these data based on students only
2.1 – 2.4	KT survey	See below
2.5	CIS	Published data
2.6	CIS	Published data
2.7	Eurostat	Published data
2.8	Science metrics / Scopus	Data also published through Innovation Union Scoreboard
3.1 – 3.2	KT survey	See below
3.3	Eurostat	Published data
3.4 – 3.6	KT survey	See below
3.7	TBOP	Data on international flows of licensing revenue are being revised and refined, due to be implemented from 2014. This will make it possible to distinguish licensing derived from technology etc from artistic or 'cultural' IP. To split these into public and private sector streams will require some estimation which as of yet is not scheduled to take place uniformly across Europe. For further details, see (Finne *et al.*, 2010) Annex 3

3.8	KT survey	See below

Most of the data marked LFS, CIS, TBOP and Eurostat are available from Eurostat's publicly available online databank at http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database. For GEM data, see http://www.gemconsortium.org. For CDH data, see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Careers_of_doctorate_holders. New data are due to be released 2011.

A separate annual KT survey targeting HEIs/PROs or their related KTOs is considered the best way to capture data for a number of indicators as long as they are not reported on a regular basis to authorities and national statistics agencies. The Expert Group on metrics identified 14 initiatives of different duration and standing addressing this need in various parts of Europe (EUR 23894, 2009). These are typically conducted by or for or in collaboration with professional associations for knowledge transfer professionals, and their primary purpose is typically to contribute to the professional development of members. However, the metrics report (*ibid.*) showed that at least two of these survey initiatives, those of ASTP and ProTon Europe, could be coordinated to provide a useful starting point for collecting data also for a European indicator set. While no concrete assessment has been made of the cost associated with expanding these initiatives to produce national counts of IP management related indicators, it seems that it would be far less costly at this time than initiating a separate series of official statistical investigations.[16] The quality of results for the purpose of producing national statistics would depend on designing the surveys with this in mind. The European Commission is currently commissioning such a survey within a scoreboard framework (see http://www.knowledge-transfer-study.eu); experience from this exercise may be important in designing a future, more regular KT survey, possibly in co-operation with surveys of professional organisations such as exemplified above.

[16] In some countries, national authorities and professional associations already combine efforts in collecting these data.

4 PROPOSED AGGREGATION TO A COMPOSITE INDICATOR

4.1 Current and future picture

The 22 proposed component indicators will be put together in a composite indicator as suggested in Figure 2, where a suggestive shorthand notation is used to characterise and group the components. Data sources are listed in the second ring from the outside; sources marked in red indicate lack of national estimates for a large number of countries. KTS is the knowledge transfer survey as discussed throughout this report. For other abbreviations, see the tables of component indicators or the running text.

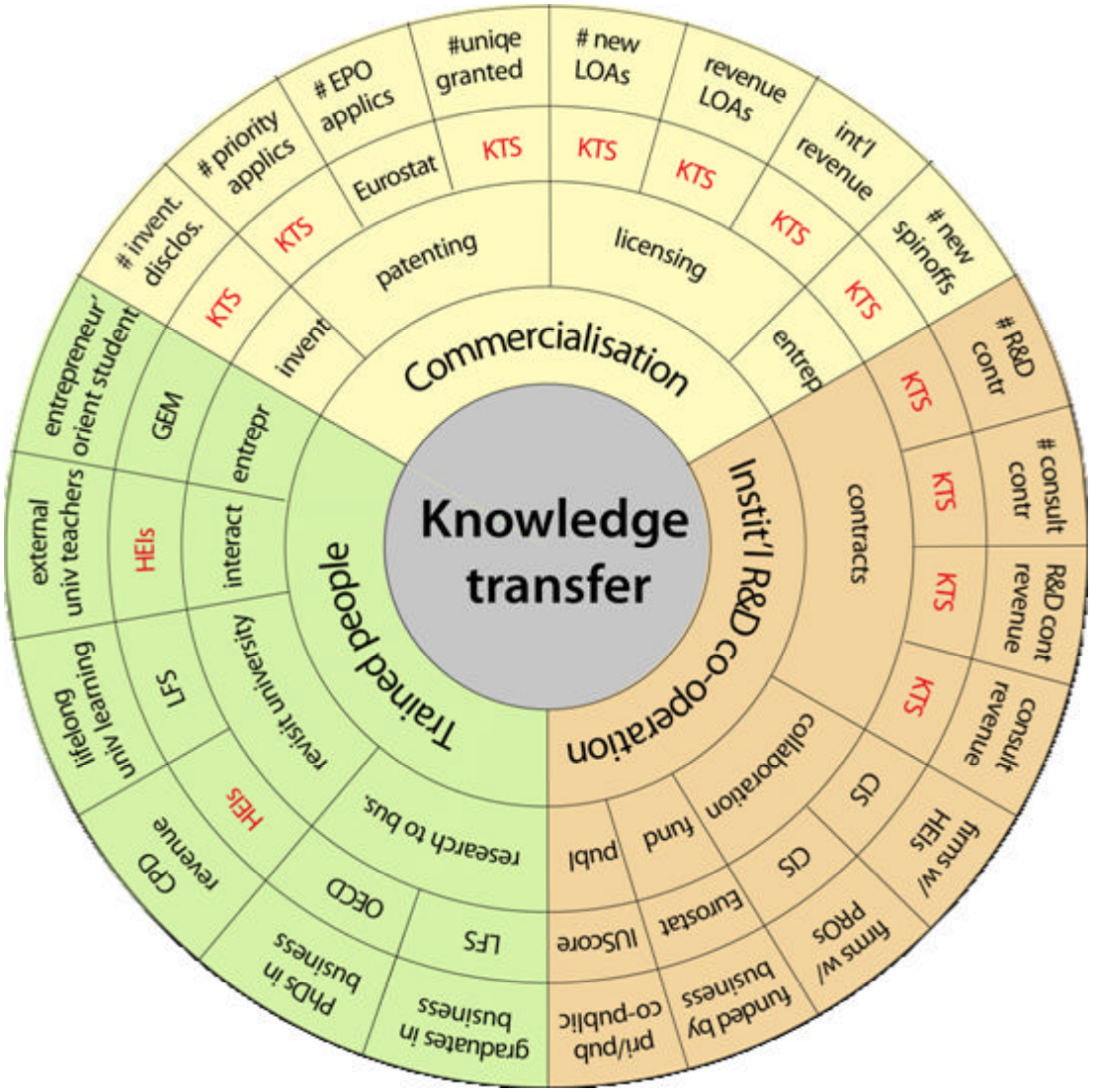

Figure 2: A composite indicator for knowledge transfer

4.2 Normalisation, aggregation, weighting

The first normalisation for each component indicator, as described in chapter 3, ensures comparability between countries. In order to construct a composite indicator, component indicators must be normalised a second time against each other. For joint normalisation between component indicators, the scales of each component are con-

verted linearly in such a way that the lowest score among individual countries one year for a component indicator is set to 0 and the highest score is set to 1. The composite scores will then vary between the theoretical lower and upper bounds of 0 and 1.

This is a frequently preferred solution which amounts to a sophisticated ranking system among participating nations. It also has the consequence that numerical values of the composite are not directly comparable from one year to the next. This means that time series of the composite score are not directly comparable within each country; however, countries can use the composite scores to compare their own development over time with that of similar countries.[17]

For comparison at the component indicator level, it is recommended to use data that have not gone through this second level of normalisation. This will allow comparisons both over time within and between countries and also direct comparisons between countries.

Extreme values (outliers) are identified but not adjusted for, at least not in this first version of the composite. Nor has it been considered necessary at this stage to make any non-linear transformations of any of the underlying component indicators. Missing data are imputed by repeating the most recent data prior to the missing data points. This means, for example, that Community Innovation Survey data are used for two consecutive years because these surveys are run every two years.

Within each of the three main areas, a technical area-specific composite is constructed as the average of its available normalised component indicators for each country. This will reduce the need to reconsider detailed weighting when more component indicators become available for individual countries. This choice also makes it possible to calculate a country specific composite even in the absence of some component indicators. However, it should be noted in the interpretation what components are missing. In calculating the total composite indicator for KT, the Expert Group has weighted the three main areas as follows: people transfer 20 per cent, R&D co-operation 40 per cent, and commercialisation 40 per cent. The slight relative down-weighting of knowledge transfer through people is due to the lack of experience with using available data as indicators for knowledge transfer. If one ore more of these is missing, no total composite indicator is calculated.

The resulting composite indicator will have a value in the range fro 0 to 1, with higher values indicating higher volumes of knowledge transfer when compared across countries. Time series of composite scores are comparable between countries in the sense that they show whether individual countries are catching up with others or lagging behind.

4.3 Robustness and sensitivity

Data are available for 15 of the 22 proposed component indicators, and only 8 of these have good homogenous coverage. Therefore, only a highly preliminary testing of robustness and sensitivity to individual components has been possible. The correlation

[17] Other ways to construct a composite exist that will allow direct comparisons both over time and between countries; they are, however, far more elaborate.

between component indicators varies greatly within the available data, but there are no alarming signs for the overall composite. We recommend that a fuller analysis be performed when knowledge transfer survey data become available from the current *ad hoc* KT survey commissioned by the European Commission and mentioned towards the end of chapter 3.5.

5 INDICATOR VALUES USING SAMPLE DATA

Table 9 on page 31 shows sample data for available component indicators and the resulting composite indicator for 2008. Before the table, we present some details about the underlying data and a guide to its reading. After the table, we discuss some aspects of the actual data.

Data for component 1.1 are estimated using published data for the entire labour force and subtracting sectors that together capture most of the non-business sectors (NACE codes O, P, Q, T, and U). There will be some inaccuracies in these numbers.

Data for the numerators of components 2.1, 3.1, 3.2, 3.5, 3.6 and 3.8 are collected through ProTon Europe's KT survey (Balderi and Piccaluga, 2010). For these, two comments are in place. Only a small number of countries are sufficiently covered to warrant a near full count. That survey has respondents in many countries, but too small samples in most countries to warrant generalisation to the national level. The main challenge is that high performers tend to participate more than low performers. However, if nearly all major actors take part, their data together may provide a good estimate of the total activity in that country. For a discussion of generalisation to national level in biased self-selected samples in KT surveys, see (EUR 23894, 2009).

Second, it has been necessary to normalise all of these by total R&D expenditure in the HEI sector (HERD) because PROs are not included and because data for FTE researchers, which might have been a preferable normalisation factor for components 2.1, 3.1, 3.2, and 3.8, are not available for all of these countries.

Data for component 1.6 relate to 2007 and for 1.2 to 2006. These were the most recent data available in the spring of 2011.

In the lower half of the table, normalised scores for each component indicator are shown for each country where the data are available. This table is also indicative of which data are available for each country over time. Outliers, defined as departing more than 2 standard deviations from the mean of data for available countries, are marked with underscores.

In the upper half of the table, each of the data points from the lower part is converted to scores in the range 0 – 1 as explained in chapter 4. At the top of each section, the corresponding area-specific composite is calculated, and at the very top (line 2), the resulting overall composite is displayed for each country.

The composite should be interpreted with extreme care because there are so many component indicators without data and because the coverage of countries varies between components. Commercialisation currently depends on a single component for the majority of countries. The small number (four) of countries where other commercialisation indicators are present, makes the contribution of these components to the composite somewhat unreliable because the real maxima and minima might be outside the range found in these countries. An alternative composite score without the KT survey has been calculated for comparison (line 3 in the table). Consequently, the calculated composite values are not suitable for publishing an official ranking between countries.

Table 9: Composite indicator for knowledge transfer (2008)

Data for 2008; calculated composite indicator (all components: scale 0-1)	EU	BE	BG	CZ	DK	DE	EE	IE	GR	ES	FR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE	UK	HR	TR	IS	NO	CH	RS	MK
Knowledge transfer	**0.32**	**0.68**	**0.05**	**..**	**0.47**	**0.29**	**..**	**..**	**0.08**	**0.27**	**0.42**	**0.09**	**..**	**0.19**	**0.19**	**..**	**..**	**..**	**0.57**	**0.39**	**0.15**	**0.11**	**0.13**	**0.40**	**..**	**0.52**	**0.32**	**0.67**	**..**	**..**	**..**	**..**	**0.81**	**..**	**..**
Alternative without KT survey data					0.60					0.17		0.10																0.26							
Mobility	**0.46**	**0.39**	**0.12**	**0.24**	**0.71**	**0.28**	**0.57**	**0.45**	**0.26**	**0.47**	**0.32**	**0.18**	**0.52**	**0.22**	**0.37**	**0.48**	**0.13**	**0.25**	**0.42**	**0.58**	**0.20**	**0.12**	**0.18**	**0.39**	**0.11**	**0.67**	**0.68**	**0.54**	**0.25**	**0.25**	**0.61**	**0.79**	**0.93**	**..**	**0.30**
1.1 HEI graduates employed in private sector	0.53	0.81	0.34	0.01	0.64	0.41	0.79	0.97	0.37	0.78	0.71	0.00	0.91	0.45	0.76	0.63	0.21	0.09	0.69	0.14	0.33	0.05	0.25	0.37	0.03	1.00	0.59	0.74	0.23	0.49	0.58	0.72	0.87	..	0.50
1.2 PhDs employed in business enterprise sector (2006)	..	0.48	0.00	0.32	0.99	..	..	..	..	0.18	..	..	0.31	0.17	0.19	..	..	..	..	1.00	0.01	..	0.27	..	0.12	..	..	..	..	..	..	..	..	..	..	..
1.3 Continued professional development revenue to HEIs																																			
1.4 Employed people with tertiary education age 25-64 involved in training	0.39	0.24	0.00	0.43	0.98	0.27	0.35	0.26	0.09	0.44	0.21	0.38	0.35	0.23	0.17	0.33	0.08	0.41	0.56	0.61	0.25	0.20	0.00	0.58	0.16	0.76	0.77	0.76	0.03	0.07	0.87	0.66	1.00	..	0.11
1.5 Teaching in HEI by people with primary job outside HEI/PRO																																			
1.6 Students' entrepreneurship propensity (2007)	..	0.04	..	0.18	0.22	0.17	..	0.13	0.31	..	0.05	0.17	..	0.03	..	..	0.09	..	0.00	..	..	0.11	0.22	0.22	..	0.25	..	0.12	0.50	0.18	0.40	1.00	..	..	..
R&D co-operation	**0.34**	**0.50**	**0.06**	**0.30**	**0.49**	**0.23**	**0.14**	**0.19**	**0.06**	**0.10**	**0.28**	**0.07**	**0.08**	**0.29**	**0.26**	**0.33**	**0.49**	**0.00**	**0.43**	**0.40**	**0.25**	**0.16**	**0.21**	**0.65**	**0.37**	**0.80**	**0.45**	**0.57**	**0.37**	**0.00**	**0.84**	**0.50**	**1.00**	**0.02**	**..**
2.1 HEI/PRO R&D contracts with firms	..	..	..	..	..	..	..	..	..	0.00	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	..	..	..	..	..	..	..
2.2 HEI/PRO consultancy contracts with firms																																			
2.3 HEI/PRO revenue from R&D contracts with firms																																			
2.4 HEI/PRO revenue from consultancy contracts with firms																																			
2.5 Share of firms co-operating with HEIs	..	0.64	0.07	0.40	0.59	0.31	0.16	0.25	..	0.11	0.38	0.09	0.13	0.31	0.39	0.36	0.63	0.00	0.44	0.67	0.31	0.24	0.08	0.81	0.38	1.00	0.46	..	0.46	..	..	0.39	..	..	..
2.6 Share of firms co-operating with PROs	..	0.54	0.11	0.22	0.61	0.13	0.07	0.19	..	0.23	0.33	0.01	0.07	0.24	0.37	0.52	0.23	0.00	0.39	0.27	0.35	0.19	0.07	0.71	0.33	1.00	0.29	..	0.44	..	..	0.55	..	..	..
2.7 R&D in HEIs/PROs funded by business	0.50	..	..	0.45	0.12	..	0.25	..	..	..	0.26	..	..	0.61	0.25	..	1.00	0.00	..	..	0.34	..	0.67	0.84	0.71	0.67	..	0.40	0.48	..	0.82	..	..	..	..	..
2.8 Public/private co-publications	0.18	0.31	0.01	0.12	0.62	0.24	0.09	0.12	0.06	0.07	0.16	0.10	0.04	0.00	0.01	0.12	0.09	0.00	0.45	0.28	0.01	0.04	0.03	0.25	0.05	0.52	0.59	0.31	0.08	0.00	0.86	0.55	1.00	0.02	..
Commercialisation	**0.23**	**1.00**	**0.00**	**..**	**0.35**	**0.35**	**..**	**..**	**0.02**	**0.34**	**0.62**	**0.06**	**..**	**0.07**	**0.04**	**..**	**..**	**..**	**0.79**	**0.29**	**0.02**	**0.06**	**0.01**	**0.16**	**..**	**0.16**	**0.02**	**0.84**	**..**	**..**	**..**	**..**	**0.56**	**..**	**..**
3.1 Invention disclosures from HEI employees	..	..	..	..	0.27	..	..	..	..	0.51	..	0.00	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	..	..	..	..	..	..	..
3.2 Priority patent applications submitted from HEIs	..	..	..	..	0.17	..	..	..	..	0.52	..	0.00	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	..	..	..	..	..	..	..
3.3 EPO patent applications from HEI/GOV	0.23	1.00	0.00	..	0.66	0.35	..	..	0.02	0.05	0.62	0.09	..	0.07	0.04	..	..	..	0.79	0.29	0.02	0.06	0.01	0.16	..	0.16	0.02	0.02	..	..	..	..	0.56	..	..
3.4 Patents granted to HEIs and PROs																																			
3.5 New licensing agreements with HEIs	..	..	..	..	0.10	..	..	..	..	0.09	..	0.00	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	..	..	..	..	..	..	..
3.6 Licensing revenue to HEIs	..	..	..	..	0.88	..	..	..	..	0.07	..	0.00	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	..	..	..	..	..	..	..
3.7 International licensing trade from HEIs/PROs																																			
3.8 New spin-offs from HEIs	..	..	..	..	0.00	..	..	..	..	0.81	..	0.29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1.00	..	..	..	..	..	..	..

Data for 2008; component indicators	EU	BE	BG	CZ	DK	DE	EE	IE	GR	ES	FR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE	UK	HR	TR	IS	NO	CH	RS	MK
Knowledge transfer																																			
Mobility																																			
1.1 HEI graduates employed in private sector (% of employment in sector)	24.1	31.3	19.5	11.2	26.9	21.3	30.7	35.3	20.0	30.4	28.7	10.8	33.7	22.1	30.0	26.6	16.1	13.0	28.2	14.3	19.1	12.1	17.1	20.1	11.7	36.0	25.8	29.5	16.5	23.1	25.3	28.9	32.7	..	23.3
1.2 PhDs employed in business enterprise sector (% of recent doctorates) (2006)	..	17.9	2.2	12.6	34.5	..	..	..	..	8.1	..	..	12.2	7.7	8.3	..	..	..	..	34.8	2.7	..	10.9	..	6.1	..	..	..	..	..	..	..	..	..	..	..
1.3 Continued professional development revenue to HEIs (% of GDP)																																			
1.4 Employed people with tertiary education age 25-64 involved in training (%)	17.5	11.6	2.8	18.7	39.5	12.7	15.9	12.3	6.0	19.4	10.7	16.8	15.7	11.2	9.0	15.2	5.7	18.1	23.7	25.6	12.2	10.3	2.7	24.6	8.9	31.3	31.6	31.2	3.7	5.2	35.4	27.5	40.3	..	6.9
1.5 Teaching in HEI by people with primary job outside HEI/PRO (% of all teaching)																																			
1.6 Students' entrepreneurship propensity (%) (2007)	..	0.49	..	1.50	1.71	1.39	..	1.11	2.38	..	0.59	1.37	..	0.42	..	..	0.89	..	0.25	..	..	0.99	1.73	1.73	..	1.95	..	1.06	3.65	1.48	2.95	7.05	..	..	..
R&D co-operation																																			
2.1 HEI/PRO R&D contracts with firms (per 1,000 FTEs in HEIs/PROs)	..	..	..	..	..	..	..	..	..	2.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10.7	..	..	..	..	..	..	..
2.2 HEI/PRO consultancy contracts with firms (per 1,000 FTEs in HEIs/PROs)																																			
2.3 HEI/PRO revenue from R&D contracts with firms (% of total R&D expenditure)																																			
2.4 HEI/PRO revenue from consultancy contracts with firms (% of total R&D expenditure)																																			
2.5 Share of firms co-operating with HEIs (%)	..	0.19	0.05	0.13	0.18	0.11	0.07	0.09	..	0.06	0.12	0.05	0.06	0.11	0.13	0.12	0.19	0.03	0.14	0.20	0.11	0.09	0.05	0.23	0.13	0.28	0.14	..	0.14	..	..	0.13	..	..	..
2.6 Share of firms co-operating with PROs (%)	..	0.13	0.04	0.06	0.15	0.04	0.03	0.06	..	0.06	0.09	0.02	0.03	0.07	0.10	0.13	0.07	0.02	0.10	0.07	0.09	0.06	0.03	0.17	0.09	0.23	0.08	..	0.11	..	..	0.13	..	..	..
2.7 R&D in HEIs/PROs funded by business (%)	7.2	..	..	6.5	2.0	..	3.8	..	..	..	3.9	..	..	8.7	3.8	..	13.9	0.4	..	..	4.9	..	9.5	11.7	10.1	9.4	..	5.8	6.9	..	11.5	..	..	..	..	..
2.8 Public/private co-publications (per million population)	36.2	61.5	2.3	24.7	123	49.5	19.0	25.8	12.5	15.9	31.8	20.7	8.3	2.0	3.0	24.9	19.6	1.2	90.0	56.3	2.5	8.7	6.3	51.0	10.3	105	117	61.7	17.7	1.7	170	111	198	4.2	..
Commercialisation																																			
3.1 Invention disclosures from HEI employees (per M€ total R&D expenditure)	..	..	..	..	0.16	..	..	..	..	0.25	..	0.07	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.42	..	..	..	..	..	..	..
3.2 Priority patent applications submitted from HEIs (per M€ total R&D expenditure)	..	..	..	..	0.07	..	..	..	..	0.14	..	0.04	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.22	..	..	..	..	..	..	..
3.3 EPO patent applications from HEI/GOV (per million population) (2007)	1.64	7.20	0.01	..	4.77	2.55	..	..	0.18	0.40	4.44	0.65	..	0.51	0.31	..	..	..	5.73	2.08	0.16	0.43	0.07	1.18	..	1.20	0.17	0.17	..	..	..	..	4.01	..	..
3.4 Patents granted to HEIs and PROs (per 1,000 FTEs in HEIs/PROs)																																			
3.5 New licensing agreements with HEIs (per M€ total R&D expenditure)	..	..	..	..	0.05	..	..	..	..	0.04	..	0.01	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.37	..	..	..	..	..	..	..
3.6 Licensing revenue to HEIs (€ per k€ total R&D expenditure)	..	..	..	..	5.59	..	..	..	..	0.62	..	0.21	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6.36	..	..	..	..	..	..	..
3.7 International licensing trade from HEIs/PROs (% of GDP)																																			
3.8 New spin-offs from HEIs (per 100 M€ total R&D expenditure)	..	..	..	..	0.66	..	..	..	..	2.59	..	1.36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3.05	..	..	..	..	..	..	..

Many of the outliers (underscored) are only slightly outside the ±2 standard deviations range and have little impact on the scores for the composite. The exceptions are component 1.4 (adult education at university) for DK and CH, 1.6 (students' entrepreneurship propensity) in NO, 2.5 (firms co-operating with HEIs) and 2.6 (with PROs) in FI, 2.8 (private/public co-publication) in IS and CH, and 3.3 (EPO applications) in BE. These high values result in most of the countries being clustered together on the lower part of the scale for these indicators. Any adjustments because of this would have to be considered carefully.

The introduction of KT survey data for four countries changes the commercialisation score for these countries as compared with only using component 3.3, and the changes are quite large and go both ways. The score for UK in particular changes dramatically. This is partly due to a methodological artefact because only four countries have these data. This shows that it is imperative to include a KT survey to get a good composite indicator for knowledge transfer.

Total composites have been calculated for 19 EU Member States, four of which include a broader range of components because of availability of data from a KT survey. As stipulated before, these are based on sample data and should not be interpreted as official rankings. We therefore abstain from comments on the scores of individual countries.

6 CONCLUSIONS AND RECOMMENDATIONS

As the foremost outcome of its work the Expert Group on Knowledge Transfer has shown that it is possible to construct a reasonable composite indicator for knowledge transfer at the national level in Europe. The composite indicator will provide a highly needed overall view for improving knowledge transfer as well as relevant components to account for national differences in strategy. A total of 22 indicators have been proposed, grouped under the headings of

- commercialisation of research
- institutional co-operation in R&D and other phases of innovation
- knowledge transfer through trained people

Existing multi-year datasets have been found for 15 of these component indicators. For eight of these, data exist for a large number of countries. For another seven, data exist from many countries, but they are not necessarily ready for aggregation to the national level. But even with the current datasets, a composite indicator seems a more appropriate representation of knowledge transfer than any of the two previously proposed headline indicators alone. The coverage is best in the areas of knowledge transfer through people and through institutional co-operation. It is smallest in the core area of commercialisation backed by IP management, which is the main area of concern leading to the present report. As it is, EPO patent applications from the public sector is the only indicator covering a wide range of countries; this is too scant to represent valorisation of research results at HEIs and PROs in Europe.

In order to be able to produce an annual composite indicator of knowledge transfer, there are three sets of tasks that need to be undertaken, listed in order of priority:

- To generate more and better data on commercialisation at the national level (task 1)
- To collect and collate data from the various sources and integrate them in a published composite indicator system (task 2)
- To improve data for other component indicators (task 3).

Task 1 has the highest priority: to generate data that give reliable estimates of commercialisation indicators at the national level. Without these, the composite indicator will not be a sufficient monitor of progress in all three areas of knowledge transfer. There appears to be three options for this task, all of them focusing on the collection of data from, or about, HEIs and PROs, either from these directly or from KTOs that serve them.

The first option is for states to implement harmonised reporting requirements for HEIs and PROs concerning commercialisation of research results according to the definitions of indicators 3.1, 3.2, 3.4, 3.5, 3.6 and 3.8. It would be advantageous in such an exercise also to include data for indicators 1.3 and 1.5 on training from HEIs and 2.1 through 2.4 on institutional co-operation from HEIs and PROs. Some of these data are already collected by some national authorities as part of the regular annual reporting routines of HEIs and PROs and their experiences could be important in establishing a harmonised effort.

The second option is for the European Commission to instigate a series of annual surveys collecting these data. The surveys could be directed to HEIs and PROs or to KTOs. KTOs are in most cases closer to commercialisation activities but may have little incentive to collect data about activities beyond their own. HEIs and PROs may be in a position to demand data from KTOs serving them but usually not the other way around. Experiences from the on-going KT survey of the European Commission should be taken into account for deciding on this option.

The third option is for the European Commission to liaise with one or more owners and operators of recurring knowledge transfer surveys directed to KTOs. Some of these have long standing alliances with national KTO networks. This fact allows for high response rates and even, in some countries, for almost full coverage of all HEIs with commercialisation activities. Two such survey owners, ASTP and ProTon Europe, have agreed to standardise their data collection on core performance indicators for KTOs. A scheme for collating data from their surveys has also been devised.

Of these three options, the first one will probably give the most reliable data collection over time. The third one will probably be able to start producing national estimates much faster and also be the least expensive because routines already exist and KTOs have an established practice of returning quality data on commercialisation. Given that the greatest shortage of data is in this area, the Expert Group recommends option 3. The main challenge for this option is how to achieve reliable data on national volumes in countries where the surveys do not have full coverage of institutions. In these cases, techniques of stratification of samples may improve the reliability of national estimates. The agreement with the relevant voluntary organisations will also have to settle questions of ownership and use of the data collected.

Task 2, combining data to a composite indicator, is one with which the European Commission has some experience organising, *e. g.* in having the Innovation Union Scoreboard produced. There is also, in fact, some overlap in indicators between innovation and knowledge transfer. There may be some benefit in co-ordination of collection and dissemination of the two sets of indicators. However, the primary need is to i) have the data on knowledge transfer collated with high quality, ii) published, and iii) entered into policy discussions and decisions at national and international levels. The preparation and publication of a composite indicator and its use for policy purposes should progress in close co-ordination with the work on collecting more data on commercialisation, regardless of the solution chosen for task 1.

The Expert Group recommends for the European Commission, in suitable collaboration with ERAC and its member states, to initiate both tasks as one undertaking, with a single, strong project manager to secure sufficient quality, progress, and impact in both tasks.

The Expert Group has assigned lower priority to task 3, improving the availability and quality of other data, as it does not make sense to initiate this task without initiating the two others. It should be the responsibility of the appointed project manager of tasks 1 and 2 to also ensure progress in task 3. The present report contains a thorough review of the relative strengths and shortcomings of existing datasets and a number of them would benefit from modifications to serve well as component indicators for knowledge transfer. The Expert Group acknowledges the fact that adapting existing

datasets to fit a purpose for which they were not originally designed may require extensive effort at the national level. It is therefore more appropriate to prioritise efforts between such modifications once the entire project is under way. The present report should serve as a useful reference for the project manager and others in improving the quality of the composite indicator for knowledge transfer in a stepwise approach.

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ANNEX 1: Short biographies of authors, and acknowledgements

The report is written by an Expert Group appointed by the European Commission, Directorate General for Research and Innovation, Directorate C – Research and Innovation, Unit C.6 – Economic analysis and indicators. The group is composed as follows and all members have contributed to the report:

Mr Håkon Finne, the group's chair, is a research manager with SINTEF, a large foundation for applied research, in Trondheim, Norway. He holds an MSc in engineering from the Norwegian University of Science and Technology. He has a long record of researching government-research-industry relations in R&D and innovation at home and abroad, with a particular emphasis on small firms. He has previously chaired the European Commission's Expert Group on Knowledge Transfer Metrics and has also been seconded to the Research Council of Norway for several years.

Mr Adrian Day is senior policy adviser in the Business and Community team of the Higher Education Funding Council for England. Since 2001 he has worked on all aspects of knowledge exchange policy from developing data and funding processes to implementation of a formula-driven stream of funding for knowledge exchange. He is also involved in wider aspects of innovation policy having advised various organisations at home and abroad on how to make the most from investment in higher education. He holds a BA in international relations. He was a member of the European Commission's Expert Group on Knowledge Transfer Metrics.

Mr Andrea Piccaluga is professor of innovation and technology management at Scuola Superiore Sant'Anna in Pisa, Italy, where he is Director of the PhD course in Management. He holds an MSc in technology and innovation management from SPRU at the University of Sussex and a PhD in innovation management from Scuola Superiore Sant'Anna. His research activities include innovation and R&D management, high-tech entrepreneurship and technology transfer. He is on the board of Netval, the Italian network of university technology transfer offices (TTOs) and of Proton Europe. For both organizations he has authored their annual survey reports for the last few years, collecting information from hundreds of TTOs.

Mr André Spithoven is a senior researcher at the Belgian Science Policy Office where he analyses data on R&D and innovation. In addition he is part time researcher at the Vrije Universiteit Brussel. He holds a PhD in applied economics from the Universiteit Gent. He publishes on R&D data of the non-profit sector in Belgium, especially on technology transfer intermediaries, open innovation, spatial organisation of R&D and innovation. He has co-edited books on the internationalization of R&D and on industry-science relationships, and has published in international refereed academic journals.

Ms Patricia Walter is a senior expert in the area of balance of payments at the Oesterreichische Nationalbank (OeNB). She holds a PhD on transition economies from Leopold-Franzens-University in Innsbruck. She has worked with the research department at the Vienna Stock Exchange before she started working at OeNB in 2001. Currently she is engaged in research on cross-border trade in services by linking micro data on firm-level and is also active in further developing data on cross-border R&D and license revenue streams.

Ms Dorien Wellen is Head of the Knowledge and Technology Transfer Office of the University Medical Centre St Radboud and Radboud University Nijmegen, where she advises the board of the university and supervises all knowledge transfer activities from grants, industry contracts, IP, business development, spin-off creation, incubation buildings and managing a Centre of Entrepreneurship. She is involved in national and international advisory boards on knowledge and technology transfer and is chairman of the Dutch Association of TTO practitioners. She has extensive prior experience from industry (business to business) and she holds an MA in economic history.

The group would also like to thank Dr Georg Buchtela of the Österreichisches Forschungsinstitut für Chemie und Technik for eminently liaising with the ERAC working group on knowledge transfer and Mr Patrick McCutcheon of the European Commission for his untiring assistance in providing a context for the group's work. The group's members have also consulted individually with a number of relevant individuals and institutions on selected parts of the work and we equally thank them for their time and their comments.

ANNEX 2: Selected prior work that broadens the scope of knowledge transfer

The following pages show parts of the path followed by the Expert Group in establishing a wider concept of knowledge transfer.

Knowledge can travel many ways from the research sector to a broader audience

The linear understanding of research producing new knowledge that is then transferred to industry and subsequently used as a source for innovation has been supplemented with various metaphors indicating the complexities of an innovation ecosystem. Despite this, however, the terms technology transfer and knowledge transfer have essentially been maintained, although the Higher Education Funding Council for England (HEFCE) currently talks about knowledge exchange and thus acknowledges the interactive nature of many activities around the university/industry links.

For the purpose of this report, we primarily consider knowledge transfer from the research sector to other parts of society, mostly the economic sector, which is predominantly private. The research sector consists of universities, other higher education institutions, research institutes, teaching hospitals, government laboratories and other similar institutions with a mission to perform research. For the sake of brevity, we group these into HEIs and PROs. HEIs teach while PROs usually don't. Some HEIs perform little research but nevertheless maintain (and teach) research based knowledge. Most HEIs in Europe are owned and financed (to a high degree) by public authorities. Many PROs are private non-profit organisations but receive substantial amounts of funding originating in public budgets. There are great differences between countries in the organisation of the research sector, *e.g.* in whether PROs are predominantly government owned or private foundations. [18,19]

The production and application of new knowledge through research and development and related innovation activities takes many paths. Knowledge transfer in this context is basically processes and activities that help knowledge that is developed and held in academia become available for the production of new socio-economic and cultural value in society at large.[20] The knowledge about how KT actually takes place in different contexts is accumulating but many questions still remain unanswered. Traditional academic publication of research is important for quality assurance and diffu-

[18] Obviously much knowledge is produced in the private sector, too. Large corporations frequently have their own research facilities primarily directed towards creating commercial value; these do not belong to the research sector in this context, even though many of them may be playing important bridging roles. There is of course also much private/private, public/public and private/public knowledge transfer, which is basically outside the scope of this report.

[19] The problem of too little knowledge transfer is sometimes cast as a problem of making the results of public funding available for the private sector and sometimes as a problem of communication between the academic (or research) sector and other sectors capable of turning knowledge into benefits for society. Both formulations are of course legitimate and even though they do in principle draw the border between knowledge transferring and knowledge receiving actors along different lines, in practice there is great overlap. The Expert Group has chosen a pragmatic approach to these distinctions.

[20] A large sample of definitions of KT and related concepts is maintained at http://whatiskt.wikispaces.com. Large areas of practical approaches and research in many traditions called knowledge transfer are not covered by our review. The focus here is on what has been the major concern of classical technology transfer (see below) and the IP recommendation and extensions to that.

sion of knowledge but frequently insufficient for an optimal uptake among existing enterprises, new entrepreneurs, government agencies and other actors.[21]

Clearly, much knowledge is transferred without much intervention. Sometimes, new research results are instantly taken up by innovating firms. In other cases, new pieces of knowledge can function as input to series of new research projects before something actually applicable appears. The time from transfer until actual use can also vary tremendously. Large numbers of students can learn something at university before one of them uses it as a crucial background component for developing something new. Most of the time, catching up with old knowledge will be necessary for firms before they can learn how to apply the most recent findings. And even the famous science based blockbusters can go through many years of entrepreneurial work before commercial results appear. To consider only direct, 'supervised' linkages in the form of clearly identified and organised activities between a new research result and a socio-economic benefit would therefore be to underestimate the intertwining and mutually supportive informal and formal flows of old and new knowledge which together make up knowledge transfer.

Technology transfer takes a lead

However, the need to increase uptake has resulted in various initiatives. A large number of technology transfer offices have been established over several decades to enhance university – industry links in particular, reflecting the need for specialised competencies in order to establish and develop these links. The OECD has contributed to the awareness of this specialised knowledge by defining technology transfer as activities "to identify, protect, exploit and defend intellectual property" (OECD, 2003 p. 37) – in short, IP management. A 2003 survey identified close to 1,400 technology transfer institutions in Europe, more than half of which were engaged in IP licensing and a similar number in patenting, and many were engaged in a wide variety of linking activities (ITTE Expert Group, 2004). Professional associations for technology transfer offices and officers have developed their own national and international surveys for the purposes of monitoring technology transfer activities, benchmarking performance between themselves, displaying their achievements to authorities and the public, and contributing to professionalization of their work. Many of these surveys are built on the long standing licensing survey of the US based Association of University Technology Managers (AUTM), often considered the 'gold standard' of such surveys.[22, 23]

The core common interest of these surveys is to monitor performance on a number of technology transfer activities that will not only improve the use of research results but also frequently generate additional revenue for the research institutions in question. Such revenue is also one among several justifications for establishing and maintaining dedicated technology transfer offices. This has contributed to associating technology

[21] Those expected to turn science into value are primarily private firms in the business enterprise sector. However, also publicly owned businesses, public services, and other economic actors can play important roles in innovation. Again the Expert Group has chosen a pragmatic approach, although the emphasis is on private firms.

[22] An overview and comparison of surveys by different associations can be found in (EUR 23894, 2009). After that, both ASTP and ProTon Europe have maintained their output of annual surveys.

[23] For a thorough comparison of the contents of 14 such series of (or occasional) surveys, see (EUR 23894, 2009).

transfer with primarily commercial motives. However, from a public policy point of view, the purpose may just as well be to work with commercial actors because these are often considered more effective than research institutions in turning new technology into socio-economic value for society at large. For one thing, many exploitation processes require large amounts of capital and market knowledge that it would be difficult to find in the research sector itself.

The understanding of knowledge transfer is currently broader than the leading definition of technology transfer as IP management provided by the OECD. While the need for effective IP management is in no way diminished, it is recognized that knowledge is transferred through many channels, in several forms and by many activities, frequently in combination. This also helps broaden the scope from technology to other fields of knowledge. Even though technology transfer offices, now increasingly called knowledge transfer offices (KTOs), are a predominant and useful organisational form for managing IP issues, much knowledge is transferred throughout each HEI/PRO, often embedded in other activities with another primary purpose, with or without the involvement of KTOs. This insight has also resulted in works by several actual and potential survey providers to reassess the need for monitoring KT. We will briefly review some of these reassessments here.

Initiatives to broaden monitoring from technology transfer to knowledge transfer

The previously mentioned Expert Group on Knowledge Transfer Metrics defined metrics for a set of core indicators to be shared by survey providers such as the Association of European Science & Technology Transfer Professionals (ASTP) and the European knowledge transfer association ProTon Europe in their recurring surveys and hopefully also by *e.g.* national authorities initiating new monitoring schemes. ASTP and ProTon Europe agreed to harmonize their own metrics accordingly. These core metrics focused on the activities of KTOs and were limited in scope by the ability of these organisations to provide data that could reliably reflect knowledge transfer in their associated HEIs and PROs as a whole: invention disclosures, patent applications, patent grants, licenses executed, license income earned, spin-offs established, and research agreements. For details, see Table 10 below.

Table 10: Key performance indicators for knowledge transfer offices

Recommended core indicators for KTO surveys

1. Research agreements	
Definition: All contracts where a firm funds the PRO to perform research on behalf of the firm, with the results usually provided to the firm. Include collaborative agreements where both partners provide funding and share the results. Exclude cases where the firm funds a research chair or other research of no expected commercial value to the firm. Also exclude consultancy contracts. **Potential additional question(s):** ***Collaborative research agreements: Agreements where both the firm and the PRO participate in the design of the research project, contribute to its implementation and share the project outputs.* ***Contract research agreements: Agreements where all research is performed by the PRO.* ***Consultancy agreements: Agreements where the PRO provides expert advice without performing new research.* *Share of total research expenditures funded by the private sector.* ***Financial value of all research agreements; for each type of research agreement (collaboration, contract) or of consultancy contracts.*	**Comments:** An important indicator to balance patent indicators, since for many PROs, research agreements are a more important form of knowledge transfer. However, many KTOs may not know the answer, since contracts may be managed by individual departments or even by individual researchers. This question had the lowest item response rate out of the seven core indicators in the ASTP survey. Space permitting, it could be possible to obtain disaggregated count data on the number of each type of research agreement. Consultancy differs from research agreements in that it does not involve new research. In some countries consultancy could be an important method of knowledge transfer. It is not clear if the KTO is likely to be aware of all consultancy contracts, which could be drawn up between firms and individual research staff. If any of the three first additional questions are asked, it is important to clarify that collaborative and contract are subsets of research agreements, whereas consultancy contracts are not included in research agreements. Data on private sector funding is useful as a measure of the commercial orientation of the affiliated institution.
2. Invention disclosures	
Definition: Descriptions of inventions or discoveries that are evaluated by the KTO staff or other technology experts to assess their commercial application.	**Comments:** Core indicator that is easy for KTOs to provide.
3. Patent applications	
Definition: New priority patent applications. Exclude double counting, such as a patent application for the same invention in more than one patent jurisdiction. **Potential additional question(s):** *New patent applications to the EPO.* *New patent applications to the USPTO.*	**Comments:** Core indicator that is easy for KTOs to provide. Limitation to priority patents should be sufficient to prevent double counting. If questions about EPO or USPTO patents are asked, it is important to clarify that EPO or USPTO applications may or may not be priority applications. Non-priority EPO or USPTO applications may be technically equivalent to priority patent applications submitted in other jurisdictions in the same year or earlier.

Recommended core indicators for KTO surveys

4. Patent grants	
Definition: Technically unique patents granted. Count a patent grant for the same invention in two or more countries as one technically unique patent. If a technically unique patent grant has been counted in a previous year, it cannot be counted again. **Potential additional question(s):** *New patent grants from the EPO.* *New patent grants from the USPTO.*	**Comments:** The main problem is maintaining comparability across countries. It could be more difficult for respondents to give the number of technically unique patents than to give the number of USPTO or EPO patents. It may be best to ask for both.
5. Licenses executed	
Definition: Include all licenses, options and assignments (LOAs) for all types of IP (copyright, know-how, patents, trademarks, etc.). Count multiple (identical) licenses with a value each of less than 500 Euros as one license. A license grants the right to use IP in a defined field of use or territory. An option grants the potential licensee a time period to evaluate the technology and negotiate the terms of a license. An assignment transfers all or part of the right to IP to the licensee.	**Comments:** Core indicator that is easy for KTOs to provide. There are national differences in the survey definition of licenses, with AUTM in the United States excluding software licenses worth less than 1000 dollars.
6. License income earned	
Definition: Total income from all types of know-how and IP (patents, copyright, designs, material transfer agreements, confidentiality agreements, plant breeder rights, etc.) before disbursement to the inventor or other parties. Include license issue fees, annual fees, option fees and milestone, termination and cash-in payments. Exclude license income forwarded to other institutions than those served by the KTO or to companies.	**Comments:** Core indicator that is difficult for KTOs to answer (only 69% answered the question in the ASTP survey). Corresponds with the AUTM definition. The question could benefit from cognitive testing to determine the cause of the problem. For instance, the definition could be too complex or leave out an important component of license revenue.
7. Spin-offs established	
Definition: A new company expressly established to develop or exploit IP or know-how created by the PRO and with a formal contractual relationship for this IP or know-how, such as a license or equity agreement. Include, but do not limit to, spin-offs established by the institution's staff. Exclude start-ups that do not sign a formal agreement for developing IP or know-how created by the institution.	**Comments:** Core indicator that is easy for KTOs to provide. The definition of a spin-off is compatible with the definition used by the AUTM for a start-up. With our definitions, a start-up is any new company involving either people (staff or students) from the PROs or a formal knowledge transfer agreement (or both); start-ups and spin-offs are overlapping concepts. If a survey requests both start-ups and spin-offs, the overlap must be clear; for example, by asking for spin-offs and for start-ups that are not spin-offs.

Notes:
All questions refer to a one year reference period. All data are count data unless otherwise indicated.
Text in *italics* indicates potential additional question.
** means that the question needs to undergo pilot cognitive testing.
Source: (EUR 23894, 2009 table 5.3).

That Expert Group also recognized a much broader set of channels for interactive or uni-directional knowledge transfer, ranging from student placement via facility sharing to supporting start-ups and licensing of IP. In so doing, they also reflected the

insight that knowledge can be made available in codified form such as patents and publications, and embedded in artefacts and in knowledgeable persons. This reflects the need to consider transfer of knowledge not only in codified but also in tacit form, both of which are important for turning research into value. The group recommended broadening the range of activities to monitor in the future beyond those typically undertaken by KTOs (EUR 23894, 2009). The European Commission also followed up by commissioning a unified pan-European survey of KTOs and HEIs using many of these metrics, with results due to be published in 2011 and 2012.[24]

In 2007, the AUTM began reviewing the need for metrics and has come up with a proposal for an Institutional Economic Engagement Index (IEEI) ([AUTM], [2010]). Realizing that "reporting only on licensing activity seriously understates university contribution" (p. 1) to "the economic health of their communities" (p. 1), the proposal advocates a broader view. Under the headings of "institutional support for entrepreneurship & economic development", "ecosystem of institution", "human transfer activities", "technology knowledge transfer activities", "network creation activities" and "value creation activities" they have proposed a total of 40 themes or areas for which to develop monitoring metrics; see Table 11 below for a full list. They have also decided that much of that which is important to monitor is outside the scope of their members and therefore ought to be collected by the universities themselves.

Table 11: Metrics for institutional economic engagement

Proposed metric theme/area
Institutional support for entrepreneurship & economic development
1. Conflict of interest policy and procedures support institutions – community engagement
2. Sales of goods and services policies and procedures support institution – community engagement
3. Leave of absence policies and procedures support institution – community engagement
4. Institution has stated goals, policies and resources which support institution - community engagement. Programs to support faculty – staff interaction / Promotion & Tenure policy
5. Institution's senior administration has demonstrable support for institution - community engagement
6. Institution has dedicated staff comparable to peer institutions responsible for enabling the public use of institution works
7. Institution's finances are structured to not require or maximize income from community – institution engagement ... institution has budget to support community - institution engagement
8. Institution has clearly identified mechanisms on front page of website to engage with institution
Ecosystem of institution
1. State/ city/ etc. policies and procedures which enable easy business establishment (nature – fund of funds, investment programs, tax)
2. Business support services and activities available to local companies (nature of services, number of staff, annual budget, diversity of support – contributors to budget, their key metrics)
3. Incubator with business support services to support small companies (number of staff, number of clients, annual budget, diversity of support – contributors to budget, sq. ft. space available)
4. Seed funds active locally to support small companies (number, fund size, focus areas, average investment size, annualized number of investments)
5. Venture funds active locally to support growth of companies (number, fund size, focus areas, average investment size, annualized number of investments)
6. Mechanisms for connecting professionals active in area to entrepreneurial activities
7. Creative Class Ranking of Metropolitan Area

[24] See http://www.knowledge-transfer-study.eu

8. Number of specialized events or community-based organizations for entrepreneurial activity and support

Human Transfer Activities

1. Number of students enrolled / graduated / year
2. Number of graduate students enrolled / year
3. Number of graduates who remain within 60 miles of alma mater upon graduation
4. Former institution staff who remain within 60 miles of former employer
5. Internships
6. Community work projects (as part of class)
7. Courses / year designed for external community audience
8. Continuing professional development class enrolment
9. Number of students and companies engaged in "capstone" or other experiential learning opportunities

Technology Knowledge Transfer Activities

1. Number of students and companies engaged in "capstone" or other experiential learning opportunities
2. Number of companies within x miles (or State) of institution who have a contractual relationship with institution regarding technology use or development
3. Number of new companies / year who have new contractual relationships with institution
4. Number of recurring companies / year who have contractual relationships with institution
5. Number of consulting agreements / year with faculty or staff from institution
6. Number of faculty involved in consulting / research / other knowledge transfer activities with community
7. Number of companies launched / year associated with institution technology (as evidenced through some type of contractual relationship)
8. Number of start-up companies still in business, and their employment, associated contractually with institution
9. Institution research projects which have strategy for distribution of research assets

Network Creation Activities

1. Community engagement events for increasing economic interactions held by institution designed for community
2. Number of people met by institution senior officials from community

Value Creation Activities

1. Licensing income
2. Research income by source type (Federal, Industrial, other)

3. Other Knowledge transfer income

- Consulting income

- professional training income

- income from economic development agencies

- SBIR awards

- Investment in spin-out companies.

4. Gift income from
a. private sector companies
b. private sector companies with research relations

Source: ([AUTM], [2010]).

PraxisUnico, a UK non-profit educational organisation for the promotion of commercialisation of public and charity funded research, in 2007 commissioned a study to identify important aspects of knowledge transfer from academic research into the commercial sphere and propose metrics for indicators of such aspects at the level of individual research organisations. Their definition of knowledge transfer from universities was "The process by which knowledge, expertise and intellectually linked assets of Higher Education Institutions are constructively applied beyond Higher Education for the wider benefit of the economy and society, through two-way engagement with business, the public sector, cultural and community partners" (Holi *et al.*, 2008 p. 8). The approach applied in that project was to use focus group interviews with research funders, senior university management (representing researchers), and the business community in order to identify important mechanisms of knowledge transfer. A consensus was formed around the following mechanisms worth monitoring (in descending order of importance): networks, spin-outs, collaborative research, contract research, continuing professional development (CPD), consultancy, licensing, other measures, and teaching. Following that, a number of measures of quantity and quality of activities making use of each type of knowledge transfer mechanism were proposed. Many of these quantity measures are available from UK universities due to UK government policy of linking funding to reporting on several indicators for knowledge exchange. However, none of the proposed quality measures were found on record (Holi *et al.*, 2008).[25] For the whole list, see Table 12 below.

[25] In the UK, universities regularly collect and report to funding councils data on a very long list of indicators on all aspects of their activities. Many of these are linked to funding decisions; decisions see http://www.hefce.ac.uk/econsoc/buscom/measure/ for further detail.

Table 12: Metrics for knowledge transfer from universities

Mechanism of Knowledge Transfer	Measures of Quantity	Measures of Quality
Networks	# of people met at events which led to other Knowledge Transfer Activities	% of events held which led to other Knowledge Transfer Activities
Continuing Professional Development (CPD)	Income from courses, # of courses held, # people and companies that attend	% of repeat business, customer feedback
Consultancy	# and value/income of contracts, % income relative to total research income, market share, # of client companies, length of client relationship	% of repeat business, customer feedback, quality of client company, importance of client relative to their company
Collaborative Research	# and value/income of contracts, market share, % income relative to total research income, length of client relationship	% of repeat Business, customer feedback, # of products successfully created from the research
Contract Research	# and value/income of contracts, market share, % income relative to total research income, length of client relationship	% of repeat Business, customer feedback, # of products successfully created from the research
Licensing	# of licenses, income generated from licenses, # of products that arose from licenses	Customer feedback, quality of licensee company, % of licenses generating income
Spin-Outs	# of spin-outs formed, revenues generated, external investment raised*, market value at exit (IPO or trade sale)	Survival rate, quality of investors, investor/ customer satisfaction, growth rate
Teaching	Graduation rate of students, rate at which students get hired (in industry)	Student satisfaction (after subsequent employment), employer satisfaction of student
Other Measures	Physical Migration of Students to Industry, Publications as a Measure of Research Output	

Source: (Holi *et al*., 2008 table 7).

A Dutch initiative with emphasis on health sciences has probably thrown the net wider than most when categorising impact of (new) knowledge (references here). They have divided targets (and target audiences) for knowledge transfer in four: knowledge (science itself), culture (general audiences), prosperity (private professional sector) and well-being (public professional sector). For each of these they have then spelled out typical impacts of research by identifying typical knowledge products (such as scientific and popular publications, patents, products, services, guidelines, etc), a range of typical forms of knowledge transfer (such as lectures, prizes, training courses, consultations and target group influence on directions of research), and indications of how knowledge is being used to provide benefits to society. For a full list, see Table 13 below.

Table 13: Indicators for impact of science on society

IMPACT on knowledge (Science)	IMPACT on culture (General audience)	IMPACT on economic welfare (Private professional sector)	IMPACT on well-being (Public professional sector)
Knowledge products - SCI-publications - Contribution academic congresses - Chapters in academic books	**Knowledge products** - Popular science publications - Media attention - Web publications	**Knowledge products** - Patents - Products - Services	**Knowledge products** - Scientific journal publications - Developed guidelines - Products and services
Transfer of knowledge - Invited speeches at academic congresses - Functions in academic community - International academic participation in directing own research - Academic prizes and decorations - Courses for academic personal (participants, benefits) - International scientific consultations	**Transfer of knowledge** - Performances for general audience - General public functions - Participation of general audiences in directing own research - Public prizes and decorations - Courses for general audiences (participants, benefits) - Consultations from general audience	**Transfer of knowledge** - Performances for businesses - Functions for businesses - Business participation in directing own research - Prizes and decorations from business sector - Courses for businesses (participants, benefits) - Consultations from businesses	**Transfer of knowledge** - Performances for care & policy sector - Functions for care & policy sector - Care & policy sector participation in directing own research - Prizes and decorations from care and policy sector - Courses for care & policy sector (participants, benefits) - Consultations from care & policy sector
Use of knowledge - SCI-citations - Use, acquisition and purchase of academic books	**Use of knowledge** - Public citations - Use, acquisition and purchase of knowledge products by audience	**Use of knowledge** - Benefits from patents - Benefits from products and services	**Use of knowledge** - Citations in scientific journals - Use, acquisition and purchase of guidelines, products and services

Notes:
SCI = science citation index; service by Thomson Reuters that records individual scientific articles and measures their citation by each other.
Source: Adapted and translated from Dutch (van Ark and Klasen, 2007).

The ERAC Knowledge Transfer Working Group has adopted a wide approach, not limiting the scope to activities aimed at generating economic value, but without committing to a specific framework at this time.

ANNEX 3: Acronyms

Acronyms are explained where they first appear in the text. For convenience, these are repeated here in alphabetical order.

ASTP: Association of European Science & Technology Transfer Professionals
AUTM: American University Technology Managers, a professional organisation that *i.a.* performs and publishes annual licensing surveys
BERD: Business enterprise sector expenditure on R&D
CDH: Careers of doctorate holders; project intermittently undertaken by OECD, UNESCO Institute for Statistics, and Eurostat
CIS: Community innovation survey, large European survey of firms performed bi-annually by national statistics bureaus and published by Eurostat
CPD: Continued professional development
CREST: Scientific and Technical Research Committee (now ERAC)
EPO: European Patent Office
ERAC: European Research Area Committee
FTE: Full time equivalent; full and part time positions converted to full time positions
GEM: Global Entrepreneurship Monitor, a consortium led by Babson College that performs and publishes annual surveys on entrepreneurship in a large number of countries
GDP: Gross domestic product
HEFCE: Higher Education Funding Council for England
HEI: Higher education institution
HERD: Higher education sector expenditure on R&D
IP: Intellectual property
IPR: Intellectual property rights
IEEI: Institutional economic engagement index, a proposal by AUTM
IISER: The integrated information system on European researchers; undertaken by the JRC
ITTE: Institutions of transfer of technology
JRC: Joint Research Centre of the European Commission
KT: Knowledge transfer
KTO: Knowledge transfer office
LFS: Labour force survey, large surveys performed several times a year in a large number of countries, co-ordinated by Eurostat
OECD: Organisation of Economic Cooperation and Development
OeNB: Austrian National Bank
PRO: Public research organisation. Sometimes defined as a government owned research organisation, usually broader defined as a research organisation that receives substantial amounts of public funding and plays a role in public policy. Sometimes HEIs are counted as PROs, but in this report we distinguish between them
SINTEF: A private non-profit foundation in Norway for performing applied research
TBOP: Technology balance of payments; part of database of international trade etc. maintained by OECD
TT: Technology transfer
TTO: Technology transfer office
R&D: Research and development