S&T Linkage Indicators

Final Report

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1. Study Background and Organisation

The aim of the study is to develop a methodology to advance a new approach to examining the scientific base of the high- and medium-high technology intensive (HMHT) manufacturing industries. This is the third and final report under the study *S&T Linkage Indicators Code: ASSIST-2004-01-16.* Section 2 gives an executive summary.

The study includes a review of available literature from academic (e.g. universities), public organizations (e.g. research institutes) and other agencies and organsations (e.g. the OECD) engaged in measuring the scientific base of HMHT manufacturing industries and in the development of new measurement tools for the science base (Section 3).

A methodology to advance a new approach to examining the scientific base of HMHT manufacturing industries was developed. A detailed description of the methodology, including its development over the study is given in Section 4. A set of concordance tables were developed and are provided in electronic format (refer to file: and file: The citation database is presented in Section 5.

As well as developing a new methodology to link HMHT manufacturing industries and the education base, the methodology is used to examine the S&T linkages for four 'pilot' countries. The results for the four countries of France, Germany, Italy and the UK are presented in Section 6. Also provided in Section 6 is the work carried out for the OECD Blue Sky Meeting (September 2006) that demonstrates the potential of the work developed under this study. Observations and conclusions of the methodology developed under the study are given in Section 7. Dissemination options and future directions for research are given in the final Section 8.

A detailed list of references is in Section 9. In the Annex concluding the report is the draft discussion paper and presentation given at the Blue Sky Meeting as well as the concordance table allowing for the linkages to be developed between citations, patents and education.

2. Executive Summary

The development of the concordance tables and the methodology developed and tested under this study tell us the availability of a complete set of concordance tables allows analyzing relationships between components of innovation systems in novel ways. Such analysis bears considerable potential for informed policy making. The analysis piloted in this study reveals the feasibility of such an endeavour, already at this stage several interesting observations become worth highlighting.

- It now becomes feasible to align or translate the amount of activity within science, technology, education and economy towards one classification scheme spanning all activity domains.
- The availability of a comprehensive set of different concordance tables covering education-science-technology-industry offer a range of possibilities to further examine the dynamics of innovation systems. For example, it is now possible to engage in empirical analysis whereby the relationships between the components of the different activity realms can be analyzed in a more fine-grained manner.
- Harmonized data offer potential for fine grained analysis oriented towards understanding dynamics and relationships between different components of innovation system.

The results of the data sets and analysis carried out under this study reveal Indicators pertaining to human capital (educational data) deserve our serious attention when looking at technological and industrial activities of HT industries. Country differences pertaining to technology development and human capital do translate into economical differences at the industry level. The extent to which technology and human capital differences become translated into industrial activity seems to be country specific, directing out attention to the institutional and market factors that moderate this relationship.

- European countries show relative strong positions in terms of science, technology and education. In terms of economic performance, the European countries under study are being outperformed by the US, Japan and even Korea.
- For each of the EU countries, it is in HT intensive manufacturing industries one observes the highest concentration of researchers as measured by share of R&D personnel. At almost nine researchers out of ten R&D personnel in the HT industries and three in five in the MT industries, the UK reports the highest concentration of researchers to total R&D personnel.

There are a number of key policy issues issues with regards to linking technological performance and the education base as measured by human capital indicators. For example,

- **Does education, in this case as measured by PhDs in S&T, contribute to HT technological performance?** Although it appears that although money certainly matters, people really matter when it comes to HT technological performance. The correlation between R&D expenditures and HT productivity is not necessarily low but the correlation between education (PhDs in S&T) and HT productivity is significant.

- **Does educational strength (as measured by PhDs in S&T) contribute to HT technological performance?** Although clearly technological performance hinges on the combination of money (R&D expenditures) and people, people are important and not to be excluded from measurement of HMHT performance. Results suggest a distinctive and considerable impact of educational strength on technological performance.
- **Does educational strength (as measured by PhDs in S&E) contribute to technological performance in general?** Is the correlation between human capital and performance unique to the HT intensive manufacturing industries (e.g. one might expect this correlation HT industries), or does the result hold for other industries. Analysis was carried out on HT, MHT, MLT and LT industries for seven countries over six time periods. The findings suggest a positive relationship between PhDs and technological output and this is not limited to HT industries — this applies across all industries.
- The results suggest considerable country differences both in terms of absolute strengths and even in terms of the relationship between technological capabilities and the performance of HT industries. The relevance of further stressing investments in R&D, technology and people (see also the Lisbon goals) is confirmed by this analysis; at the same time the amount of variance that is country specific is considerable.
- Differences between countries do not seem to limit themselves to differences in absolute size. The strength of the relationship between innovation related indicators (patents, R&D, PhD in S&E) on the one hand and economical performance on the other hand seems to be to a large extent country specific. Korea and Germany represent the most extreme cases in terms of strength of the relationship: a similar increase in absolute patent activity coincides with an increase in industrial added value which is about ten times higher for Korea than for Germany. The analysis suggests to a need to engage in further analysis whereby factors affecting the translation of innovative activities into economical activities become a central focus.

It goes without saying that the results of this study are of an exploratory and preliminary nature. Further research is needed unravel the potential offered by the availability of a full set of concordance tables. Further work is needed to link traditional structural indicators of R&D and innovation to human capital in order to better understand the ‘how’ of science and innovation.

The methodology developed for this study and the preliminary results have already generated a lot of reaction in the research community (e.g. OECD Blue Sky for new measures and indicators).

3. Literature Survey

3.1. Towards science-technology concordance tables based on citations in patents to research literature.

Whereas research papers represent scientific progress, especially basic scientific research, patents represent technical developments and are good candidates to help shed further light on the R&D-based innovation potential in certain technical areas. The “non-patent references” (NPRs) listed on the front pages of patents (USPTO patents), or in the patent examiner reports (EPO patents), represent an explicit link between patented technical inventions (‘technology’) and published scientific and engineering research (‘science’). Especially in the case of the R&D-intensive industries, one will find many patents also citing scientific and technical literature, including research articles in international scientific and technical journals. As such, NPC data offer a proxy measure for the industrial relevance of basic and applied scientific research. Moreover, to the extent that such references are numerous, they allow for a systematic assessment of the relationship or concordance between scientific and technological fields.

3.1.1. A closer look at prior art and non-patent references found within patent documents.

Patents are documents issued by an authorized agency, granting exclusive right to the applicant to produce or to use a specific new device, apparatus or process for a limited period. They are granted to the applicant after an examination that focuses on the novelty, inventive activity and industrial applicability. During the granting process, patent examiners review the prior art that pertains to the invention. Based on information archives and databases, the examiners decide which references are relevant for assessing the patent and its constituting claims. In this process, examiners do not limit themselves to the prior art that was signaled by inventors and/or applicants. The front pages of patent documents include *examiner-given* references that do not necessarily coincide with references that are provided by the inventor: the latter may be omitted by the examiner and/or the examiner may add references that were not mentioned by the inventor. It can be noted here that the specific role of references in patent applications differs to some extent from the role that references or citations play in scientific publications. Article references indicate sources of influence or serve as reference points to delineate differences (novelty). They are introduced by the authors (sometimes with some support from reviewers), implying that the cited references are always known to the author(s). Therefore, following the argument on cumulativeness in knowledge production (Foray, 2004), it can be argued that the cited references have influenced the genesis of the insights developed in the citing article. This is not necessarily the case for the front-page references in patent documents.

In terms of content, several types of prior art can be distinguished. A distinction is generally made between patent references and other – mostly scientific – references.

A majority of previous research has focused on the role of *patent* references and citations, used as an indication of patent value (Fleming and Sorenson, 2001; Jaffe et al., 2002; Harhoff et al., 2003; Reitzig, 2004). The patent citation-based approach for analysing science-technology linkages by looking at *non patent references* (NPR's) dates back to the pioneering work by Carpenter et al. (1980), Carpenter and Narin (1983), Narin and Noma (1985), Van Vianen et al. (1990), Narin & Olivastro, 1992; Narin et al., 1995; 1997.

Studies have investigated the nature of science-technology relationships as implied by citation links (e.g. Narin and Noma, 1985), the role of public science for developing technology (e.g. Narin et al. 1997), the frequency and nature of occurrence of such interactions in new emerging technology domains (Van Vianen et al. 1990; Meyer, 2000a; McMillan et al., 2000; Tijssen et al.; 2000; Tijssen, 2001; Verbeek et al. 2002; Acosta and Coronado, 2003), as well as the relationship between the science intensity of patents – as measured by the amount of other references – and technological productivity (Van Looy et al., 2003b). Proponents sometimes portray scientific references in patents as signaling a direct influence of science on technology (e.g. Narin et al. 1997), while others advocate a more modest interpretation. Meyer (2000a, 2000b, 2001), after having performed a number of detailed patent case studies, concludes that non-patent references should *not* be interpreted as indicating a *direct* and *uni-directional* link or influence from science to technology. Tijssen (2001, 2002) and Tijssen et al. (2000), having surveyed inventors on scientific contributions to their patents, point in a similar direction: non-patent references should be considered a general indicator of interaction between science and technology, rather than as the reflection of scientific sources leading directly to the invention (Tijssen, 2001, p. 39). In line, several authors point to contextual elements that should to be taken into account when interpreting such indicators. Michel and Bettels (2001) argue that the comprehensiveness and the quality of citation lists appearing in patent documents vary significantly as a function of the patent office. Differences between the USPTO and EPO examination procedures may influence the number and type of references cited, as will become illustrated further. Harhoff et al. (2003) and Van Looy et al. (2003a,b) point to field specific effects to be taken into account when using and interpreting patent related indicators.

One should be careful in depicting citations in patents as interactions or direct links of causation between two bits of information. These references are part of the context in which the patent and its claims are situated. The presence of scientific research in the 'prior art' description of a patented invention should be considered an indicator of the relevance of scientific findings for assessing and contextualizing technology development. At the same time, it is plausible to state that more scientific references signal more relevance or relatedness between the technology at hand and scientific activity[1]. As such, indicators based on these references might provide useful information on science-technology relatedness and might enable the construction of concordance tables relating scientific fields and technology, at least if their presence displays sufficient levels of occurrence.

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[1] Notice that Science-Technology relatedness as described here also has a counterpart, namely references towards patents found within scientific publications.

3.1.2. On the frequency and occurrence of NPR's

In the next section, we provide a systematic view on the information that is observable, i.e. the amount of non-patent references in patents. This allows assessing the feasibility of developing indicators and concordance tables based on non-patent references.

In terms of content, several types of prior art can be distinguished. A distinction is generally made between patent references and other – mostly scientific – references[2]. In this section, we report on the occurrence of patent and other references that are found in the EPO and USPTO patent systems (see also Callaert et al., forthcoming). For this analysis, all granted patents were considered with application year between 1991 and 2001, with data extraction taking place during the summer of 2002. Table 1 provides an overview of the occurrence of both patent and non-patent references observed in this period[3].

Table 1. Occurrence of patent and non-patent references (USPTO – EPO).

USPTO granted patents with application year between 1991 and 2001					
Total # patents (1)	1,299,817	Total # references	17,757,797		
# patents containing patent references	1,173,593 (90%)	# patent references	14,738,854 (83%)	Technology-intensity *With (1) as denominator:*	12.55 *11.33*
# patents containing non-patent references	445,466 (34%)	# non-patent references	3,018,943 (17%)	NPR-intensity *With (1) as denominator:*	6.77 *2.2*
EPO granted patents with application year between 1991 and 2001					
Total # patents (1)	342,704	Total # references	1,698,218		
# patents containing patent references	334,413 (98%)	# patent references	1,404,241 (83%)	Technology-intensity *With (1) as denominator:*	4.20 *4.09*
# patents containing non-patent references	130,511 (38%)	# non-patent references	293,977 (17%)	NPR-intensity *With (1) as denominator:*	2.25 *0.86*

(Source: Callaert et al)

Table 1 shows that the majority of patents contain patent references (90% and 98% for USPTO and EPO respectively). This is not the case for non-patent references: the proportion of patents containing such references amounts to 34% for USPTO and 38% for EPO. Moreover, patent references are more numerous resulting in a share of 83% compared to non-patent references. As a consequence, for both USPTO and EPO patents, the average number of patent references per patent ('technology intensity')

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[2] Patent references differ not only from 'other references' in terms of the nature or the cited documents (patents versus all other types of documents). Extracting and assessing 'other references' is also a more complicated endeavour, due to the idiosyncrasies in terms of reporting such references as well as the multitude and variety of written documents being cited (for an extensive overview, including the outline of an adequate parsing method, see Verbeek et. al., 2002).

[3] Currently we have undertaken all steps necessary to update the patent databases (USPTO, EPO) in order to extend the time period to 2003/2004.

doubles the average amount of non-patent references per patent (‘NPR-intensity’[4]). This observation may – at least partly – be associated to alleged search impediments in the examiner procedures. As the President of the International Intellectual Property Institute pointed out (Lehman, 2001), the USPTO and other patent offices lack comprehensive and easily accessible databases of non-patent prior art. Effective examination today requires comparing claimed inventions with information disclosed in countless journals and other publications to which examiners have limited access and for which they lack effective search tools. In practice, the USPTO purchases access to electronic databases that contain many publications in electronic form (e.g. Derwent, Nexis, Dialogue). But none of these are searchable across the entire database, and they may be searched only using the key words familiar to a given examiner. The fact that there is such a difference in terms of complexity and scope between patent database searches and those of non-patent literature (see also: Sampat, 2004) undoubtedly explains part of the relatively lower occurrence of non-patent references.

A second aspect that should be highlighted is the concentration and distribution of patent and non-patent references over the different fields of technology. By examining and regrouping the classification of a patent (IPC), a distribution of references over broader technological areas can be established (the nomenclature used here is based on the technology classification scheme designed by OST in France in collaboration with the Fraunhofer Institute and INPI). The findings are presented in Table 2.

Table 2. - Breakdown of NPR- and technology-intensity per technology domain.
(USPTO and EPO patents with application year between 1991 and 2001)

	EPO patents		**USPTO patents**	
Technology field	Technology intensity	NPR-intensity	Technology intensity	NPR-intensity
Electrical engineering	3.74	2.24	11.25	4.83
Instruments	4.34	2.32	13.76	6.72
Chemistry, pharmaceuticals	3.87	2.68	11.39	13.23
Process engineering, special equipment	4.46	2.08	14.17	4.66
Mechanical engineering, machinery	4.64	1.74	13.06	3.27

(Source: Callaert et al. forthcoming)

For the EPO data, one observes the highest intensity of patent references per patent for Mechanical engineering and machinery (technology-intensity of 4.64), followed by process engineering and special equipment (4.46). Electrical engineering fields display the lowest average number of references to patent documents. As for NPR-intensity, Chemistry and pharmaceuticals show the highest number of NPR’s (2.68 non-patent references per patent). Comparing these findings to the USPTO data, we find that process engineering and special equipment display the highest average

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[4] The term ‘science’ intensity is mostly used for the average number of non-patent references per patent. This suggests that all other references would be references to the scientific literature. As we will see further on, this is not completely accurate. Therefore, at this stage we prefer to use the term “NPR intensity”.

number of patent references (14.17) followed by instruments and mechanical engineering and machinery (respectively 13.76 and 13.06 references per patent). Here too, chemistry and pharmaceuticals contain the highest average number of non-patent references (see also Verbeek et al., 2002).

Whereas for the USPTO and EPO systems, proportions of the different reference types are comparable (see Table 1), it can be seen that – in absolute terms – USPTO patents hold on average about 3 times more references than EPO patents. Such an observation could be directly related to the differences in the rationale of citing prior art between the American and the European system. [2.1] In the USPTO system, the 'duty of candour' principle postulates that all prior art documents (including patents and other written documents) that are in any way considered relevant to the patentability of the invention, must be disclosed. Failing to do so can result in patent litigation and severe penalties. The European system, on the other hand, postulates no such requirement. To this date, no obligation is placed on the applicant or his representative to inform the EPO of any prior art believed to be relevant and no penalties exist for not disclosing relevant prior art (Akers, 2000). Such different disclosing obligations can be considered an important reason for the higher number of references in USPTO compared to EPO.

In general, the most important information source of technology development is technology itself (other patents). However, occurrence of other references can be considered non-trivial, especially in certain technological domains most notably in chemistry and pharmaceuticals. Therefore, a further assessment of the nature of these other references seems appropriate. To the extent these other references are of a scientific nature, developing a concordance table that allows relating science and technology fields becomes feasible. A closer look at the nature of the references in patents, as provided in the next section, helps uncovering possibilities and limitations in this regard.

3.1.3. A closer look at the nature of non-patent references

Systematic overviews of the nature of other references in patents are scarce, although some efforts in this direction were made in the past. Narin and Noma (1985) reported – for the period 1978-1980 – on average 0.3 other references per patent, which is considerably lower than what we observed. Thirty seven percent of these references related to SCI journals, 11% to other journals, 15% to books and 11% to abstracts. The final 26% related to miscellaneous sources. Van Vianen et al. (1990), in their exploration of the science base of technology, found that for a total of 2900 Dutch patents between 1982 and 1985 from all technological classes, 55.7% of the non-patent references were journal citations. Of these, 82% were SCI covered journals. Non-journal references appeared to cite mostly books and abstract services, and to a lesser extent meeting abstracts. Harhoff et al. (2003) also briefly illustrated the fact that not all non-patent references refer to scientific sources. They evaluated 100 patent document records, and found about 60% of non-patent references referring to scientific and technical journals. The remainder was largely made up of references to trade journals, to firm publications or to standard texts in the technical fields e.g. for the classification of chemical substances or specific mechanical designs.

In order to create an updated insight into the nature of the other references, Callaert et al. (forthcoming) extracted two samples of non-patent references from the USPTO and the EPO databases. In each database, 5000 non-patent references were randomly drawn from granted patents with application year between 1996 and 2001. For USPTO patents, front-page references were extracted. For EPO, the Reference File (REFI) database was used. To ensure a representative sample, the group of patents from which references were drawn was stratified according to the overall distribution of patents over technology domains (IPC, 3-digit level). Both samples of non-patent references (EPO and USPTO) were classified; each citation was classified according to the document type that was referred to. The taxonomy of reference types used was based on previous categorizations (Narin and Noma, 1985; Van Vianen, 1990; Harhoff et al., 2003) and extended while conducting the content analysis of the extracted sample of references (Table 3). Most of the non-patent references could be categorized in this scheme. Only for a limited number of references, incomplete information did not allow for a precise categorization. They are referred to as ‘other’.

In the group of non-patent references, a first distinction can be made between journal and non-journal references. In a narrow sense, only journal references refer to the actual scientific journal literature. Scientific journal references were most easily recognized when the journal was SCI covered: a match of the journal title with an existing list of SCI covered journals, allowed for straightforward identification of these references. For other serial references, a case-by-case evaluation was needed on whether they were references to scientific literature or rather to a publication (e.g. newspaper or magazine) with a non-scientific orientation. The latter are classified as ‘non-journal references, newspapers / magazines’. This assessment was based on the cycle of appearance (e.g. weekly: more likely to point to non-journal category), references and descriptions in academic databases (e.g. EBSCO host, Academic Search Premier), as well as a content analysis of a limited sample of issues.

Table 3. Taxonomy of reference types to be found in patent documents.

Category	Sub-category	Description	Illustration
Serial journal references:	*SCI covered*	References to scientific publications published in serial journal literature and covered by the scientific database, The Science Citation Index (a Thomson-ISI product)	*Schoentag et al.. (1987), Cancer Research 47: 1695-1700 *MacDonald et al.; The American Journal of Cardiology; 62: 16J-27J (1988); "Preclinical Evaluation of Lovastatin".
	Not SCI covered	References to scientific publications published in serial journal literature but NOT covered by the scientific database, The Science Citation Index (a Thomson-ISI product)	*Pharmazeutische Zeitung, 124 No. 20, May 17, 1979, pp. 946-957. *"Formation of Si-Si Bonds From Si-H Bonds in the Presence of Hydrosilation Catalysts", Organometallics 1987, 6, 1590-1591, Katherine A. Brown-Wesley.
Non Journal references:	*Conference Proceedings*	Proceedings from conferences, workshops, consortia,… except for those that are WoS covered serials (such as some IEEE proceedings and Proceedings of the National Academy of Sciences)	Kellner, R. and G. Jung., Proc. 20th Europ. Peptide Sym. 366-368 (1988).
	Reference Books / Databases	Encyclopaedia, Dictionary, Lexicon, Handbook, Manuals, Databases of genetic sequencing, protein information,… (e.g. GenBank, Swissprot, EMBL, PIR,…), but also Chemical Abstracts, Biological Abstracts. Manuals that are clearly associated to a company product are categorized as 'industry documents'	*Maniatis et al, In Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Labs. 1982, pp. 3-5, 24-27 and 31 *Suzuki et al., Chem. Abs., vol. 107, (1987), Abs. 87142x.
	Industry / Company related documents	Catalogues (e.g. Nike Footwear Catalog, Fall 1993, published Dec. 1, 1992 (pp. 10,16)); Brochures (e.g. "OCULUS-300", Product Brochure of Coreco Inc., date unknown.); IBM Technical Disclosure Bulletin; Advertisement (e.g. Passage St. Roch, Eyeglass Advertisement); Product information (e.g. Natuzzi Model 1207, Oct. 1994, at International Home Furnishings Market in High Point, North Carolina); Internal Company Project Reports	*USCU Sales Brochure 6-74/5070107. *Brochure entitled, "Danniflex CPM 500" by Danninger Medical Technology Inc. *Cross R.G. "Keyboard Overlay", IBM Technical Disclosure Bulletin, vol. 15 No. 1, Jun. 1972.
	Books	All books except for those categorized as Reference Books	Burger, "Medical Chemistry", 2nd Ed., pp. 72-88 (1960).
	Patent related documents	Patents (including the JAPIO abstract service); Legal documents (motion, declaration, letter); Duplicates (documents that represent a re-issued patent); Search Reports; License agreements	*Japanese Laid-open Patent Application No. 294848/86, dated Dec. 25, 1986. *European Search Report of European Application No. EP 94 30 6086. *License Agreement Between Dr. Albert M. Kligman and Johnson & Johnson, Jul. 18, 1984
	Research / Technical Reports	Patient Information Sheets; Reported Results of experiments/try outs; Technical or research reports of (public) research centres; PhD and master's thesis	*1987 and 1988 Tables of Data from Official Canadian Rapeseed CO-OP Trials. * 1982 ACM 0-89791-066-4, pp. 39-47, "The 801 Minicomputer", by G. Radin.
	Newspapers / magazines	Non-scientific, popular (e.g. PC Magazine, the Wall Street Journal, Dr Dobb's Journal,…)	*Grabowski, Ralph, "Z Mouse Gives CAD Designers 3-D Control," Infoworld, p. 93, Jul. 13, 1992. *Michael Segell, Sports Illustrated, 1985, 1 pg.
	Unclear / other	If source could not be identified in a straightforward way	*Protectoral Features * B.B. Sol 1974.

Table 4 shows the relative occurrence of journal and non-journal references in the USPTO and EPO samples of non-patent references. For both USTO and EPO references, more than half are journal references. An additional check reveals that the

SCI database provides an almost full coverage for these journal references, holding respectively 90% and 86% of journal references in our USPTO and EPO sample.

Table 4. – Occurrence of Journal and Non-Journal References in USPTO and EPO: observed values.

	Journal	Non-journal	Total NPR's
	(row percentages between brackets)		
USPTO	2,766 (55%)	2,242 (45%)	5,008
EPO	3,218 (64%)	1,803 (36%)	5,021
Total	5,984	4,045	10,029

(Source: Callaert et al).

3.1.4. Intermediate conclusions

This literature review; including the analysis of the occurrence of references in patents, shows the non-trivial nature of non-patent references. In addition, when looking at the nature of these references, a majority consists of references to the scientific literature. These observations allow for the conclusion that developing recurrent, robust indicators based on these references is plausible and that this information can be used to develop a concordance table that relates technological domains (IPC) and scientific fields.

While possibilities for analyzing the obtained indicators are numerous, some limitations should be taken into account when interpreting them. One limitation became apparent in this overview. When conducting large-scale analysis for examining patent-to-patent citations and patent-to-paper citations, for examples, one is confined to database availability and limits. For large-scale analysis of non-patent references in which information is needed on characteristics of the cited documents, one has to rely on publication databases that allow one to qualify the information obtained in a systematic and consistent way (e.g. scientific discipline, affiliation). The most widely adopted publication database for such purposes is the ISI Web of Science database (see below) that covers a large share of the scientific journal literature in many scientific disciplines. The other types of non-patent references – as well as the journal articles not covered in the Web of Science database – are far less captured in such encompassing databases and are, therefore, much harder to include in large-scale quantitative analyses. Our analysis revealed that 50% to 55% of non-patent references are journal references covered by the Web of Science.

Secondly, our findings reveal that the amount of scientific references found in patents differs between technological fields. This implies that the possibilities and relevance of using such references varies, depending on the technology domain under consideration.

Finally, a proper interpretation of indicators based on other references should take into account the context in which patent documents are situated. Several differences between the EPO and USPTO system were pointed out above. These differences can mostly be attributed to the fact that the EPO system does not have the USPTO's duty of candor, which can influence reference patterns. When interpreting any patent related indicator, one should always be aware of the procedure that has preceded the grant or application of the patent documents under consideration.

Notwithstanding these concerns, our findings reveal that citations in patents allow for development of non-trivial and robust indicators. The majority of all non-patent references are journal references, providing ample possibilities for large-scale analyses focusing on the extent to which technological developments are situated within the vicinity of scientific knowledge, including supporting the development of a concordance table relating science and technology domains. Adopting the above analytical framework, and implementing these convenient operationalisations of science and technology is probably the only way to generate a statistically robust and systematic overview of empirical linkages between individual technological areas and fields of science. The various connections and relationships between both domains of knowledge production enable us to gauge and assess the strength and distributional characteristics of the linkages in terms of quantitative-statistical measures. This information provides the framework for a formalized concordance system between science and technology – that is for those fields where research articles in peer-reviewed international journals do actually represent global activities. Until now, none of these studies have produced a fully-fledged concordance system across fields of science or technology areas, at least none that were made publicly available. In more recent years, the EC-funded study by Tijssen and Van Looy (2005) has produced a prototype concordance system based on USPTO/IPC-defined areas and ThomsonScientific/JSC-defined subfields, derived from bibliographic information referring to the years 1996-2001.

Choice of databases

The patent data is usually drawn from either the European Patent Office (EPO), or the patent database of the United States Patent and Trademark Office (USPTO). Most of NPR studies were based on USPTO patents, or combinations of EPO patents and USPTO patents. These two patent databases have been key sources of statistical information for economic studies of technical change and technological innovation since the 1970s even though a number of important caveats apply to these patent data.[5] Nonetheless, patents provide a detailed and verified source of comparative empirical information on inventive activity, as well as, under specific conditions, offering the added bonus of enabling more detailed analyses of R&D processes.[6] As became clear, EPO patents contain few NPRs where the USPTO patents contain many (especially in life sciences-related technologies). For that reason we re-confirm the option to work both with the USPTO and EPO patent databases within the framework of this project. Both patent databases are available in a relational environment at

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[5] First and foremost, most patents do not cover specific marketable 'innovations', but might conceivably contribute in some fashion to one or more such products (or product related processes/services) in the future. Patents do not reflect innovative behaviour, particularly in medium tech and low tech domains where intangible external factors (markets, organizational and managerial variables, marketing strategies, etc.) largely drive and shape the non-technological innovation capabilities. Secondly, many technologies are not patented because it rests mainly on tacit knowledge and non-codifiable know-how (e.g., software), because it is kept secret (e.g. process technology), or because it is very difficult to protect through patenting. These non-patented technologies are likely to be less dependent on basic or applied science, and more on engineering skills and industrial design.

[6] See the handbook chapters by Breschi, and by Nesta and Patel for other applications of patent based indicators and statistics.

INCENTIM, K.U.Leuven. Moreover, the complete set of NPR's has been extracted by applying and developing specific parsing algorithms (see Verbeek et al., 2002, Tijssen & Van Looy, 2004). At this moment, all NPR's obtained by applying these algorithms are available within a relational database environment, enabling further development efforts towards S-T concordance tables.

The vast majority of the NPR linkages studies discussed above have operationalised "science" in terms of the peer-reviewed journals indexed by Thomson Scientific (formerly known as the Institute for Scientific Information – ISI), a subsidiary company of Thomson International, for this collection of Citation Indices (nowadays incorporated in the web-based version Web of Science). Thomson Scientific assigns each journal to one or more Journal Subject Categories (JSC), which often correspond to "research subfields" as perceived in the international academic community (e.g. Electrical and electronic engineering, or Immunology).7 CWTS has created this dedicated bibliometric database of documents published in journals and serials processed by Thomson Scientific for the CD-ROM versions of the Science Citation Index and eight associated citation indices (CIs): the Science Citation Index (SCI), the Social Science Citation Index (SSCI), and the Arts & Humanities Citation Index (AHCI), and six specialty Citation Indexes (Chemistry, Compumath, Materials Science, Biotechnology, Biochemistry & Biophysics, and Neuroscience). This CWTS-Thomson Scientific database will be superseded by a Web of Science-based version that will become operational in the second half of 2005.

3.2. Field of science and technology — industrial activities and field of science and technology — education.

In this section, we consider what we can expect to encounter when developing a concordance between the OECD fields of science and technology and ISCED 1997.

As mentioned earlier, there is a tradition in education fields to sort out coding problems by assigning the field to the one in which the student spends most of his/her time was mentioned earlier. This field assignment also applies to faculty and researchers (e.g. research and teaching activities) — a 'home' department is used for internal administration. The stakes are high for universities. Research output indicators are used for attracting students and faculty and influence government and industrial R&D investment. One of the positive side effects of the university 'ratings' game is there is attention paid to developing and updating education field taxonomies. The problem is they are often done by region and differ across countries (even within countries at times).

Graduate programs vary by university and by country. In turn, the recognition of areas of research may vary by university, by region and by country. For instance, in some universities a programme may be independent (e.g. anthropology, department of) it may be part of a broader doctorate programme (e.g. sub field of sociology).

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[7] The subfields are delineated by the classification of the journals in which research publications appear. Each journal category contains a collection of journals covering the same, or close related, research topics or areas. Journals are assigned to sub-fields based on their inter-journal citations patterns. Quite a few of those scientific journals are assigned to multiple journal categories.

Another problem not to be overlooked is the effect of the ‘personality’ of disciplines. Published scholarship can vary by field. For example for many of the social sciences, publication often comes in the form of books rather than journal articles and so density varies. This would be the case for anthropology and history. For other social sciences like economics, the publication in reports and journal articles is more typical of other ‘hard’ science fields. There is biomedical science in life sciences and biomedical science in agriculture and the coding may depend upon the university focus.

It used to be that research was narrow and well defined — readily classified. Today although research may be increasingly highly specialized, knowledge creation is characterised by the rise of multi- and inter-disciplinary programs (Graham and Diamond) and interdisciplinary research networks. Add to this the changing nature of research teams and networks brought about by internationalisation of research and globalisation of research units. The changes in how research is conducted have consequences for R&D measures (e.g. R&D funding, degrees awarded, citations) and for coding requirements to reflect, as accurately as possible, the input from a number of disciplines. It moves the discipline assignment beyond the taxonomies of existing fields of study.

Scholarly societies and university departments can be consulted about major field subdivisions and the threshold for the subdivisions, but there is little that can be done about multidiscipline ranking that is reported based on the ‘lead’ programme such as the case of a classification like ISCED 1997. As with any taxonomy, the use of ISCED 1997 shows the limitations of the system and that coding of field (and discipline) of education still relies upon arbitrary decisions.

Coding of education has other problems beyond tackling the changing nature of research pressures to consider multi-disciplinarity. What about new and diversifying disciplines? There is the time gap (e.g. between classification revisions) between the emergence of a new discipline and the revision of the coding structure. Design/systems engineering remained under ‘other’ engineering until there were sufficient numbers for it to emerge as a unique discipline in the coding structure; the emergence of design/systems engineering as a unique discipline varied across universities and national systems. Some universities maintain separate records for emerging fields while others include them as sub-fields of existing fields. The field of biological sciences is the typical example for a coding structure that may not necessarily reflect the programmes. Then there are interdisciplinary fields such as neuroscience and biomedical engineering? Biological sciences will present a number of problems for the concordance tables.

3.2.1. ISCED 1997 field of education

The first ISCED classification was issued in 1976 and revised in the ISCED 1997. It is a classification that provides a set of definitions and criteria that help with international comparability of education statistics. ISCED 1997 provides guidelines for comparability of degrees (e.g. level of degree) and broad fields of science. It is supposed to take into account recent development in education including diversification of disciplines. ISCED 1997 has 25 fields of education (expanded from 21 in the 1976 version)[8]. The breakdown of field of study may be useful at the national level but will be limited for international comparisons.

In terms of the challenge of multi-disciplinary reporting, ISCED 1997 maintains the traditional approach — the field of education is coded according to the field of education in which the student spends most of his/her time. It is a structure that does not lend itself too well to researchers in an international research environment expanded by globalisation of industrial R&D and formation of networks.

3.2.2. Correspondence between ISCED 1997 and OECD fields of science and technology

The OECD has a tradition of using existing international classifications when possible so there is at the least a common language with S&T and so the exercise of building concordance between OECD field of S&T and ISCED 97 has a good foundation.

There is 'broad' correspondence between ISCED 1997 and the OECD fields of science and technology. The OECD sub-sector classifications are based on the six major fields of study of UNESCO:

1. Natural sciences
2. Engineering and technology
3. Medical sciences
4. Agricultural sciences
5. Social sciences
6. Humanities

According to the OECD Frascati manual research activities can be split into two main groups: natural sciences and engineering (NSE) including natural sciences and technology, medical and agricultural sciences, and social sciences and humanities (SSH). These can be accommodated by ISCED 1997. The table below shows examples of existing concordance between the OECD field of science and technology and the broad fields of ISCED 1997.

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[8] In 1999, UNESCO together with Eurostat broke out the main fields to some 80 sub fields (detailed) to accommodate classification needs of Eurostat but this was done mainly for vocational level education)

Table 5. Considering concordance between the OECD field of science and technology and broad fields of ISCED 1997.

OECD field of science and technology	ISCED 1997
1. **Natural sciences** 1.1. Mathematics/computer sciences 1.2. Physical sciences 1.3. Chemical sciences 1.4. Earth and environmental sciences 1.5. Biological sciences	***Science*** 46 Mathematics/statistics 44 Physical sciences 48 Computing see 44 43 Life sciences
2. **Engineering and technology** 2.1. Civil engineering 2.2. Electrical engineering 2.3. Other engineering	***Engineering, manufacturing and construction*** 52. Engineering/engineering trades
3. **Medical sciences** 3.1. Basic medicine 3.2. Clinical medicine 3.3. Health sciences	***Health and Welfare*** 72. Health
4. **Agricultural sciences** 4.1. Agriculture/foresty/fishing 4.2. Veterinary medicine	***Agriculture*** 62. Agriculture/foresty/fishing 64. Veterinary
5. **Social sciences** 5.1. Psychology 5.2. Economics 5.3. Education 5.4. Other social sciences	***Social sciences, business, law*** 31. Social/behavioural sciences 34. Business administration 38. Law
6. **Humanities** 6.1. History 6.2. Languages/literature 6.3. Other humanities	***Humanitites and Arts*** 22. Humanities 21. Arts

Table 5 shows, even at the broad level, concordance will ask for assignment for disciplines below the field level. We will also make assignments using manuals and guidelines to assign sub-disciplines such as previous editions of coding manuals (e.g. prior to aggregation and/or collapsing of categories) and earlier manuals of other organisations such as Eurostat's *Field of Education and Training — Manual (1999)*.

4. Methodology

4.1. Towards concordance between ISI and OECD fields of S&T

This section presents a proposal to link the Fields of Science (FOS) classification for R&D used by the OECD (Frascati Manual, 2002) with the ISI subject categories present in Thomson's Citation Indices. Thomson lists subject categories in three fields:

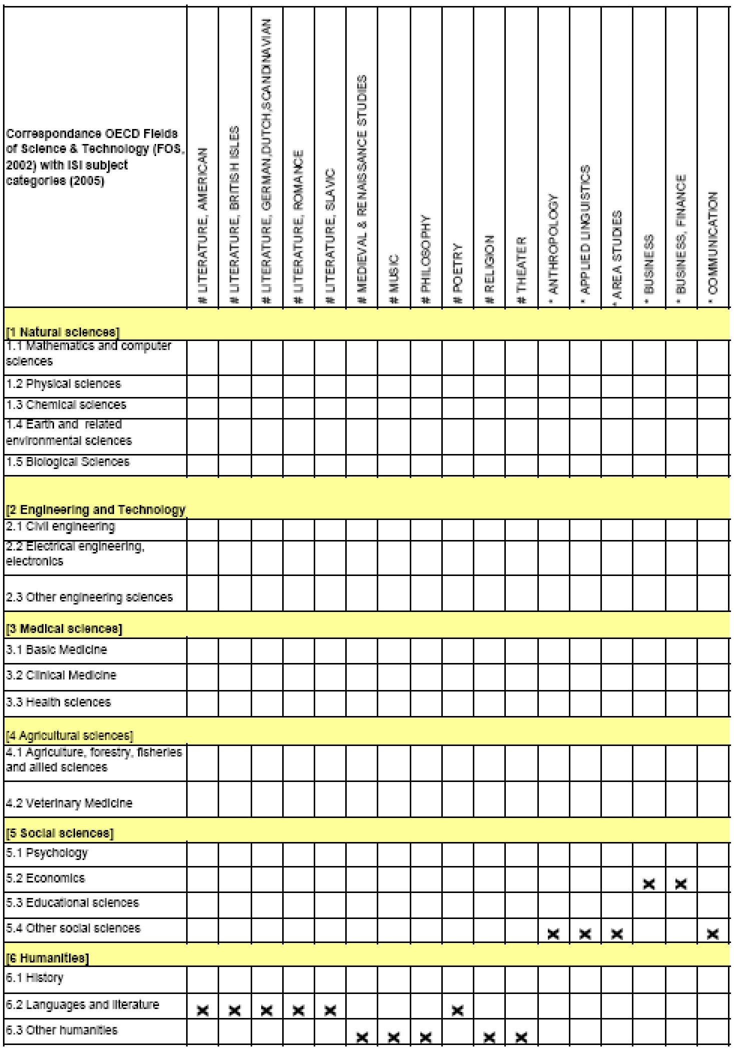
1. Science Citation Index, Science Citation Index expanded
2. Social Science Citation Index
3. Arts & Humanities Citation Index.

Each subject category contains a number of serials.

The OECD is revising FOS but the revision was not available at the start of this study. The FOS classification as listed in the Frascati Manual (2002) was used for this study.

The linkage of FOS and ISI subject categories was made at the level of the first digit of the FOS classification. Figure 1 provides an example of the concordance.

Figure 1. Example of concordance between ISI subject categories and OECD field of science.



Correspondance OECD Fields of Science & Technology (FOS, 2002) with ISI subject categories (2005)	# LITERATURE, AMERICAN	# LITERATURE, BRITISH ISLES	# LITERATURE, GERMAN,DUTCH,SCANDINAVIAN	# LITERATURE, ROMANCE	# LITERATURE, SLAVIC	# MEDIEVAL & RENAISSANCE STUDIES	# MUSIC	# PHILOSOPHY	# POETRY	# RELIGION	# THEATER	* ANTHROPOLOGY	* APPLIED LINGUISTICS	* AREA STUDIES	* BUSINESS	* BUSINESS, FINANCE	* COMMUNICATION
[1 Natural sciences]																	
1.1 Mathematics and computer sciences																	
1.2 Physical sciences																	
1.3 Chemical sciences																	
1.4 Earth and related environmental sciences																	
1.5 Biological Sciences																	
[2 Engineering and Technology																	
2.1 Civil engineering																	
2.2 Electrical engineering, electronics																	
2.3 Other engineering sciences																	
[3 Medical sciences]																	
3.1 Basic Medicine																	
3.2 Clinical Medicine																	
3.3 Health sciences																	
[4 Agricultural sciences]																	
4.1 Agriculture, forestry, fisheries and allied sciences																	
4.2 Veterinary Medicine																	
[5 Social sciences]																	
5.1 Psychology																	
5.2 Economics															x	x	
5.3 Educational sciences																	
5.4 Other social sciences												x	x	x			x
[6 Humanities]																	
6.1 History																	
6.2 Languages and literature	x	x	x	x	x				x								
6.3 Other humanities						x	x	x		x	x						

The full concordance table is extensive and is submitted in electronic format with this report.
Filename: LINKST OECD FoS x ISI.xls.

4.1.1 Method

In addition to our experience based on numerous studies in each of the six major fields, we have drawn upon (confidential) extant studies of subfields. Some of the findings were discussed with expert(s) in (sub)fields. Also used is the classification schedule developed in the Netherlands Observatory on Science and Technology linking broad fields of science and technology with ISI subject categories (Tijssen, Hollanders, Van Leeuwen & Nederhof, 2004).

Thomson Scientific, as many other classification systems, does not categorize subfields in a strict hierarchical system, reflecting the frequently non-hierarchical structure of science and technology fields. There is often considerable overlap among fields, and, if anything, this overlap seems to be increasing.

In this and other matters, a pragmatic approach seems necessary. We have opted to stay as close as possible to the extant FOS classification. If a (sub)field is mentioned in FOS as belonging to a certain classification unit, that classification was always followed, disregarding whether or not the FOS classification was thought to be optimal.

Many subfields are not specifically named in FOS. In this case, we have looked at the higher classification level. In a number of cases, it was difficult to decide which ISI subject category belonged to what FOS field. For example, '*Virology*' is a field with an interdisciplinary orientation, as it has strong ties to both biology and medical sciences. However, in recent years a number of AIDS journals have been added to the Virology subfield, so that the citation link with medical sciences turns out to be just stronger than that with biology, and so *Virology* was classified under Medical Sciences (3.3 Health Sciences) because of links with subfields such as Infectious diseases, Parasitology, and Tropical Medicine. This is not very satisfying, but the FOS classification does not know a general 'other' classification within the Natural Sciences and Medical Sciences main fields, nor classes for overlapping subfields.

As another example, '*Crystallography*' is a field with a strong interdisciplinary orientation, as it used to have strong ties to both chemistry and physics. However, recently, citation links with Biochemistry & Molecular Biology and related subfields turned out to be clearly strongest, followed at a distance by Chemistry subfields, while Physics is now a relatively minor player, and so *Crystallography* was classified under Biology.

Descriptions of the main content of ISI subject categories and the (names of) journals included in the subject categories helped in providing clues in matching.

The sets of 'matching' ISI subject categories were used as a building block for not yet classified ISI subfields. ISI subject categories with strong citation links to already classified groups of subfields were added to these. Thus, ISI subfields with relatively strong mutual links, such as *Food Science & Technology* and *Nutrition & Dietetics*, still ended up in different FOS fields (2.3 Other Engineering Sciences and 3.3 Health sciences).

4.1.2. Matching ISI subject categories to FOS

Introduction

As stated before, the constraints of the commissioned task call for a pragmatic approach. As agreed, the first and second digits of the original FOS classification were used in the matching with ISI subfields. It should be noted that the original FOS classification was intended, and used as such in the production of statistics, to classify research in just six main fields, using the second digit only as support in this task.

Some comments

Materials science and technology; Engineering

Materials science and technology is another field that develops fast. Some of the relevant research is relatively basic and is closest to corresponding natural sciences as, for example, condensed matter physics (a rather applied Physics subfield). Other research is clearly applied and product-oriented. For instance, Materials Science, Paper & Wood (strongly related to Forestry) and Materials Science, Textiles (related to Chemistry, Applied and Engineering, Chemical) are clearly applied subfields, related to topics mentioned in the FOS 2.3 category.

The most important Materials Science subfields have the strongest citation links with two applied physics subfields, Physics, Applied and Physics, Condensed Matter. The citation balance indicates that the largest Materials Science subfield, Materials Science, Multidisciplinary, is more applied than Physics, Applied. This is also true for Materials Science, Coatings & Films, the one but largest subfield in Materials Science. The smaller Materials Science subfields, Materials Science, Composites and Materials Science, Ceramics, depend on Materials Science, Multidisciplinary.

The Engineering subfield Metallurgy & Metallurgical Engineering is strongly dependent upon Materials Science, Multidisciplinary and Materials Science, Coatings & Films. There are also citation links of some importance with Engineering subfields such as Mechanics, Engineering, Electrical & Electronic, and Engineering, Mechanical. Both Mechanics and Engineering, Mechanical are important subfields for Materials Science, Characterization & Testing. There is a strong mutual dependence between Materials Science, Biomaterials and Engineering, Biomedical.

Given the applied nature of an important part of materials science and technology research, Materials science subfields have been classified under Engineering & Technology, Other Engineering fields (2.3.).

Biotechnology

A specific problem is the ISI subject category ‘Biotechnology & Applied Microbiology’. Biotechnology is not even mentioned in the FOS system, even though it has been of great scientific, technological, and commercial interest for decades. After long consideration, basic biotechnology research is likely to end up, at least partially (through shared journals) in fields such as ‘Biochemistry & Molecular Biology’, ‘Microbiology’, ‘Cell biology’ or ‘Genetics & Heredity’. According to ISI, ‘Biotechnology & Applied Microbiology’ covers ‘a broad range of topics on the manipulation of living organisms *to make products or solve problems that meet human needs*’ [italics added AJN]. Thus, this subfield is closest to technology and engineering, the more so as it covers topics such as genetic engineering, bioprocessing of foods and drugs, biological control of pests, molecular diagnostic and therapeutic techniques, and bio-energy production. Therefore, ‘Biotechnology & Applied Microbiology’ has been matched with main field 2.3 of FOS, “Engineering & technology’.

Environmental sciences

Environmental sciences have been listed under 1.4 (natural sciences part), while it is also a topic in the social sciences (5.4).

FOS heading 1.4 contains sciences related to both Earth sciences and Environmental studies. However, related biological fields, such as Ecology, Marine & Freshwater Biology, and Biodiversity Conservation have been listed under 1.5 Biological sciences, as they are closer empirically related with Biology subfields.

Information science in the social and behavioural sciences

In the social sciences, information science has been linked to library science, for example in the Social Sciences Citation Index of Thomson Scientific-ISI. In the ISI subject categories Business, Management, and to some extent, Communication, similar methods are used and/or similar topics covered (e.g., Nederhof & Van Wijk, 1997). Other social sciences subfields (for example econometrics and data-analysis in psychology, social sciences and so on) apply methods derived from mathematics and information science. In the present study, the subject category Information Science & Library Science has been classified under 5.4 ‘Other social sciences’, as it does not clearly belong to psychology, economics, or educational sciences, and has relatively strong links with various Computer Sciences.

4.1.3 Conclusions — concordance between ISI and OECD fields of S&T

A thorough analysis of fields and subfields of science and technology would require a major study covering several publication years. For an optimal study of the structure of the major science and technology subfields, a start would be an extensive analysis of:

(1) Citation relations at the level of (sub)fields;

(2) Citation relations at the journal level; and

(3) ‘Cognitive address’ information derived from the address fields of authors (e.g., (Institute of) Nanotechnology);

(4) Mapping the topics of papers as related to (sub)fields;

(5) A similar set of analyses might be directed at patent data;

(6) Furthermore, complementary analyses might be needed on business and PNP databases, and those of government institutions and educational institutions. Even then, it would not be an easy task to match results with the FOS classification.

Developments in science and technology are frequently occurring fast, so regular updates of the classifications and its correspondence with ISI subject categories are needed. Empirical studies can aid in improving the basis of the FOS classification correspondence with the Thomson Scientific/ISI subject categories.

4.2. Developing a bridge between education (ISCED) and OECD field of S&T

The OECD fields of science and technology total six:

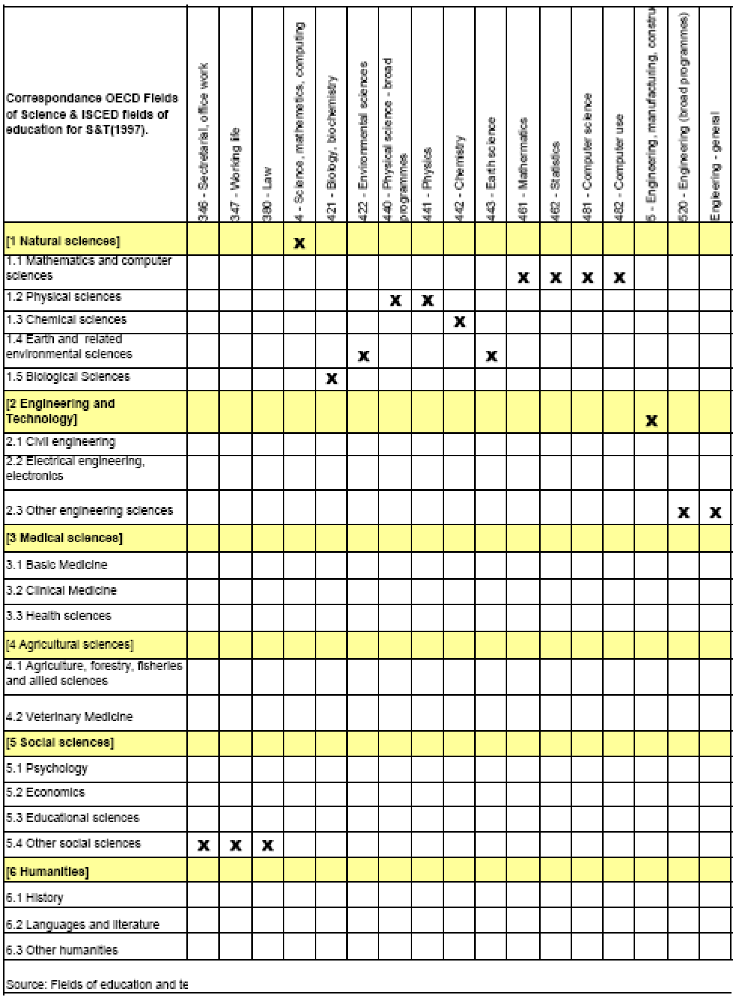
- Natural sciences.
- Engineering and technology.
- Medical sciences.
- Agricultural sciences.
- Social sciences.
- Humanities.

In ISCED, there are a total of 25 major categories that can be aggregated to correspond fairly well to the OECD fields of S&T. We know that there would be good correspondence between the OECD and ISCED ’97 given the organizations cooperative efforts on education and S&T classifications.

This concordance between OECD fields of S&T and the HMHT manufacturing industries and OECD fields of S&T and ISCED means we can describe the scientific base of the industries according to education and look for opportunities to explore additional links of R&D statistics and education data such as PhD graduates, and according to scientific discipline.

The common platform for us to move between R&D indicators and measures and the scientific base for the HMHT manufacturing industries is the OECD field of S&T. This is shown in Figure 1 above. At the same time, we need a concordance between OECD fields of S&T and ISCED fields of education. Figure 2 gives an example of the concordance developed for the OECD fields of S&T and ISCED fields of S&T.

Figure 2. Example of concordance for OECD field of S&T and UNESCO ISCED 1997 field of study.



Correspondance OECD Fields of Science & ISCED fields of education for S&T(1997).	346 - Secretarial, office work	347 - Working life	380 - Law	4 - Science, mathematics, computing	421 - Biology, biochemistry	422 - Environmental sciences	440 - Physical science - broad programmes	441 - Physics	442 - Chemistry	443 - Earth science	461 - Mathematics	462 - Statistics	481 - Computer science	482 - Computer use	5 - Engineering, manufacturing, constru	520 - Engineering (broad programmes)	Engieering - general
[1 Natural sciences]				x													
1.1 Mathematics and computer sciences											x	x	x	x			
1.2 Physical sciences							x	x									
1.3 Chemical sciences									x								
1.4 Earth and related environmental sciences						x				x							
1.5 Biological Sciences					x												
[2 Engineering and Technology]															x		
2.1 Civil engineering																	
2.2 Electrical engineering, electronics																	
2.3 Other engineering sciences																x	x
[3 Medical sciences]																	
3.1 Basic Medicine																	
3.2 Clinical Medicine																	
3.3 Health sciences																	
[4 Agricultural sciences]																	
4.1 Agriculture, forestry, fisheries and allied sciences																	
4.2 Veterinary Medicine																	
[5 Social sciences]																	
5.1 Psychology																	
5.2 Economics																	
5.3 Educational sciences																	
5.4 Other social sciences	x	x	x														
[6 Humanities]																	
6.1 History																	
6.2 Languages and literature																	
6.3 Other humanities																	

Source: Fields of education and te

The full concordance table is extensive and is submitted in electronic format with this report.

Filename: LINKST OECD FoS x ISCED.xls.

5. Citation database

Table 6. Citation linkages between top technology domains and top science domains (in absolute measures)

	C12	C07	A61	G01	A01	H01	G06	C08	G02	H04	B01	A23	B32	C23	C01	C30	C22	B22	B09	C21	G12	TOTAL
BIOCHEM & MOL BIO	22345	18277	13473	3879	4727	175	536	311	38	128	268	423	59	16	65	32	10	2	22	9	24	64819
CELL BIOLOGY	6787	4930	3826	1141	1373	47	203	58	14	42	40	67	28	3	13	10	1	1	1	0	12	18597
PHARMAC & PHARMA	1217	4018	7678	344	877	26	71	102	9	29	121	58	64	2	9	8	0	0	4	1	3	14641
ENG, ELEC & ELECTR	46	92	281	1268	7	4326	3166	26	1614	3149	40	5	78	165	12	36	6	4	0	5	0	14326
IMMUNOLOGY	3460	3406	5199	956	821	20	43	29	5	22	65	75	8	1	23	1	2	0	4	0	10	14150
CHEMISTRY, ORGANIC	753	6947	3569	240	528	60	31	450	31	7	238	31	15	31	23	1	0	41	0	0	0	12996
BIOTEC & A. MICROBIOL	5143	2511	1609	561	1204	49	149	111	12	10	81	232	50	0	25	1	19	2	93	12	8	11882
GENETICS & HEREDITY	5328	3142	1151	480	1018	43	105	15	5	22	49	31	5	1	12	6	0	1	2	1	4	11421
CHEMISTRY, MULTIDISC	1241	4197	3035	594	366	136	99	632	57	11	511	23	124	50	143	12	30	39	5	0	0	11305
ONCOLOGY	2716	2696	3783	583	699	31	57	34	14	16	32	50	8	4	6	5	0	0	0	0	2	10736
PHYSICS, APPLIED	29	129	107	1229	17	5659	253	115	991	389	97	7	265	820	60	229	7	14	0	10	1	10428
MICROBIOLOGY	4156	2317	1737	304	851	20	43	52	1	3	28	160	22	0	17	1	20	1	97	6	3	9839
PLANT SCIENCES	3887	1126	607	84	3564	29	133	39	4	10	3	71	3	3	3	0	10	0	0	0	2	9578
BIOPHYSICS	2319	2174	2410	703	440	48	57	39	21	17	82	74	28	2	7	8	0	1	0	0	5	8435
CHEMISTRY, MEDIC.	365	3298	3720	146	379	13	51	61	5	16	39	21	14	1	5	5	0	1	4	0	0	8144
MED. RES. & EXP.	1746	1718	2902	444	461	20	21	19	3	17	30	31	8	2	8	3	0	0	0	0	9	7442
CHEMISTRY, ANAL.	1456	1060	684	1951	97	318	44	121	70	7	870	51	102	16	28	1	6	1	4	1	16	6904
BIOCHEM. RES. METH.	2311	1703	1003	1106	218	35	67	49	18	13	254	42	18	0	20	4	1	1	0	1	1	6865
HEMATOLOGY	1330	1400	2638	467	450	33	26	31	3	10	123	28	7	4	11	0	1	0	0	0	0	6562
NEUROSCIENCES	1109	1514	3072	334	373	24	48	4	2	25	4	17	13	1	0	0	0	0	0	0	0	6540
VIROLOGY	2554	1350	1569	202	339	7	15	11	1	9	4	38	0	0	0	2	0	0	0	0	2	6103
ENDOCRIN. & METAB.	809	1679	2562	427	234	9	73	8	0	7	2	28	6	0	5	0	1	0	0	1	0	5851
OPTICS	17	22	204	1044	3	1274	301	32	2018	575	9	2	36	24	9	6	0	3	0	0	0	5579
POLYMER SCIENCE	101	365	531	124	47	272	30	2252	71	3	293	18	363	24	22	4	1	54	1	0	0	4576
CHEMISTRY, PHYSICAL	273	852	260	331	34	442	13	227	83	6	413	9	161	92	317	28	28	16	0	0	2	3587
MATER. SC, MULTIDISC	33	104	136	188	15	1052	52	247	128	13	103	3	239	249	201	75	180	125	1	20	0	3164
FOOD SC. & TECH	717	331	379	80	313	1	16	65	0	1	46	653	20	4	5	0	2	3	0	2	4	2642
ELECTROCHEMISTRY	99	66	62	351	4	1117	19	80	73	6	38	2	68	103	130	60	5	2	0	1	0	2286
ENG, CHEMICAL	183	401	189	180	32	81	68	194	18	3	537	23	105	23	156	0	46	8	3	10	0	2260
CHEMISTRY, APPLIED	460	421	446	52	215	9	17	207	2	1	57	236	32	11	26	0	7	3	1	4	0	2207
MAT. SC, COAT & FILMS	5	40	33	117	6	1098	15	126	60	7	44	3	90	323	88	68	3	6	0	1	0	2133
PHYS., COND. MATTER	36	69	35	192	6	1079	37	63	107	7	51	2	89	159	76	48	15	7	0	4	0	2082
COMP SC, HW & ARCHIT.	3	7	5	64	0	96	1502	5	25	339	2	0	5	4	0	1	2	0	0	0	0	2060
COMP SC, SW ENG	5	6	18	29	0	14	1554	1	4	259	0	0	3	0	0	0	1	0	0	0	0	1894
COMP SC, THEO & METH	1	4	17	21	0	6	1036	2	5	219	0	2	0	0	0	0	0	0	0	0	0	1313
NUTRIT. & DIETETICS	97	110	546	19	136	1	4	11	0	7	9	193	2	1	0	0	0	0	0	0	0	1136
CRYSTALLOGRAPHY	11	118	42	42	1	182	13	45	100	2	63	3	16	24	18	178	4	9	0	0	0	871
METALL. & METALL. ENG	13	7	11	27	1	51	4	11	3	3	22	0	64	35	52	9	248	116	4	65	0	746
AGRIC, DAIRY & ANIM SC	128	61	207	27	59	0	1	1	0	0	5	254	0	0	0	0	0	0	0	0	0	743
TOTAL	73289	72668	69736	20331	19915	17903	9973	5886	5615	5410	4673	2966	2218	2198	1595	842	656	461	246	154	108	316843

Source: INCENTIM-CWTS9

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[9] CESE-IRRA project - Research project funded by EC-DG Research - contract number HPV2-CT2001-00012. Carried out by: Centre for Science and Technology Studies (CWTS), Leiden University, Netherlands and International Centre for Studies in Entrepreneurship and Innovation Management (INCENTIM), Catholic University Leuven, Belgium. R.J.W. Tijssen (project coordinator), Th. N. Van Leeuwen, E. Van Wijk, P. Negenborn, B. van der Wurff; B. van Looy, J. Callaert & K. Debackere.

Table 7. Science – Technology Matrix – column percentages [10]

	C12	C07	A61	G01	A01	H01	G06	C08	G02	H04	B01	A23	B32	C23	C01	C30	C22	B22	B09	C21	G12
BIOCHEM & MOL BIO	23.4%	20%	12.2%	13%	17%	0.8%	3.4%	4.3%	0.6%	1.5%	4.3%	11%	2.1%	0.6%	2.9%	3.3%	1.2%	0.4%	5.7%	4.5%	16.0%
CELL BIOLOGY	7.1%	5.4%	3.5%	3.8%	4.9%	0.2%	1.3%	0.8%	0.2%	0.5%	0.6%	1.7%	1.0%	0.1%	0.6%	1.0%	0.1%	0.2%	0.3%	0.0%	8.0%
PHARMAC & PHARMA	1.3%	4.4%	7.0%	1.2%	3.2%	0.1%	0.5%	1.4%	0.1%	0.3%	2.0%	1.5%	2.3%	0.1%	0.4%	0.8%	0.0%	0.0%	1.0%	0.5%	2.0%
ENG, ELEC & ELECTR	0.0%	0.1%	0.3%	4.3%	0.0%	21.0%	20.3%	0.4%	25.4%	37.1%	0.6%	0.1%	2.8%	6.4%	0.5%	3.7%	0.7%	0.7%	0.0%	2.5%	0.0%
IMMUNOLOGY	3.6%	3.7%	4.7%	3.2%	3.0%	0.1%	0.3%	0.4%	0.1%	0.3%	1.1%	1.9%	0.3%	0.0%	1.0%	0.1%	0.2%	0.0%	1.0%	0.0%	6.7%
CHEMISTRY, ORGANIC	0.8%	7.6%	3.2%	0.8%	1.9%	0.3%	0.2%	6.2%	0.5%	0.1%	3.8%	0.8%	0.5%	1.2%	1.0%	0.1%	0.0%	7.2%	0.0%	0.0%	0.0%
BIOTEC & A. MICROBIOL	5.4%	2.7%	1.5%	1.9%	4.3%	0.2%	1.0%	1.5%	0.2%	0.1%	1.3%	6.0%	1.8%	0.0%	1.1%	0.1%	2.4%	0.4%	24.1%	6.0%	5.3%
GENETICS & HEREDITY	5.6%	3.4%	1.0%	1.6%	3.7%	0.2%	0.7%	0.2%	0.1%	0.3%	0.8%	0.8%	0.2%	0.0%	0.5%	0.6%	0.0%	0.2%	0.5%	0.5%	2.7%
CHEMISTRY, MULTIDISC	1.3%	4.6%	2.8%	2.0%	1.3%	0.7%	0.6%	8.7%	0.9%	0.1%	8.3%	0.6%	4.5%	1.9%	6.4%	1.2%	3.7%	6.9%	1.3%	0.0%	0.0%
ONCOLOGY	2.8%	2.9%	3.4%	2.0%	2.5%	0.2%	0.4%	0.5%	0.2%	0.2%	0.5%	1.3%	0.3%	0.2%	0.3%	0.5%	0.0%	0.0%	0.0%	0.0%	1.3%
PHYSICS, APPLIED	0.0%	0.1%	0.1%	4.1%	0.1%	27.4%	1.6%	1.6%	15.6%	4.6%	1.6%	0.2%	9.5%	31.8%	2.7%	23.3%	0.9%	2.5%	0.0%	5.0%	0.7%
MICROBIOLOGY	4.3%	2.5%	1.6%	1.0%	3.1%	0.1%	0.3%	0.7%	0.0%	0.0%	0.5%	4.2%	0.8%	0.0%	0.8%	0.1%	2.5%	0.2%	25.1%	3.0%	2.0%
PLANT SCIENCES	4.1%	1.2%	0.6%	0.3%	12.8%	0.1%	0.9%	0.5%	0.1%	0.1%	0.0%	1.8%	0.1%	0.1%	0.1%	0.0%	1.2%	0.0%	0.0%	0.0%	1.3%
BIOPHYSICS	2.4%	2.4%	2.2%	2.4%	1.6%	0.2%	0.4%	0.5%	0.3%	0.2%	1.3%	1.9%	1.0%	0.1%	0.3%	0.8%	0.0%	0.2%	0.0%	0.0%	3.3%
CHEMISTRY, MEDIC.	0.4%	3.6%	3.4%	0.5%	1.4%	0.1%	0.3%	0.8%	0.1%	0.2%	0.6%	0.5%	0.5%	0.0%	0.2%	0.5%	0.0%	0.2%	1.0%	0.0%	0.0%
MED. RES. & EXP.	1.8%	1.9%	2.6%	1.5%	1.7%	0.1%	0.1%	0.3%	0.0%	0.2%	0.5%	0.8%	0.3%	0.1%	0.4%	0.3%	0.0%	0.0%	0.0%	0.0%	6.0%
CHEMISTRY, ANAL.	1.5%	1.2%	0.6%	6.5%	0.3%	1.5%	0.3%	1.7%	1.1%	0.1%	14.1%	1.3%	3.7%	0.6%	1.3%	0.1%	0.7%	0.2%	1.0%	0.5%	10.7%
BIOCHEM. RES. METH.	2.4%	1.9%	0.9%	3.7%	0.8%	0.2%	0.4%	0.7%	0.3%	0.2%	4.1%	1.1%	0.6%	0.0%	0.9%	0.4%	0.1%	0.2%	0.0%	0.5%	0.7%
HEMATOLOGY	1.4%	1.5%	2.4%	1.6%	1.6%	0.2%	0.2%	0.4%	0.0%	0.1%	2.0%	0.7%	0.3%	0.2%	0.5%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
NEUROSCIENCES	1.2%	1.7%	2.8%	1.1%	1.3%	0.1%	0.3%	0.1%	0.0%	0.3%	0.1%	0.4%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
VIROLOGY	2.7%	1.5%	1.4%	0.7%	1.2%	0.0%	0.1%	0.2%	0.0%	0.1%	0.1%	1.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	1.3%
ENDOCRIN. & METAB.	0.8%	1.8%	2.3%	1.4%	0.8%	0.0%	0.5%	0.1%	0.0%	0.1%	0.0%	0.7%	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%	0.5%	0.0%
OPTICS	0.0%	0.0%	0.2%	3.5%	0.0%	6.2%	1.9%	0.4%	31.8%	6.8%	0.1%	0.1%	1.3%	0.9%	0.4%	0.6%	0.0%	0.5%	0.0%	0.0%	0.0%
POLYMER SCIENCE	0.1%	0.4%	0.5%	0.4%	0.2%	1.3%	0.2%	30.9%	1.1%	0.0%	4.7%	0.5%	13.1%	0.9%	1.0%	0.4%	0.1%	9.5%	0.3%	0.0%	0.0%
CHEMISTRY, PHYSICAL	0.3%	0.9%	0.2%	1.1%	0.1%	2.1%	0.1%	3.1%	1.3%	0.1%	6.7%	0.2%	5.8%	3.6%	14.2%	2.8%	3.5%	2.8%	0.0%	0.0%	1.3%
MATER. SC, MULTIDISC	0.0%	0.1%	0.1%	0.6%	0.1%	5.1%	0.3%	3.4%	2.0%	0.2%	1.7%	0.1%	8.6%	9.6%	9.0%	7.6%	22.3%	22.0%	0.3%	10.0%	0.0%
FOOD SC. & TECH	0.7%	0.4%	0.3%	0.3%	1.1%	0.0%	0.1%	0.9%	0.0%	0.0%	0.7%	16.9%	0.7%	0.2%	0.2%	0.0%	0.2%	0.5%	0.0%	1.0%	2.7%
ELECTROCHEMISTRY	0.1%	0.1%	0.1%	1.2%	0.0%	5.4%	0.1%	1.1%	1.1%	0.1%	0.6%	0.1%	2.4%	4.0%	5.8%	6.1%	0.6%	0.4%	0.0%	0.5%	0.0%
ENG, CHEMICAL	0.2%	0.4%	0.2%	0.6%	0.1%	0.4%	0.4%	2.7%	0.3%	0.0%	8.7%	0.6%	3.8%	0.9%	7.0%	0.0%	5.7%	1.4%	0.8%	5.0%	0.0%
CHEMISTRY, APPLIED	0.5%	0.5%	0.4%	0.2%	0.8%	0.0%	0.1%	2.8%	0.0%	0.0%	0.9%	6.1%	1.2%	0.4%	1.2%	0.0%	0.9%	0.5%	0.3%	2.0%	0.0%
MAT. SC, COAT & FILMS	0.0%	0.0%	0.0%	0.4%	0.0%	5.3%	0.1%	1.7%	0.9%	0.1%	0.7%	0.1%	3.2%	12.5%	4.0%	6.9%	0.4%	1.1%	0.0%	0.5%	0.0%
PHYS., COND. MATTER	0.0%	0.1%	0.0%	0.6%	0.0%	5.2%	0.2%	0.9%	1.7%	0.1%	0.8%	0.1%	3.2%	6.2%	3.4%	4.9%	1.9%	1.2%	0.0%	2.0%	0.0%
COMP SC, HW & ARCHIT.	0.0%	0.0%	0.0%	0.2%	0.0%	0.5%	9.6%	0.1%	0.4%	4.0%	0.0%	0.0%	0.2%	0.2%	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%
COMP SC, SW ENG	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	10.0%	0.0%	0.1%	3.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
COMP SC, THEO & METH	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	6.6%	0.0%	0.1%	2.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NUTRIT. & DIETETICS	0.1%	0.1%	0.5%	0.1%	0.5%	0.0%	0.0%	0.2%	0.0%	0.1%	0.1%	5.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CRYSTALLOGRAPHY	0.0%	0.1%	0.0%	0.1%	0.0%	0.9%	0.1%	0.6%	1.6%	0.0%	1.0%	0.1%	0.6%	0.9%	0.8%	18.1%	0.5%	1.6%	0.0%	0.0%	0.0%
METALL. & METALL. ENG	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%	0.4%	0.0%	2.3%	1.4%	2.3%	0.9%	30.8%	20.4%	1.0%	32.3%	0.0%
AGRIC, DAIRY & ANIM SC	0.1%	0.1%	0.2%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	6.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL	76.6%	79.4%	63.3%	68.1%	71.7%	86.7%	63.9%	80.9%	88.4%	63.7%	75.6%	77.0%	79.8%	85.2%	71.7%	85.7%	81.4%	81.0%	63.7%	76.6%	72.0%
Other Science Domains	23.4%	20.6%	36.7%	31.9%	28.3%	13.3%	36.1%	19.1%	11.6%	36.3%	24.4%	23.0%	20.2%	14.8%	28.3%	14.3%	18.6%	19.0%	36.3%	23.4%	28.0%

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[10] The denominator used for calculation of the column percentages is the total number of links found for each of the technology domains (in all science domains, not only in the selection presented here).

Table 8. Science – Technology Matrix – row percentages [11]

	C12	C07	A61	G01	A01	H01	G06	C08	G02	H04	B01	A23	B32	C23	C01	C30	C22	B22	B09	C21	G12	Total	Other Science Domains
BIOCHEM & MOL BIO	34.0%	27.8%	20.5%	5.9%	7.2%	0.3%	0.8%	0.5%	0.1%	0.2%	0.4%	0.6%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	98.5%	1.5%
CELL BIOLOGY	36.0%	26.2%	20.3%	6.1%	7.3%	0.2%	1.1%	0.3%	0.1%	0.2%	0.2%	0.4%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	98.7%	1.3%
PHARMAC & PHARMA	8.2%	27.0%	51.5%	2.3%	5.9%	0.2%	0.5%	0.7%	0.1%	0.2%	0.8%	0.4%	0.4%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	98.3%	1.7%
ENG. ELEC & ELECTR	0.2%	0.5%	1.5%	6.6%	0.0%	22.6%	16.5%	0.1%	8.4%	16.4%	0.2%	0.0%	0.4%	0.9%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	74.8%	25.2%
IMMUNOLOGY	24.2%	23.8%	36.3%	6.7%	5.7%	0.1%	0.3%	0.2%	0.0%	0.2%	0.5%	0.5%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	98.8%	1.2%
CHEMISTRY. ORGANIC	5.6%	51.9%	26.7%	1.8%	3.9%	0.4%	0.2%	3.4%	0.2%	0.1%	1.8%	0.2%	0.1%	0.2%	0.2%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	97.1%	2.9%
BIOTEC & A. MICROBIOL	41.5%	20.2%	13.0%	4.5%	9.7%	0.4%	1.2%	0.9%	0.1%	0.1%	0.7%	1.9%	0.4%	0.0%	0.2%	0.0%	0.2%	0.0%	0.7%	0.1%	0.1%	95.8%	4.2%
GENETICS & HEREDITY	46.2%	27.3%	10.0%	4.2%	8.8%	0.4%	0.9%	0.1%	0.0%	0.2%	0.4%	0.3%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	99.1%	0.9%
CHEMISTRY. MULTIDISC	10.2%	34.5%	25.0%	4.9%	3.0%	1.1%	0.8%	5.2%	0.5%	0.1%	4.2%	0.2%	1.0%	0.4%	1.2%	0.1%	0.2%	0.3%	0.0%	0.0%	0.0%	93.0%	7.0%
ONCOLOGY	25.0%	24.8%	34.8%	5.4%	6.4%	0.3%	0.5%	0.3%	0.1%	0.1%	0.3%	0.5%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	98.8%	1.2%
PHYSICS. APPLIED	0.2%	0.9%	0.8%	8.8%	0.1%	40.7%	1.8%	0.8%	7.1%	2.8%	0.7%	0.1%	1.9%	5.9%	0.4%	1.6%	0.1%	0.1%	0.0%	0.1%	0.0%	75.1%	24.9%
MICROBIOLOGY	40.8%	22.7%	17.0%	3.0%	8.3%	0.2%	0.4%	0.5%	0.0%	0.0%	0.3%	1.6%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	1.0%	0.1%	0.0%	96.5%	3.5%
PLANT SCIENCES	39.9%	11.5%	6.2%	0.9%	36.5%	0.3%	1.4%	0.4%	0.0%	0.1%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	98.2%	1.8%
BIOPHYSICS	27.0%	25.3%	28.0%	8.2%	5.1%	0.6%	0.7%	0.5%	0.2%	0.2%	1.0%	0.9%	0.3%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	98.0%	2.0%
CHEMISTRY. MEDIC.	4.4%	39.9%	45.0%	1.8%	4.6%	0.2%	0.6%	0.7%	0.1%	0.2%	0.5%	0.3%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	98.5%	1.5%
MED. RES. & EXP.	23.1%	22.7%	38.4%	5.9%	6.1%	0.3%	0.3%	0.3%	0.0%	0.2%	0.4%	0.4%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	98.4%	1.6%
CHEMISTRY. ANAL.	19.6%	14.3%	9.2%	26.3%	1.3%	4.3%	0.6%	1.6%	0.9%	0.1%	11.7%	0.7%	1.4%	0.2%	0.4%	0.0%	0.1%	0.0%	0.1%	0.0%	0.2%	93.0%	7.0%
BIOCHEM. RES. METH.	32.8%	24.2%	14.2%	15.7%	3.1%	0.5%	1.0%	0.7%	0.3%	0.2%	3.6%	0.6%	0.3%	0.0%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	97.5%	2.5%
HEMATOLOGY	19.8%	20.8%	39.3%	7.0%	6.7%	0.5%	0.4%	0.5%	0.0%	0.1%	1.8%	0.4%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.7%	2.3%
NEUROSCIENCES	16.8%	23.0%	46.6%	5.1%	5.7%	0.4%	0.7%	0.1%	0.0%	0.4%	0.1%	0.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.3%	0.7%
VIROLOGY	41.6%	22.0%	25.5%	3.3%	5.5%	0.1%	0.2%	0.2%	0.0%	0.1%	0.1%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.3%	0.7%
ENDOCRIN. & METAB.	13.6%	28.3%	43.2%	7.2%	3.9%	0.2%	1.2%	0.1%	0.0%	0.1%	0.0%	0.5%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	98.6%	1.4%
OPTICS	0.3%	0.3%	3.1%	15.8%	0.0%	19.2%	4.5%	0.5%	30.5%	8.7%	0.1%	0.0%	0.5%	0.4%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	84.2%	15.8%
POLYMER SCIENCE	1.7%	6.2%	9.1%	2.1%	0.8%	4.7%	0.5%	38.5%	1.2%	0.1%	5.0%	0.3%	6.2%	0.4%	0.4%	0.1%	0.0%	0.9%	0.0%	0.0%	0.0%	78.2%	21.8%
CHEMISTRY. PHYSICAL	6.0%	18.8%	5.7%	7.3%	0.8%	9.8%	0.3%	5.0%	1.8%	0.1%	9.1%	0.2%	3.6%	2.0%	7.0%	0.6%	0.6%	0.4%	0.0%	0.0%	0.0%	79.3%	20.7%
MATER. SC. MULTIDISC	0.7%	2.3%	3.0%	4.2%	0.3%	23.3%	1.2%	5.5%	2.8%	0.3%	2.3%	0.1%	5.3%	5.5%	4.5%	1.7%	4.0%	2.8%	0.0%	0.4%	0.0%	70.1%	29.9%
FOOD SC. & TECH	24.1%	11.1%	12.7%	2.7%	10.5%	0.0%	0.5%	2.2%	0.0%	0.0%	1.5%	21.9%	0.7%	0.1%	0.2%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	88.7%	11.3%
ELECTROCHEMISTRY	3.4%	2.3%	2.2%	12.2%	0.1%	38.8%	0.7%	2.8%	2.5%	0.2%	1.3%	0.1%	2.4%	3.6%	4.5%	2.1%	0.2%	0.1%	0.0%	0.0%	0.0%	79.5%	20.5%
ENG. CHEMICAL	5.6%	12.2%	5.7%	5.5%	1.0%	2.5%	2.1%	5.9%	0.5%	0.1%	16.3%	0.7%	3.2%	0.7%	4.7%	0.0%	1.4%	0.2%	0.1%	0.3%	0.0%	68.6%	31.4%
CHEMISTRY. APPLIED	17.8%	16.3%	17.3%	2.0%	8.3%	0.3%	0.7%	8.0%	0.1%	0.0%	2.2%	9.2%	1.2%	0.4%	1.0%	0.0%	0.3%	0.1%	0.0%	0.2%	0.0%	85.6%	14.4%
MAT. SC. COAT & FILMS	0.2%	1.4%	1.1%	4.0%	0.2%	37.9%	0.5%	4.3%	2.1%	0.2%	1.5%	0.1%	3.1%	11.1%	3.0%	2.3%	0.1%	0.2%	0.0%	0.0%	0.0%	73.6%	26.4%
PHYS.. COND. MATTER	1.3%	2.5%	1.2%	6.8%	0.2%	38.3%	1.3%	2.2%	3.8%	0.2%	1.8%	0.1%	3.2%	5.6%	2.7%	1.7%	0.5%	0.2%	0.0%	0.1%	0.0%	73.9%	26.1%
COMP SC. HW & ARCHIT.	0.1%	0.3%	0.2%	2.6%	0.0%	4.0%	61.8%	0.2%	1.0%	14.0%	0.1%	0.0%	0.2%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	84.8%	15.2%
COMP SC. SW ENG	0.2%	0.3%	0.9%	1.4%	0.0%	0.7%	75.1%	0.0%	0.2%	12.5%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	91.6%	8.4%
COMP SC. THEO & METH	0.1%	0.3%	1.2%	1.4%	0.0%	0.4%	71.2%	0.1%	0.3%	15.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	90.2%	9.8%
NUTRIT. & DIETETICS	8.4%	9.5%	47.0%	1.6%	11.7%	0.1%	0.3%	0.9%	0.0%	0.6%	0.8%	16.6%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.8%	2.2%
CRYSTALLOGRAPHY	1.0%	11.2%	4.0%	4.0%	0.1%	17.2%	1.2%	4.3%	9.5%	0.2%	6.0%	0.3%	1.5%	2.3%	1.7%	16.8%	0.4%	0.9%	0.0%	0.0%	0.0%	82.4%	17.6%
METALL. & METALL. ENG	1.2%	0.7%	1.1%	2.6%	0.1%	4.9%	0.4%	1.1%	0.3%	0.3%	2.1%	0.0%	6.1%	3.4%	5.0%	0.9%	23.8%	11.1%	0.4%	6.2%	0.0%	71.5%	28.5%
AGRIC. DAIRY & ANIM SC	16.1%	7.7%	26.1%	3.4%	7.4%	0.0%	0.1%	0.1%	0.0%	0.0%	0.6%	32.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	93.7%	6.3%

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[11] The denominator used for calculation of the row percentages is the total number of links found for each of the science domains (in all technology domains, not only in the selection presented here).

6. Results

6.1 Country profiles

Within the next pages, we present resultant tables with basic data on Germany, France, Italy and the UK related to science, technology, education and industry. Within a first set of tables, basic data pertaining to the different activity realms are given. For publication data we draw upon the ISI/WOS database (Thomson) while patent data relate to EPO applications. Economical data are derived from the STAN/OECD database. Finally, educational data have been obtained through the database of the National Science Foundation (Washington D.C.).

All these data sources have adopted their own, specific classification schemes. By means of the different concordance tables, it now becomes feasible to align or translate the amount of activity within science, technology, education and economy towards one classification scheme spanning all activity domains. This is done by using the concordance tables as weighting schemes. Tables 5 for each country illustrate this approach. We have chosen to align all data towards the OECD classification of manufacturing industries (HT, MHT, MLT, LT). The data from science, technology and education are in a next step being 'assigned' to these industries by using the weights of the concordance tables. For instance, the number of PhD's in Engineering is only attributed to HT industry to the extent that the different concordance tables indicate a relationship with that industry. Applying these concordance tables in a systematic manner hence allows defining a harmonized set of scientific, technological, educational and economical data. It is clear that such harmonized data offer potential for fine grained analysis oriented towards understanding dynamics and relationships between different components of innovation system.

6.1.1 Country data — France

Table 6.1.1.1. Scientific Data France by Field of Science (Broad), 2000 to 2004.

	2000	2001	2002	2003	2004
AGRICULTURE AND FOOD SCIENCE	1865	1686	1781	1746	1741
BASIC LIFE SCIENCES	6593	6797	6522	6716	6395
BIOLOGICAL SCIENCES	2149	2038	2137	2229	2005
BIOMEDICAL SCIENCES	6534	6214	6013	6281	5843
CHEMISTRY	6193	6498	6119	6801	6065
CLINICAL MEDICINE	8909	8979	8457	9372	8118
COMPUTER SCIENCES	1459	1436	1368	2392	2546
EARTH AND ENVIRONMENTAL SCIENCES	2937	2902	2940	3449	3289
ENGINEERING SCIENCES	6124	7298	6939	7354	6880
MATHEMATICS AND STATISTICS	2516	2502	2619	3014	2622
MULTIDISCIPLINARY SCIENCES	656	561	525	574	521
PHYSICS AND ASTRONOMY	9793	9881	9797	10629	9744
SOCIAL SCIENCES	1823	1780	1781	1942	2072
Total	57551	58572	56998	62499	57841

Table 6.1.1.2. Education data for France – doctorates by major field of study, 1990 to 2000.

OECD	ISCED	**Fields**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total PhDs - 1990 to 1999**
		Science + engineering sub	5158	5384	6377	6820	7555	7027	8511	8962	8359	7054		71207
1	42+44	Natural sciences	2841	2883	3525	3631	3866	3572	4052	4394	3924	2966		35654
1.1	46+48	Mathematics/computer sciences	795	831	976	1065	1203	1129	1241	869	845	769		9723
4	62	Agricultural sciences	53	38	38	52	94	84	194	207	179	179		1118
5	31	Social/behavioural sciences	488	539	663	797	1018	815	1285	1629	1559	1390		10183
2	52	Engineering	981	1093	1175	1275	1374	1427	1739	1863	1852	1750		14529
2	52	All other fields	1624	1814	2208	2475	3047	2774	2452	2111	2223	3119		23847
		Total - all fields	6782	7198	8585	9295	10602	9801	10963	11073	10582	10173		95054
Fields as a share		*Science + engineering sub*	76.1%	74.8%	74.3%	73.4%	71.3%	71.7%	77.6%	80.9%	79.0%	69.3%		74.9%
		Natural sciences	41.9%	40.1%	41.1%	39.1%	36.5%	36.4%	37.0%	39.7%	37.1%	29.2%		37.5%
		Mathematics/computer sciences	11.7%	11.5%	11.4%	11.5%	11.3%	11.5%	11.3%	7.8%	8.0%	7.6%		10.2%
		Agricultural sciences	0.8%	0.5%	0.4%	0.6%	0.9%	0.9%	1.8%	1.9%	1.7%	1.8%		1.2%
		Social/behavioural sciences	7.2%	7.5%	7.7%	8.6%	9.6%	8.3%	11.7%	14.7%	14.7%	13.7%		10.7%
		Engineering	14.5%	15.2%	13.7%	13.7%	13.0%	14.6%	15.9%	16.8%	17.5%	17.2%		15.3%
		All other fields	23.9%	25.2%	25.7%	26.6%	28.7%	28.3%	22.4%	19.1%	21.0%	30.7%		25.1%

Table 6.1.1.3. Technology Data France (EPO Patent Applications, applied from 2000-2004, Allocation based on Inventors).

A01	841	B06	23	B60	2649	C10	286	E03	70	F41	128
A21	90	B07	55	B61	120	C11	229	E04	494	F42	135
A22	40	B08	71	B62	677	C12	1382	E05	493	G01	2224
A23	481	B09	33	B63	185	C13	17	E06	256	G02	693
A24	19	B21	213	B64	331	C14	15	E21	164	G03	158
A41	117	B22	136	B65	1486	C21	131	F01	567	G04	80
A42	28	B23	414	B66	150	C22	178	F02	713	G05	375
A43	119	B24	104	B67	78	C23	243	F03	44	G06	2497
A44	57	B25	177	B68	8	C25	94	F04	226	G07	525
A45	362	B26	80	B81	44	C30	84	F15	109	G08	246
A46	65	B27	42	B82	1	D01	79	F16	1743	G09	331
A47	709	B28	71	C01	299	D02	37	F17	99	G10	188
A61	5540	B29	567	C02	212	D03	64	F21	217	G11	350
A62	102	B30	33	C03	305	D04	176	F22	18	G12	3
A63	307	B31	70	C04	251	D05	12	F23	166	G21	157
B01	1187	B32	262	C05	34	D06	220	F24	227	H01	2519
B02	28	B41	195	C06	29	D07	17	F25	228	H02	869
B03	24	B42	65	C07	2783	D21	128	F26	39	H03	570
B04	22	B43	44	C08	1311	E01	226	F27	56	H04	4158
B05	363	B44	59	C09	597	E02	170	F28	187	H05	463

Table 6.1.1.4. Economic Data for France (Value Added and Employment by Industry).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total for 1990-2001
Value-added													
TOTAL	192339	194849	197520	189240	195231	204691	204311	214035	222196	226175	236865	245857	2523309
HT	22482	22553	23134	22579	23432	26649	25510	29715	30347	31722	33274	34721	326118
MHT	50552	50191	51674	48208	51486	53760	54450	57732	61596	63853	64637	68290	676429
MLT	52013	52282	52278	48403	50603	52914	53301	54855	57030	58097	63949	64715	660440
LT	67291	69823	70436	70050	69708	71369	71051	71732	73222	72503	75005	78131	860321
Employment													
TOTAL	4396	4322	4177	3974	3871	3874	3835	3791	3788	3771	3811	3853	47463
HT	457	456	436	411	398	400	398	390	393	395	406	418	4958
MHT	1033	1019	990	943	910	908	898	889	888	885	898	910	11171
MLT	1141	1123	1083	1020	992	1008	1002	985	986	982	1002	1020	12344
LT	1767	1725	1667	1602	1572	1561	1538	1527	1522	1508	1507	1507	19003

Table 6.1.1.5. Results of concordance.

	Scientific capabilities					**Technological capabilities**				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	47361	95723	12605	12837	168527	69427	76626	24828	8722	179603
Normalized by population	778	1572	207	211	2768	1140	1259	408	143	2950
Normalized by employment	9553	8569	1021	676	3551	14003	6859	2011	459	3784
Most recent 5 years	47361	95723	12605	12837	168527	24795	20857	6766	2579	54997
Normalized by population	778	1572	207	211	2768	407	343	111	42	903
Normalized by employment	23657	21415	2534	1696	8863	12385	4666	1360	341	2892
	Industry added value					**Education (PhDs)**				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	344847	714231	696714	906392	2662184	1635	2250	328	345	4559
Normalized by population	5665	11733	11445	14889	43731	27	37	5	6	75
Normalized by employment	69554	63936	56441	47697	56090	330	201	27	18	96
Most recent 5 years	173628	343480	324553	402584	1244244	1635	2250	328	345	4559
Normalized by population	2852	5642	5331	6613	20439	27	37	5	6	75
Normalized by employment	86727	76841	65237	53174	65438	817	503	66	46	240

6.1.2 Country data — Germany

Table 6.1.2.1. Scientific Data Germany by Field of Science (Broad), 2000 to 2004.

	2000	2001	2002	2003	2004
AGRICULTURE AND FOOD SCIENCE	1993	1861	2003	1978	1878
BASIC LIFE SCIENCES	8227	8494	8225	8865	8451
BIOLOGICAL SCIENCES	2825	2661	2665	2935	2711
BIOMEDICAL SCIENCES	9243	9427	9386	9915	9278
CHEMISTRY	8610	8751	8374	8725	8676
CLINICAL MEDICINE	13572	14082	13949	14836	14024
COMPUTER SCIENCES	2027	1992	1769	3250	3469
EARTH AND ENVIRONMENTAL SCIENCES	3159	3193	3260	3741	3410
ENGINEERING SCIENCES	8339	9836	8667	9376	8523
MATHEMATICS AND STATISTICS	2650	2509	2344	2543	2315
MULTIDISCIPLINARY SCIENCES	675	666	672	653	749
PHYSICS AND ASTRONOMY	14313	14105	14251	15162	13765
SOCIAL SCIENCES	3003	3252	3159	3508	3470
Total	78636	80829	78724	85487	80719

Table 6.1.2.2. Education data for Germany – doctorates by major field of study, 1990 to 2000.

OECD	ISCED	**Fields**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total PhDs - 1990 to 2000**
		Science + engineering sub	10762	10465	10148	10200	10200	10889	11472	11728	11966	11984	11895	121709
1	42+44	Natural sciences	5319	5326	5638	5700	5700	5868	6078	6418	6625	6271	6123	65066
1.1	46+48	Mathematics/computer sciences	429	418	464	500	500	663	810	785	855	980	968	7372
4	62	Agricultural sciences	997	709	602	500	500	507	512	521	562	522	497	6429
5	31	Social/behavioural sciences	1544	1483	1344	1400	1400	1741	1803	1775	1824	1982	2082	18378
2	52	Engineering	2473	2529	2100	2100	2100	2110	2269	2229	2100	2229	2225	2225
2	52	All other fields	11610	11997	11290	11800	11800	11498	11377	12446	12924	12561	12776	154318
		Total - all fields	22372	22462	21438	22000	22000	22387	22849	24174	24890	24545	24671	253788
Fields as a share		*Science + engineering sub*	48.1%	46.6%	47.3%	46.4%	46.4%	48.6%	50.2%	48.5%	48.1%	48.8%	48.2%	48.0%
		Natural sciences	23.8%	23.7%	26.3%	25.9%	25.9%	26.2%	26.6%	26.5%	26.6%	25.5%	24.8%	25.6%
		Mathematics/computer sciences	1.9%	1.9%	2.2%	2.3%	2.3%	3.0%	3.5%	3.2%	3.4%	4.0%	3.9%	2.9%
		Agricultural sciences	4.5%	3.2%	2.8%	2.3%	2.3%	2.3%	2.2%	2.2%	2.3%	2.1%	2.0%	2.5%
		Social/behavioural sciences	6.9%	6.6%	6.3%	6.4%	6.4%	7.8%	7.9%	7.3%	7.3%	8.1%	8.4%	7.2%
		Engineering	11.1%	11.3%	9.8%	9.5%	9.5%	9.4%	9.9%	9.2%	8.4%	9.1%	9.0%	0.9%
		All other fields	51.9%	53.4%	52.7%	53.6%	53.6%	51.4%	49.8%	51.5%	51.9%	51.2%	51.8%	60.8%

Note:1993 and 1994 are the same based on NSF estimates for missing data

Table 6.1.2.3. Technology Data Germany (EPO Patent Applications, applied from 2000-2004, Allocation based on Inventors).

A01	2201	B06	51	B60	8588	C10	398	E03	461	F41	360
A21	147	B07	211	B61	566	C11	913	E04	1701	F42	205
A22	179	B08	313	B62	1724	C12	3350	E05	1739	G01	8002
A23	777	B09	69	B63	246	C13	15	E06	799	G02	1761
A24	267	B21	1176	B64	458	C14	76	E21	288	G03	813
A41	183	B22	684	B65	4107	C21	355	F01	2344	G04	109
A42	21	B23	2482	B66	695	C22	422	F02	3646	G05	1579
A43	131	B24	526	B67	207	C23	996	F03	331	G06	4505
A44	112	B25	881	B68	21	C25	402	F04	1207	G07	1097
A45	272	B26	405	B81	140	C30	131	F15	637	G08	799
A46	127	B27	401	B82	5	D01	471	F16	6875	G09	743
A47	2126	B28	289	C01	769	D02	130	F17	135	G10	619
A61	10174	B29	2231	C02	453	D03	191	F21	640	G11	900
A62	224	B30	227	C03	650	D04	399	F22	77	G12	43
A63	421	B31	195	C04	682	D05	64	F23	673	G21	263
B01	3887	B32	994	C05	98	D06	929	F24	1155	H01	7635
B02	165	B41	1425	C06	71	D07	19	F25	624	H02	3034
B03	138	B42	329	C07	6577	D21	856	F26	188	H03	1269
B04	125	B43	75	C08	4644	E01	583	F27	237	H04	7702
B05	1044	B44	194	C09	2844	E02	379	F28	655	H05	1802

Table 6.1.2.4. Economic Data for Germany (Value Added and Employment by Industry).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total for 1991-2001
Value-added													
TOTAL	N/A	387260	391030	366660	375790	382240	382780	392220	408060	408450	423570	431620	4349680
HT	N/A	41364	40111	35697	35547	33574	35062	37785	38822	42302	46675	44742	431681
MHT	N/A	163973	165909	149322	155151	161715	161342	166195	174166	171250	176839	187216	1833078
MLT	N/A	88013	88089	84731	88312	90901	90017	90331	95933	94218	97526	99611	1007682
LT	N/A	93910	96920	96910	96780	96050	96360	97910	99140	100680	102530	100050	1077240
Employment													
TOTAL	N/A	10581	9794	9110	8642	8439	8212	8088	8118	8032	8098	8129	95243
HT	N/A	1103	993	911	827	777	745	753	737	741	761	761	9109
MHT	N/A	3987	3651	3335	3141	3052	3012	2975	3019	3030	3069	3129	35400
MLT	N/A	2406	2272	2134	2036	2031	1942	1896	1922	1922	1927	1933	22421
LT	N/A	3085	2878	2729	2638	2580	2513	2465	2440	2340	2341	2306	28315

Table 6.1.2.5. Results of concordance.

	Scientific capabilities					**Technological capabilities**				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	62283	131716	17022	17308	228329	146489	242783	60444	18386	468102
Normalized by population	756	1598	207	210	2770	1777	2946	733	223	5679
Normalized by employment	6838	3721	759	611	2397	16082	6858	2696	649	4915
Most recent 5 years	62283	131716	17022	17308	228329	55933	75441	18661	5397	155432
Normalized by population	756	1598	207	210	2770	679	915	226	65	1886
Normalized by employment	16596	8653	1773	1455	5643	14904	4956	1944	454	3841
	Industry added value					**Education (PhDs)**				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	430197	1825468	1003221	1072073	4330958	2320	3424	497	557	6798
Normalized by population	5219	22148	12172	13007	52546	28	42	6	7	82
Normalized by employment	47228	51567	44745	37862	45473	255	97	22	20	71
Most recent 5 years	211627	880664	480296	502996	2075583	2320	3424	497	557	6798
Normalized by population	2568	10685	5827	6103	25182	28	42	6	7	82
Normalized by employment	56389	57855	50031	42297	51293	618	225	52	47	168

6.1.3 Country data — Italy

Table 6.1.3.1. Scientific Data Italy by Field of Science (Broad), 2000 to 2004.

	2000	**2001**	**2002**	**2003**	**2004**
AGRICULTURE AND FOOD SCIENCE	975	1004	1105	1450	1294
BASIC LIFE SCIENCES	3981	4103	4042	4538	4490
BIOLOGICAL SCIENCES	1054	1061	1132	1308	1162
BIOMEDICAL SCIENCES	5108	5106	5306	5647	5652
CHEMISTRY	3828	4070	4067	4550	4409
CLINICAL MEDICINE	8092	8756	8639	9774	9427
COMPUTER SCIENCES	1083	1148	1149	1852	2141
EARTH AND ENVIRONMENTAL SCIENCES	1581	1611	1806	2094	2090
ENGINEERING SCIENCES	3829	4535	4409	4971	4972
MATHEMATICS AND STATISTICS	1381	1517	1647	1805	1626
MULTIDISCIPLINARY SCIENCES	227	232	315	288	282
PHYSICS AND ASTRONOMY	6161	6697	6852	7396	7338
SOCIAL SCIENCES	1042	1063	1050	1189	1222
Total	38342	40903	41519	46862	46105

Table 6.1.3.2. Education data for Italy – doctorates by major field of study, 1990 to 2000.

OECD	ISCED	**Fields**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total PhDs - 1990 to 2000**
		Science + engineering sub	691	323	1296	1299	1634	1970	2035	2089	2088	2121	2417	17963
1	42+44	Natural sciences	325	122	545	632	630	736	747	757	777	759	776	6806
1.1	46+48	Mathematics/computer sciences	*included in natural sciences*											
4	62	Agricultural sciences	74	21	174	95	171	174	172	157	168	168	348	1722
5	31	Social/behavioural sciences	126	123	279	245	409	540	544	577	620	604	657	4724
2	52	Engineering	166	57	298	327	424	520	572	598	523	590	636	4711
2	52	All other fields	573	495	871	1089	1264	1645	1599	1535	1432	1451	1559	13513
		Total - all fields	1264	818	2167	2388	2898	3615	3634	3624	3520	3572	3976	31476
Fields as a share		*Science + engineering sub*	54.7%	39.5%	59.8%	54.4%	56.4%	54.5%	56.0%	57.6%	59.3%	59.4%	60.8%	57.1%
		Natural sciences	25.7%	14.9%	25.1%	26.5%	21.7%	20.4%	20.6%	20.9%	22.1%	21.2%	19.5%	21.6%
		Mathematics/computer sciences	*included in natural sciences*											
		Agricultural sciences	5.9%	2.6%	8.0%	4.0%	5.9%	4.8%	4.7%	4.3%	4.8%	4.7%	8.8%	5.5%
		Social/behavioural sciences	10.0%	15.0%	12.9%	10.3%	14.1%	14.9%	15.0%	15.9%	17.6%	16.9%	16.5%	15.0%
		Engineering	13.1%	7.0%	13.8%	13.7%	14.6%	14.4%	15.7%	16.5%	14.9%	16.5%	16.0%	15.0%
		All other fields	45.3%	60.5%	40.2%	45.6%	43.6%	45.5%	44.0%	42.4%	40.7%	40.6%	39.2%	42.9%

Table 6.1.3.3. Technology Data Italy (EPO Patent Applications, applied from 2000-2004, Allocation based on Inventors).

A01	400	B06	9	B60	950	C10	94	E03	128	F41	48
A21	107	B07	34	B61	64	C11	147	E04	370	F42	11
A22	36	B08	72	B62	373	C12	340	E05	404	G01	817
A23	334	B09	40	B63	137	C13	2	E06	177	G02	276
A24	65	B21	258	B64	44	C14	31	E21	31	G03	56
A41	94	B22	107	B65	1768	C21	52	F01	231	G04	8
A42	39	B23	411	B66	119	C22	46	F02	400	G05	199
A43	278	B24	125	B67	145	C23	94	F03	43	G06	489
A44	68	B25	134	B68	3	C25	62	F04	250	G07	180
A45	97	B26	110	B81	27	C30	12	F15	80	G08	114
A46	46	B27	123	B82	3	D01	76	F16	1054	G09	110
A47	990	B28	229	C01	82	D02	35	F17	37	G10	42
A61	2419	B29	588	C02	78	D03	107	F21	134	G11	211
A62	36	B30	70	C03	140	D04	153	F22	17	G12	2
A63	191	B31	101	C04	117	D05	38	F23	165	G21	19
B01	556	B32	182	C05	34	D06	408	F24	272	H01	942
B02	39	B41	186	C06	2	D07	13	F25	220	H02	515
B03	19	B42	51	C07	1115	D21	65	F26	53	H03	207
B04	12	B43	16	C08	668	E01	131	F27	42	H04	865
B05	218	B44	56	C09	171	E02	97	F28	128	H05	199

Table 6.1.3.4. Economic Data for Italy (Value Added and Employment by Industry).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total for 1990-2001
Value-added													
TOTAL	153411	159238	163326	164571	175158	192579	197222	202827	211523	212018	220604	227129	2279606
HT	14739	14955	14615	15019	16091	15769	17105	17184	18166	18949	21641	22602	206835
MHT	39320	39372	40072	38714	41981	48853	49417	53440	55019	56256	57505	57727	577676
MLT	39775	41613	42984	43798	47098	53803	54563	55129	57809	57061	57861	59711	611205
LT	59577	63298	65656	67039	69989	74155	76136	77076	80528	79751	83598	87088	883891
Employment													
TOTAL	5568	5539	5367	5205	5145	5140	5095	5093	5196	5170	5160	5156	62834
HT	390	386	372	362	366	356	363	353	352	358	361	368	4387
MHT	1250	1240	1200	1145	1111	1129	1115	1145	1178	1179	1184	1173	14049
MLT	1400	1371	1323	1282	1272	1279	1304	1305	1328	1355	1352	1374	15945
LT	2528	2543	2473	2417	2399	2378	2315	2291	2341	2278	2267	2242	28472

Table 6.1.3.5. Concordance results.

	Scientific capabilities					Technological capabilities				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	32697	68733	8627	9085	119143	22715	39325	11686	5265	78991
Normalized by population	562	1182	148	156	2049	391	676	201	91	1359
Normalized by employment	7453	4892	541	319	1896	5178	2799	733	185	1257
Most recent 5 years	32697	68733	8627	9085	119143	8155	12850	4268	1874	27147
Normalized by population	562	1182	148	156	2049	140	221	73	32	467
Normalized by employment	18246	11731	1285	796	4622	4551	2193	636	164	1053
	Industry added value					Education (PhDs)				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	267392	745733	789423	1143291	2945839	362	643	101	120	1225
Normalized by population	4600	12828	13579	19667	50674	6	11	2	2	21
Normalized by employment	60951	53081	49509	40155	46883	82	46	6	4	19
Most recent 5 years	121698	345870	355296	504085	1326949	362	643	101	120	1225
Normalized by population	2093	5950	6112	8671	22826	6	11	2	2	21
Normalized by employment	67912	59032	52919	44144	51482	202	110	15	10	48

6.1.4 Country data — UK

Table 6.1.4.1. Scientific Data UK by Field of Science (Broad), 2000 to 2004.

	2000	**2001**	**2002**	**2003**	**2004**
AGRICULTURE AND FOOD SCIENCE	3158	3049	2902	3036	2721
BASIC LIFE SCIENCES	9081	9048	8793	9330	9169
BIOLOGICAL SCIENCES	3558	3495	3519	3652	3390
BIOMEDICAL SCIENCES	9897	10136	9602	10066	9666
CHEMISTRY	6196	6098	5922	6084	5831
CLINICAL MEDICINE	19956	19421	18537	19861	18659
COMPUTER SCIENCES	2028	2118	2018	3209	3326
EARTH AND ENVIRONMENTAL SCIENCES	4982	4713	4561	5220	4841
ENGINEERING SCIENCES	8186	8209	7570	8353	7865
MATHEMATICS AND STATISTICS	1959	1958	2001	2100	2013
MULTIDISCIPLINARY SCIENCES	1133	969	1041	1074	998
PHYSICS AND ASTRONOMY	8958	8944	9237	9589	9373
SOCIAL SCIENCES	9462	9304	8841	9879	9548
Total	88554	87462	84544	91453	87400

Table 6.1.4.2. Education data for UK – doctorates by major field of study, 1990 to 2000.

OECD	ISCED	**Fields**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Total PhDs - 1990 to 2000**
		Science + engineering sub	6210	6300	6110	6100	6330	5130	6530	6770	7270	7390	8620	72760
1	42+44	Natural sciences	3110	3150	3050	3030	3200	2580	3380	3420	3670	3670	4370	36630
1.1	46+48	Mathematics/computer sciences	470	540	520	530	600	450	600	590	570	680	770	6320
4	62	Agricultural sciences	240	250	280	280	330	270	350	320	390	330	340	3380
5	31	Social/behavioural sciences	920	910	940	740	700	500	640	680	810	910	1140	8890
2	52	Engineering	1470	1450	1330	1520	1500	1330	1560	1760	1840	1810	2010	17580
2	52	All other fields	2030	2090	2290	2620	2670	2430	3230	3440	3720	3950	5500	33970
		Total - all fields	8240	8390	8400	8720	9000	7560	9760	10210	10990	11340	14120	106730
Fields as a share		*Science + engineering sub*	75.4%	75.1%	72.7%	70.0%	70.3%	67.9%	66.9%	66.3%	66.2%	65.2%	61.0%	68.2%
		Natural sciences	37.7%	37.5%	36.3%	34.7%	35.6%	34.1%	34.6%	33.5%	33.4%	32.4%	30.9%	34.3%
		Mathematics/computer sciences	5.7%	6.4%	6.2%	6.1%	6.7%	6.0%	6.1%	5.8%	5.2%	6.0%	5.5%	5.9%
		Agricultural sciences	2.9%	3.0%	3.3%	3.2%	3.7%	3.6%	3.6%	3.1%	3.5%	2.9%	2.4%	3.2%
		Social/behavioural sciences	11.2%	10.8%	11.2%	8.5%	7.8%	6.6%	6.6%	6.7%	7.4%	8.0%	8.1%	8.3%
		Engineering	17.8%	17.3%	15.8%	17.4%	16.7%	17.6%	16.0%	17.2%	16.7%	16.0%	14.2%	16.5%
		All other fields	24.6%	24.9%	27.3%	30.0%	29.7%	32.1%	33.1%	33.7%	33.8%	34.8%	39.0%	31.8%

Table 6.1.4.3. Technology Data UK (EPO Patent Applications, applied from 2000-2004, Allocation based on Inventors).

A01	635	B06	12	B60	830	C10	359	E03	103	F41	44
A21	59	B07	44	B61	59	C11	536	E04	394	F42	43
A22	17	B08	64	B62	220	C12	1624	E05	285	G01	2424
A23	380	B09	37	B63	107	C13	12	E06	110	G02	678
A24	45	B21	120	B64	173	C14	11	E21	340	G03	247
A41	84	B22	85	B65	1067	C21	28	F01	342	G04	26
A42	22	B23	276	B66	87	C22	105	F02	420	G05	191
A43	42	B24	69	B67	105	C23	139	F03	52	G06	2537
A44	37	B25	135	B68	19	C25	91	F04	195	G07	471
A45	102	B26	74	B81	26	C30	44	F15	68	G08	216
A46	39	B27	53	B82	1	D01	39	F16	1046	G09	358
A47	630	B28	41	C01	177	D02	16	F17	46	G10	160
A61	5338	B29	347	C02	155	D03	37	F21	82	G11	283
A62	111	B30	13	C03	101	D04	60	F22	6	G12	13
A63	258	B31	33	C04	120	D05	17	F23	89	G21	79
B01	981	B32	195	C05	22	D06	251	F24	137	H01	1520
B02	42	B41	302	C06	5	D07	2	F25	114	H02	409
B03	44	B42	89	C07	3357	D21	139	F26	28	H03	382
B04	41	B43	26	C08	647	E01	150	F27	21	H04	3449
B05	208	B44	47	C09	657	E02	140	F28	84	H05	358

Table 6.1.4.4. Economic Data for UK (Value Added and Employment by Industry).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total for 1991-2001
Value-added													
TOTAL	116424	113322	115891	120989	130767	139789	145530	151733	153616	153026	152102	151098	1644287
HT	17050	17323	16686	17386	19602	20219	20832	22732	23717	24905	25810	25534	251796
MHT	30562	28338	29061	30437	33579	37150	38965	39947	39606	38416	37153	36598	419812
MLT	27325	25614	25667	27022	29509	32035	32438	33887	34898	33687	32635	32319	367036
LT	41489	42049	44477	46144	48077	50385	53295	55167	55395	56018	56504	56647	605647
Employment													
TOTAL	5159	4749	4485	4334	4355	4430	4487	4505	4528	4362	4227	4050	53671
HT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MHT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MLT	1223	1104	1046	1019	1037	1060	1075	1073	1055	1023	987	944	12646
LT	2022	1901	1831	1819	1813	1789	1795	1802	1815	1749	1680	1602	21618

Table 6.1.4.5. Concordance results.

	Scientific capabilities					**Technological capabilities**				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	56161	137713	15378	19102	228355	68178	56145	16757	6925	148005
Normalized by population	927	2272	254	315	3768	1125	926	276	114	2442
Normalized by employment	N/A	N/A	1216	884	4255	N/A	N/A	1325	320	2758
Most recent 5 years	56161	137713	15378	19102	228355	25702	14050	4190	2029	45971
Normalized by population	927	2272	254	315	3768	424	232	69	33	758
Normalized by employment	N/A	N/A	3026	2209	10537	N/A	N/A	824	235	2121
	Industry added value					**Education (PhDs)**				
	HT	MHT	MLT	LT	Total	HT	MHT	MLT	LT	Total
All years	403280	672810	588308	970453	2634851	1773	2512	382	402	5070
Normalized by population	6654	11101	9707	16012	43473	29	41	6	7	84
Normalized by employment	N/A	N/A	46521	44891	49093	N/A	N/A	30	19	94
Most recent 5 years	194211	303494	265017	442826	1205548	1773	2512	382	402	5070
Normalized by population	3204	5007	4373	7306	19891	29	41	6	7	84
Normalized by employment	N/A	N/A	52148	51206	55627	N/A	N/A	75	47	234

As reflected in the previous tables, all these data sources have adopted their own, specific classification schemes. By means of the different concordance tables, it now becomes feasible to align or translate the amount of activity within science, technology, education and economy towards one classification scheme spanning all activity domains. This is done by using the concordance tables as weighting schemes. Table 5 illustrates this approach for Germany. We have chosen to align all data towards the OECD classification of manufacturing industries (HT, MHT, MLT, LT). The data from science, technology and education are in a next step being 'assigned' to these industries by using the weights of the concordance tables. For instance, the number of PhD's in engineering are only attributed to HT industry to the extent that the different concordance table indicate a relationship with that industry. Applying these concordance tables in a systematic manner hence allows defining a harmonized set of scientific, technological, educational and economical data. It is clear that such harmonized data offer potential for fine grained analysis oriented towards understanding dynamics and relationships between different components of innovation system.

6.2 Country results

Figures 3 to 6 summarize the results for each of the countries. The values shown are normalised indices which are calculated as the ratio between the numerator showing the share of the respective indicator for each HT to LT industry in total manufacturing and the denominator showing the share of value added for each HT to LT industry in total manufacturing.

In both Germany and Italy the scientific base is strongest in HT manufacturing, in France and in particular in the UK the scientific base is strongest in MHT manufacturing. The educational base is strongest in HT manufacturing in Germany, Italy and the UK but for France it is strongest in MHT manufacturing. Technological capabilities are strongest in HT manufacturing in Germany, Italy and the UK but for France it is strongest in MHT manufacturing.

Figure 3. Summary of country results for France.

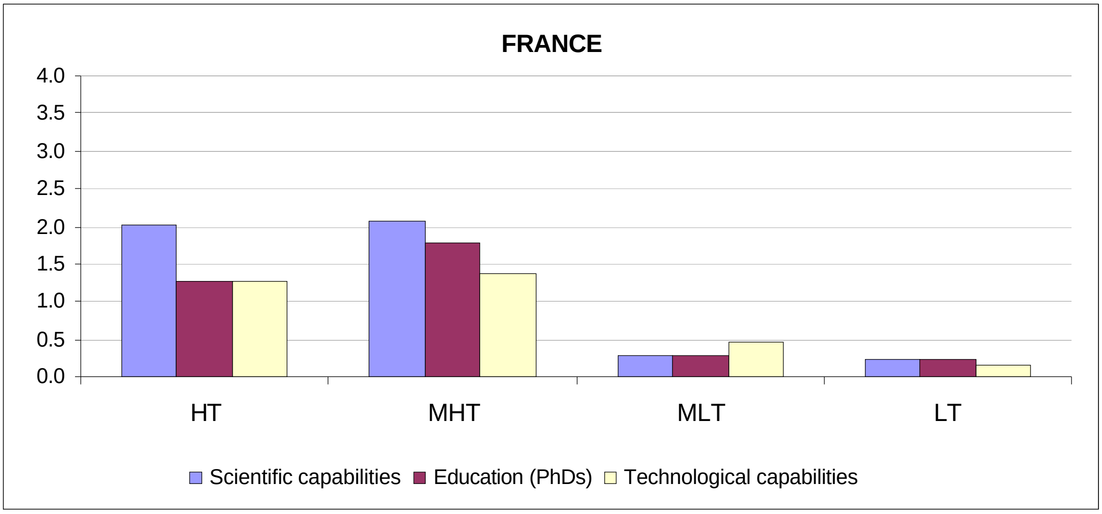


Figure 4. Summary of country results for Germany.

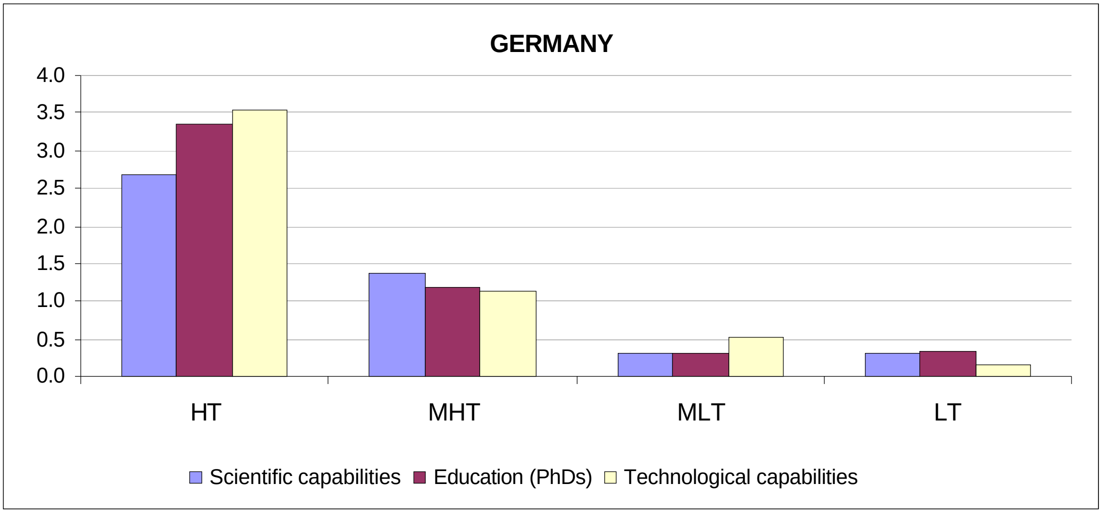


Figure 5. Summary of country results for Italy.

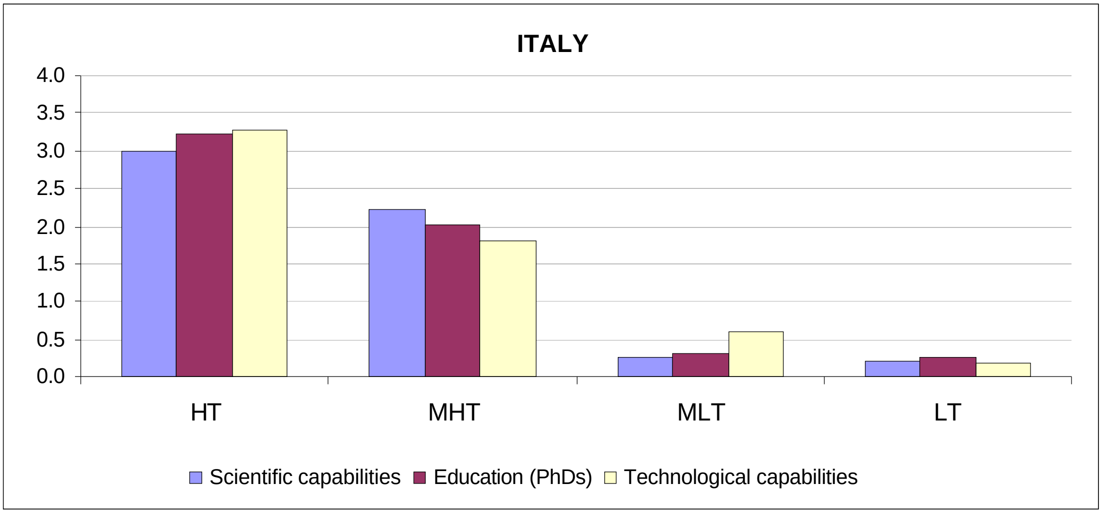
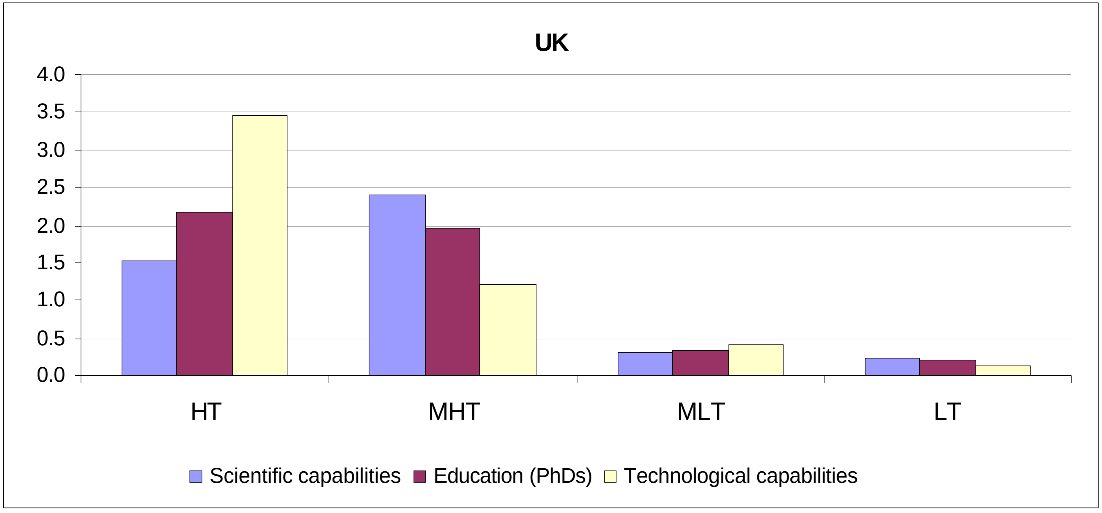


Figure 6. Summary of country results for the UK.



6.3 Discussion of country data

6.3.1. Exploring the dynamics of innovation systems by means of concordance tables

The availability of a comprehensive set of different concordance tables covering education-science-technology-industry offer a range of possibilities to further examine the dynamics of innovation systems. It becomes now possible to engage in empirical analysis whereby the relationships between the components of the different activity realms can be analyzed in a more fine-grained manner.

To illustrate the potential we present and analyze some of these relationships for a selection of a selection of OECD Countries. While a first analysis examines the relationships between education and technology, a second model explores the relationships between education, technology and economical activity. Countries under study include besides major European countries (France, United Kingdom, Germany, Italy), the United States of America, Canada and Japan (G7). For the second analysis, Korea – as an exemplar of the Asian growth economies – has been included as well.

Descriptive statistics

Within a first part, descriptive figures are presented on the level of scientific capabilities (measured by WOS publications), technology (EPO applications), economical activity (OECD figures with respect to added value within manufacturing industries) and education (PhD S&E). Both publication and patent data have been allocated to high technology manufacturing industries based on the concordance tables developed and/or refined with the framework of this project (Table 9).

Table 9. Scientific Capabilities, Technological Activity (EPO), Industry Added Value, Education (PhD S&E – Other) measured in absolute terms for a selection of OECD Countries.

Country	Scientific Capabilities HT	Technological Activity HT	Industry Added Value HT	PhD S&E
CA	28.215 (7)	8.201 (6)	69.367 (8)	2.224 (7)
DE	62.283 (3)	55.933 (3)	211.627 (4)	9.464 (2)
FR	47.361 (5)	24.795 (5)	173.628 (6)	6.545 (5)
IT	32.697 (6)	8.155 (7)	121.698 (7)	1.631 (8)
JP	66.914 (2)	70.754 (2)	607.710 (2)	6.706 (4)
KR	21.862 (8)	4.716 (8)	237.947 (3)	2.440(6)
UK	56.161 (4)	25.702 (4)	194.211 (5)	7.096 (3)
US	202.340 (1)	137.531(1)	1.359.233(1)	19.506(1)

Scientific capabilities = Total number of publications for the period 2000-2004

Technological activity = Number of patent applications for the period 1998-2002 (EPO) –
(based on inventors, full count if multiple inventors from different countries)

Industry added value total = total added value of the technology industry for the period 1997-2001 – OECD Figures

PhD's **Yearly** Average calculated on data available for the following time periods:

United States	1999-2003	Italy	1997-2002 (-2001)

Canada	1997-2001	Japan	1999-2003
France	1996-2000	Korea	1997-2002 (-2001)
Germany	1999-2003	United Kingdom	1999-2003

It becomes apparent from these data that European countries show relative strong positions in terms of science, technology and education. In terms of economical performance, the European countries under study are being outperformed by the US, Japan and even Korea. This assessment is confirmed when looking at the same data normalized by population (Table 10).

Table 10. Scientific Capabilities, Technological Activity (EPO), Industry Added Value, Education (PhD S&E – Other) normalized by population.

Country	Scientific Capabilities HT	Technological Activity HT	Industry Added Value HT	PhD S&E
CA	852 (2)	248 (6)	2096 (7)	67 (4)
DE	756 (4)	679 (1)	2568 (6)	115 (2)
FR	778 (3)	407 (5)	2852 (5)	108 (3)
IT	562 (6)	140 (7)	2093 (8)	28 (8)
JP	525 (7)	555 (2)	4768 (2)	53 (6)
KR	448 (8)	97 (8)	4871 (1)	50 (7)
UK	927 (1)	442 (4)	3204 (4)	117 (1)
US	678 (5)	461 (3)	4554 (3)	65 (5)

6.3.2 The role of human capital: Examining the relationship between PhDs (in Science and Engineering) and technological performance of national innovation systems

HMHT intensive manufacturing industries account for the lion's share of employment in the manufacturing sector. Figure 7 shows employment in HMHT intensive manufacturing industries as a share of total employment in manufacturing. [12]

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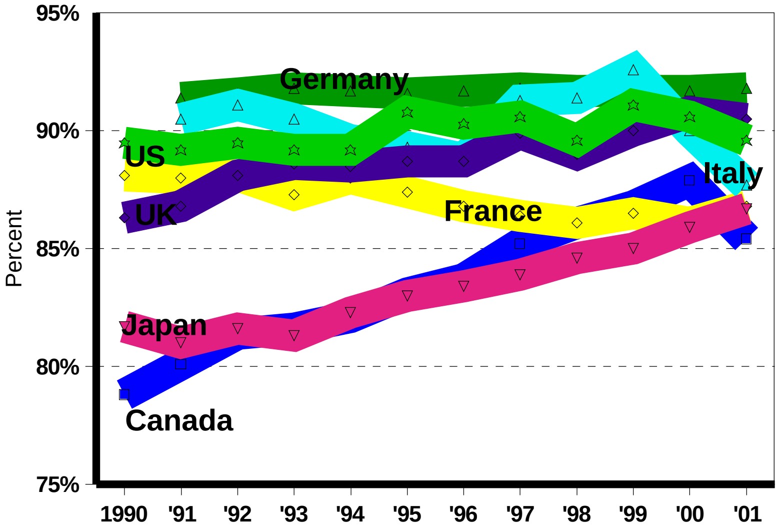
[12] We include seven countries in our analysis for this paper for Blue Sky: four EU countries (France, Germany, Italy, United Kingdom), Canada, the United States and Japan.

Figure 7. Employment in HMHT intensive manufacturing industries as a percent of total employment in manufacturing, 1990 to 2001.



Source: UNU-MERIT based on OECD data.

For countries like Canada and Japan, the share of manufacturing employment in HMHT intensive manufacturing industries rose almost every year between 1990 and 2000 with the trend in Canada extending to 2001. Germany shows a consistent picture — more than nine in ten employed in manufacturing industries were in HMHT intensive manufacturing industries throughout the period 1990 to 2001.

In the EU in 2005, human resources in science and technology (HRST) accounted for only 29% of employment in the manufacturing sector compared with 47% of employment in the services sector. Within the manufacturing sector though, the presence of S&T workers varied. Among the high technology (HT) intensive manufacturing industries, HRST accounted for more than half (52%) of total employment; in the medium technology (MT) intensive manufacturing industries, HRST accounted for 39% of total employment.[13]

Figure 8 shows the concentration of researchers among the R&D personnel[14] in HT intensive, MT intensive and total manufacturing industries. For each of the EU countries, it is in HT intensive manufacturing industries one observes the highest concentration of researchers as measured by share of R&D personnel. At almost nine researchers out of ten R&D personnel in the HT industries and three in five in the MT industries, the UK reports the highest concentration of researchers to total R&D personnel.

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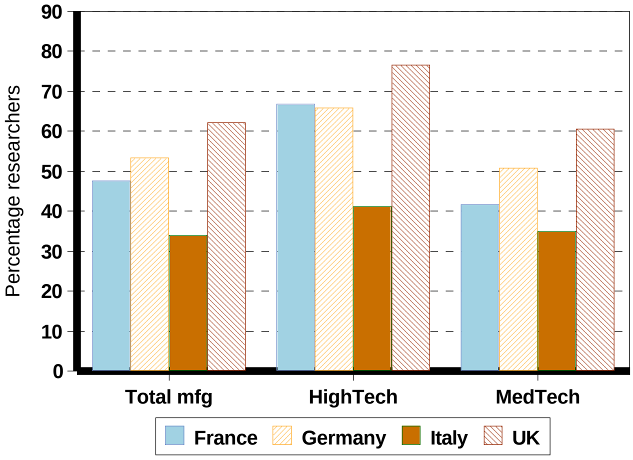
[13] Eurostat, *Statistics in Focus*, 13/2006.

[14] According to the OECD Frascati Manual 2002, R&D personnel include persons performing the scientific and technical work, persons planning and managing research projects, persons preparing the interim and final reports for R&D projects, persons providing internal services for R&D projects and persons providing support for the administration of the financial and personnel aspects of R&D projects.

Figure 8. Researchers as a percentage of total R&D personnel, 2003 .

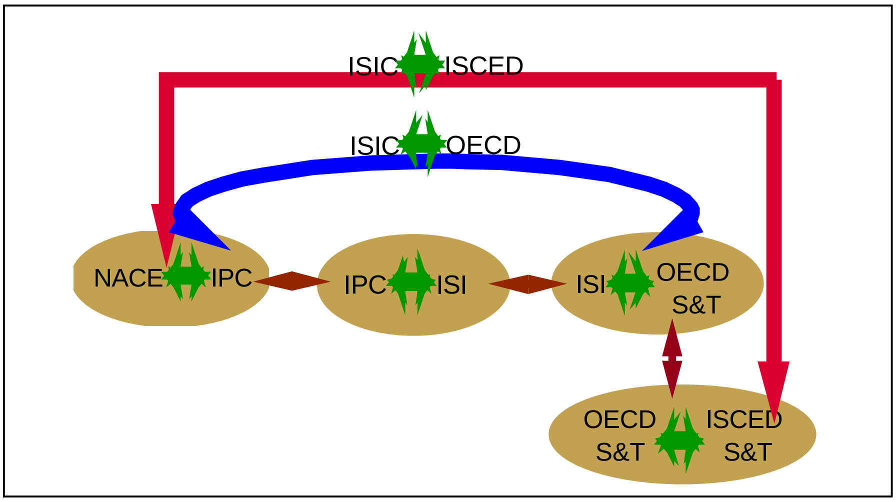


Source: MERIT based on Eurostat data.

Source: UNU_MERIT

Figure 9 shows the integral parts of moving from HMHT industries' scientific base to scientific disciplines of education as defined by ISCED 97.

Figure 9. Moving from patents and non -patents references to ISIC and ISCED.



Elements used in the examination of the relationship between performance and human capital

The work carried out for Blue Sky to examine the relationship between technological performance and human capital used the following elements:

— Analysis on the level of national innovation systems

- Countries: France, Germany, Italy, United Kingdom, Canada, the United States and Japan.
- PhD degrees awarded from 1990 to 2000: number of PhDs in major fields of science and engineering (excluding social sciences), normalized by population count.
- Technological performance: EPO patent applications from 1990 to 2004 normalized by population count, allocated to high tech, medium tech, medium low tech, low tech industries (OECD classification).
- Country allocation based on inventor nationality, full count in the case of multiple nationalities. (Note: the approach based on assignee nationally yields similar results).
- R&D expenditures for 1990 to 2000 by in industries: high tech, medium tech, medium high tech, medium low tech, and low tech.
- Time lag (between education and technology): three and four years were used.

Does education, in this case as measured by PhDs in S&T, contribute to HT technological performance?

The link between R&D expenditures and PhDs in S&T and productivity were analysed. According to the results, it appears that although money certainly matters, people really matter when it comes to HT technological performance. Figure 6 shows that although the correlation between R&D expenditures and HT productivity is not necessarily low, the correlation between education (PhDs in S&T) and HT productivity is significant (Table 11).

Table 11. Correlations between R&D expenditures, productivity and education.

	R&D Expenditures HT	**HT Productivity**	**PhD** Technologica
R&D Expenditures HT	1		
HT Productivity	.258	1	
PhDs in S&T	.481**	.538**	1

** Correlation is significant at the 0.01 level

Source: INCENTIM

Does educational strength (as measured by PhDs in S&T) contribute to HT technological performance?

Although clearly technological performance hinges on the combination of money (R&D expenditures) and people, people are important and not to be excluded from measurement of HMHT performance. Table 12 shows the Fixed Affect Analysis — results suggest a distinctive and considerable impact of educational strength on technological performance.

Table 12. HT technological performance — Fixed Effect Analysis.

	Partial Correlation (controlling for R&D expenditures and Added Value within Industry)	Significance
High Tech Industries	0,532	p=0,000
Medium High Tech Industries	0,428	p=0,018
Medium Low Tech Industries	0,580	p=0,000
Low Tech Industries	0,405	p=0,018

Source: INCENTIM.

Does educational strength (as measured by PhDs in S&E) contribute to technological performance in general?

Is the correlation between human capital and performance unique to the HT intensive manufacturing industries (e.g. one might expect this correlation HT industries), or does the result hold for other industries. Analysis was carried out on HT, MHT, ML T and LT industries for seven countries over six time periods. The findings suggest a positive relationship between PhDs and technological output and this is not limited to HT industries — this applies across all industries (Table 13).

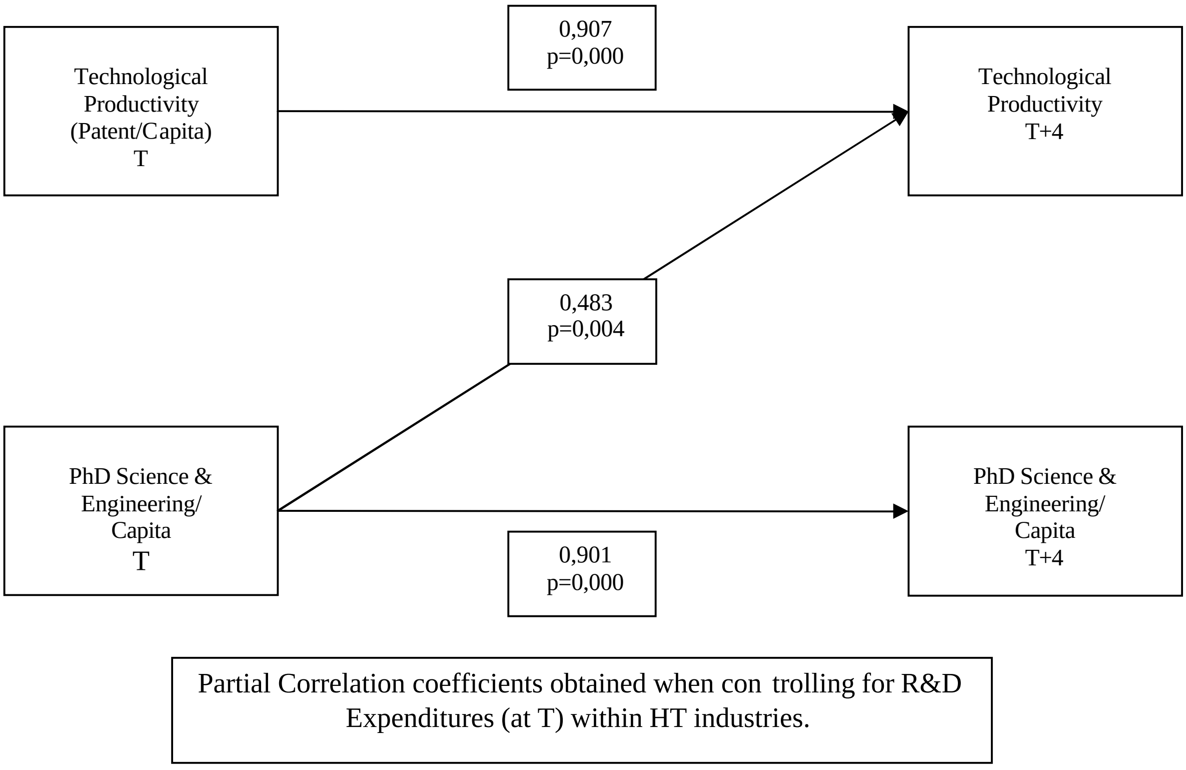
Table 13. Education strength and technological performance and all industries.

	Partial Correlation (controlling for R&D expenditures and Added Value within Industry)	Significance
High Tech Industries	0,532	p=0,000
Medium High Tech Industries	0,428	p=0,018
Medium Low Tech Industries	0,580	p=0,000
Low Tech Industries	0,405	p=0,018

Source: INCENTIM.

Figure 10 gives a disentangling of causality: a path analysis. This is important not only for what it shows but for what it does not show. For example, technological productivity (patent/capita) has a high correlation to technological productivity T+4 —as one would expect. This is the traditional patent result — the rich stay rich; the rich get richer.

Figure 10. Disentangling of causality: a path analysis .



6.3.3. One step further: Examining the relationships between Technology, Education (PhDs in Science and Engineering) and High Tech industrial activity.

Within a next step, the previous analysis has been extended by introducing data on industrial activity. For the countries under study, data on the size of industrial activity have been obtained from OECD. Within the analysis, the size of added value in high tech industries acts as dependent variable .[15]

In terms of modelling, we use both fixed effect panel models and path analysis. Within fixed effect models one takes into account unobserved differences between countries that might affect the dependent variable as well (e.g. differences in institutional framework conditions). Path analysis allows looking for reciprocal relationships between the

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[15] Based on the classification provided by OECD which distinguishes between High Tech, Medium High Tech, Medium Low Tech and Low Tech industries

different variables under study. Data have been lagged with two years in order to examine causality; so data relating to technology, education and R&D expenditures in a first period (t), are related to economical performance in a second period (t+2). The data pertain to the time period 1991-1999[16].

Within the next figures, some of the data are visually represented; whereby each country is represented by a different colour. Technological strengths – as measured by the number of EPO applications relevant for high tech industries – are plotted against the added value in the respective high tech industries (Figure 11).

Figure 11. Linking technological performance and industrial activity .

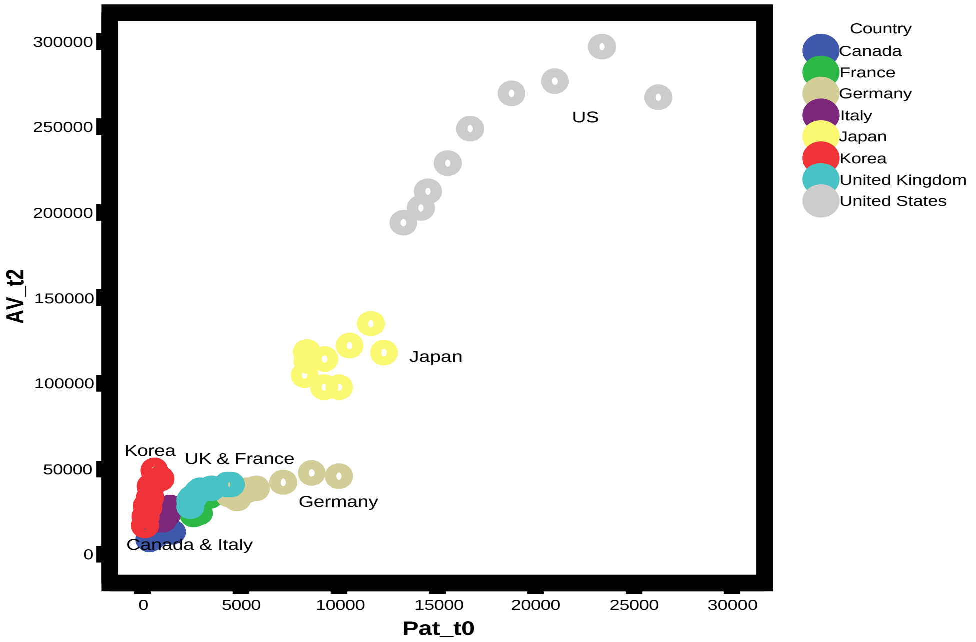

Figure 12 immediately suggests an overall positive relationship between technological and industrial activity which is being confirmed by a regression analysis ($R^2 > 0,9$).

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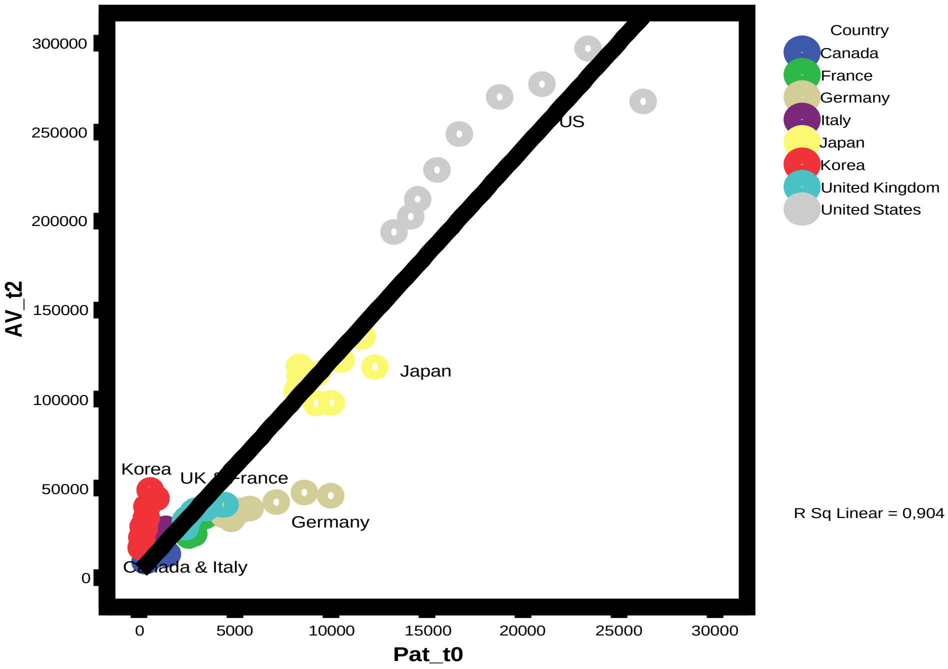
[16] For this time period, data relating to patents, R&D expenditures, added value and PhD's in Science and Engineering were readily available. In our future research we will extend the dataset to include scientific publications. At the same time, it should be noted that correlation between scientific activities and PhD in S&E is considerable for this set of eight countries during the time period 200-2004 (r=0,96 in absolute terms; and r= 0,76 for normalized data). As such, we expect scientific indicators to relate in a similar manner as the educational indicator used with respect to technological and industrial activity.

Figure 12. Positive link between technological and industrial activity .



At the same time, the graphs suggest considerable country differences both in terms of absolute strengths and even in terms of the relationship between technological capabilities and the performance of HT industries. This becomes clear when performing a fixed effect model. As Table 14 makes clear, the different variables all contribute positively to observed fluctuations in terms of added value of HT industries. So the relevance of further stressing investments in R&D, technology and people (see also the Lisbon goals) is confirmed by this analysis; at the same time the amount of variance that is country specific is considerable (almost 90%).

Table 14. Added Value (T2) in relation to R&D expenditure (T0), Technological and Educational Capabilities (T0). Fixed Effect Panel Model.

	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Added Value T0[17]	20946.66	3219.727	6.51	0.000	14496.77	27396.55
Technology T0	12.45498	1.098494	11.34	0.000	10.25443	14.65553
PhD T0°	10187.14	3922.558	2.6	0.012	2329.315	18044.97
R&D T0°	7951.735	1823.826	4.36	0.000	4298.174	11605.3
Constant	-1174.74	6230.601	-0.19	0.851	-13656.1	11306.65

Number of observations: 68; Group variable: Country - Number of groups: 8 – Observations per group: Min =5, Avg =8.5, Max = 9 - Rho= .88415717 (fraction of variance due to fixed (country) effects)

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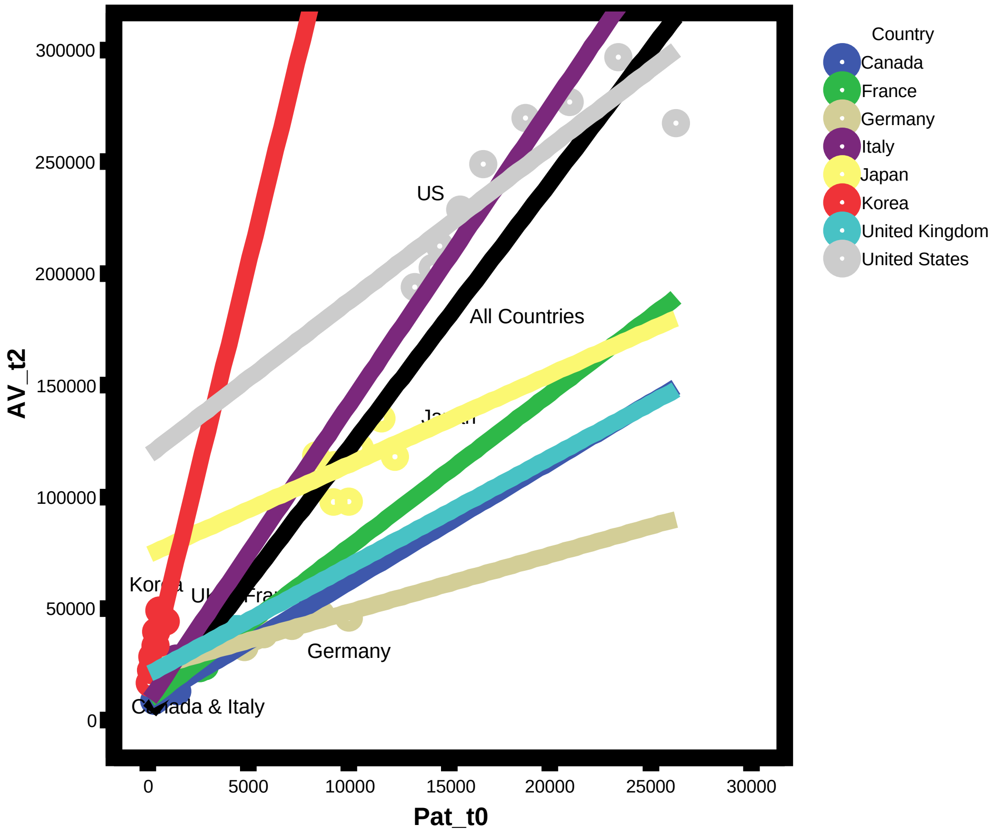
[17] In order to address multicollinearity, the shared variance with technology has been removed for these variables (estimates based on residual values obtained after regression analysis with technology as independent variable).

As mentioned, differences between countries do not seem to limit themselves to differences in absolute size; also the strength of the relationship between innovation related indicators (patents, R&D, PhD in S&E) on the one hand and economical performance on the other hand seems to be to a large extent country specific. As the next figure clarifies, considerable differences are to be observed between countries in terms of the slope of the relationship [18]. Korea and Germany represent the most extreme cases in terms of strength of the relationship: a similar increase in absolute patent activity coincides with an increase in industrial added value which is about ten times higher for Korea than for Germany. As such, this analysis suggests to policy scholars to engage in further analysis whereby factors affecting the translation of innovative activities into economical activities become a central focus (Figure 13).

Figure 13. Extreme patterns for Korea and Germany



Within a final analysis path coefficients have been calculated for the sample and variables under study. The following figure depicts the relationships observed. These findings confirm to a large extent the results obtained in the previous section and which have been presented at the Blue Sky Conference (Ottawa, Canada, September 2006). While the performance of each activity domain is driven to a considerable extent by its performance

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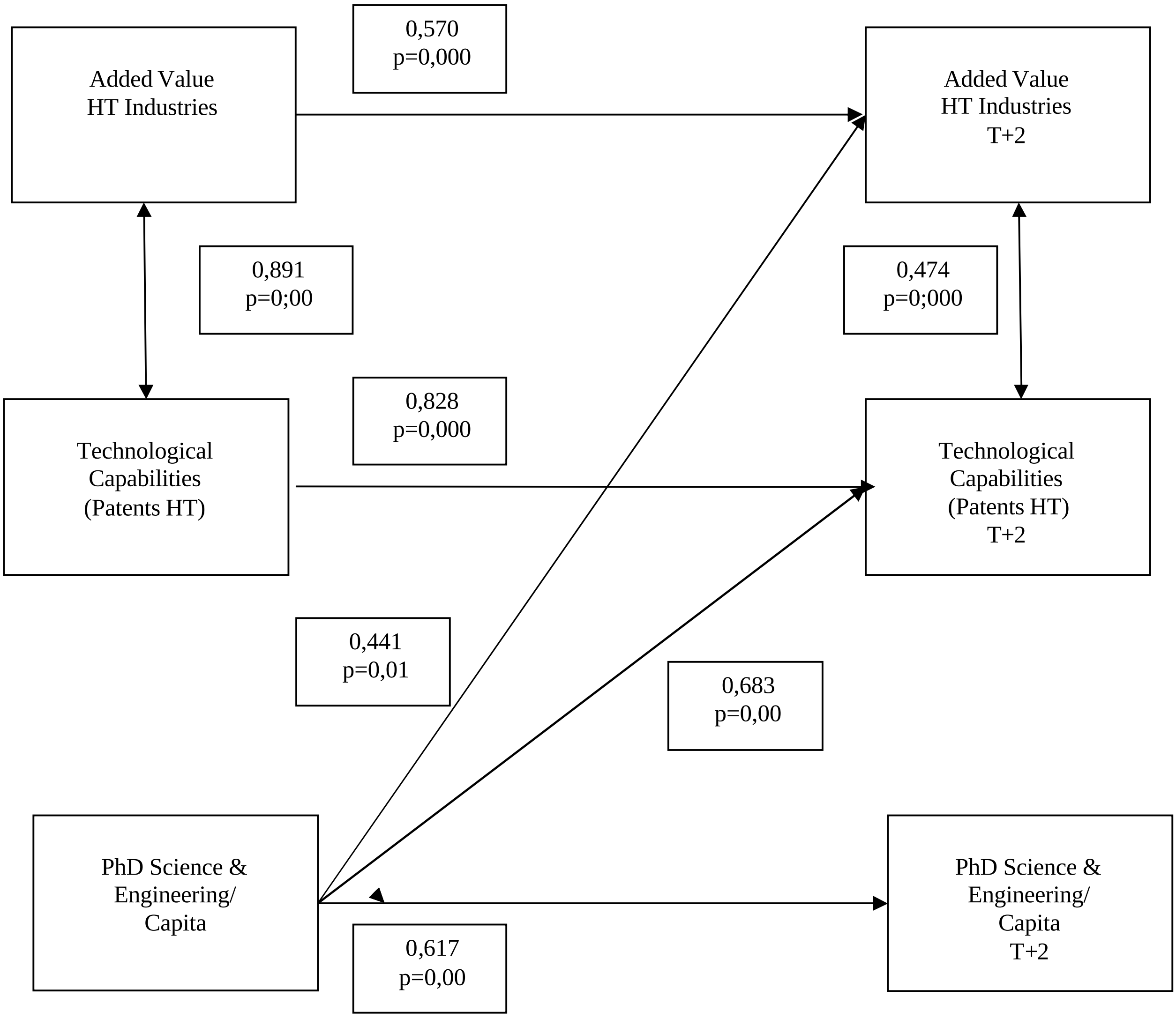
[18] The solid black line depicts the relationship for all countries.

in a previous period, one observes again a considerable influence of human capital both on technological performance *and* economical performance (Figure 14).

Figure 14. Disentangling causality: Path Analysis .



Path Analysis coefficients obtained when controlling for R&D Expenditures (at T0) within HT industries.

7. Conclusions of the study

Within this project concordance tables relating economical, scientific, technological and educational activity realms have been the central focus. The availability of a complete set of concordance tables allows analyzing relationships between components of innovation systems in novel ways. Such analysis bears considerable potential for informed policy making. The first preliminary analysis reported in the previous pages not only reveals the feasibility of such an endeavour, already at this stage several interesting observations become worth highlighting:

- Indicators pertaining to human capital (educational data) deserve our utter attention when looking at technological and industrial activities of HT industries.
- Country differences pertaining to technology development and human capital do translate into economical differences at the industry level.
- At the same time, the extent to which technology and human capital differences become translated into industrial activity seems to be country specific, directing out attention to the institutional and market factors that moderate this relationship.

It goes without saying that the results reported here are of a preliminary nature and that further research is needed to further unravel the potential offered by the availability of a full set of concordance tables. Inspired by the work undertaken within the framework of this project, we are currently engaging in further analyzing the dynamics underlying the performance of innovation systems by adding more countries as well as by introducing scientific indicators to the equations. We hope that this report will inspire colleagues to engage in similar activities in order to arrive at insights and recommendations valuable for both innovation scholars and policy makers alike.

8. Dissemination and Future Directions

8.1. Dissemination

8.1.1. Publication plans

The methodology developed for this study and the preliminary results have already generated a lot of reaction in the research community. It is important to distribute the results of the study and be able to expose the work to a broader research and policy community.

One method is to publish on the web site of DG Research and/or the research partners. It is important that this work is brought to the attention of the broader research and policy community to stimulate debate and further the work. It is therefore foreseen that an article or a number of articles be prepared for submission to key S&T and innovation and economic journals including:

- Research Policy
- The American Journal of Economics and Sociology
- The OECD Observer
- Scienometrics

Publishing in recognized journals serve two main purposes. First of all, the methodology developed under this study will have world level exposure. Second, exposure through publication will serve to stimulate debate and contribute to advancing the methodology and ideas developed under this study.

8.1.2. In the public domain

At the request of the European Commission, an abstract of the study's aim and methodology was submitted and subsequently accepted for the OECD Blue Sky Conference held in September 2006. The 2006 conference was the second such conference of the OECD to look at new areas for indicator development. One of the themes of the conference was how to make additional and/or better use of existing data sets to explore S&T and innovation in order to provide a better picture of the various actors in innovation. The work carried out under this study was seen as a good example of innovative use of existing data sets for key policy issues.

Presenting at the Blue Sky Conference put the work carried out under this study in the public domain. The papers are published on the OECD Blue Sky web site (www…….) and expressions of interest in the work were given, including that of the National Science Foundation. There is an opportunity for reference to this study in the forthcoming S&T Indicators Report of the National Science Foundation.

The results of this study are seeing additional circulation as the work and its results are referenced in other research output of the research team. It would be useful to make the results of this study available to the public through the website of DG Research and/or with links to the web sites of the research partners.

8.2. Future directions

The preliminary results of the study make it clear that it is important to pursue this work further. The work carried out under this study is of a preliminary nature with a limited number of countries and sets of indicators. The results leave no doubt about the potential of this work. In terms of future directions we that this work be carried out on a broader range of countries with enhanced data sets. The methodology developed in this study provides for a wide range of possibilities to better understand R&D and innovation and the science base and the role of human capital in S&T.

A first recommendation is for the European Commission to consider provision of funding to continue the work begun in this study to explore S&T linkages across a larger range of countries (e.g. the EU-27) and sectors and providing funding for more detailed examination of the relationships. Resources requirements are for data purchases and research and analysis.

A second recommendation is the research team pursues other avenues for funding and support to further and continue the work developed under this study. Examples:

§ Under John H. Marburger, Science Adviser to President of the US, an initiative has been launched *Science of Science and Innovation Policy* to:

  - to develop usable knowledge and theories of creative processes and their transformation into economic and social outcome;
  - develop, improve and expand models and analytical tools that can be applied in the science policy decision making process.

  Based on the Marburger priorities, the National Science Foundation (Washington DC) has put out a call for proposals to encourage collaborative partnerships and encourage research across national borders. The work would be anchored in the US.

§ 7th Framework of the European Commission (e.g. calls under Socio-economic sciences and humanities e.g. Activity 8.6: Socio-economic and scientific indicators).

§ Proposals to national agencies and organisations (e.g. Ministries of Economic Affairs, research funding councils).

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