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Mapping 21st century Science/Technology linkages: has science become more important in recent technological development?

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Working paper

2020 Directorate-General for Research and Innovation EN

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EXECUTIVE SUMMARY

Productivity slowdown, innovation and science

What is causing the long-term slowdown in productivity growth in recent decades? Are there insufficient technological or organisational innovations that lead to new products and services for global markets? Is the further development of emerging technologies hampered? Is there a lack of novel 'breakthrough' discoveries in science that may lead to innovations? Or is it because of other factors or determinants that impact on advances in innovation? Economic experts point at innovation-related knowledge diffusion processes is one of the possible explanations. But details on causal relationships are unclear.

More empirical data are sorely needed to unravel the linkages and knowledge flows between science, technology and innovation. Hence, one of the topics of rising interest in contemporary science and innovation policy is the role of basic and applied scientific research as a driving force of new emerging technologies and related technological innovations. This empirical study is meant to help clarify contributions of science to advanced technological development, by addressing the question: is discovery-oriented science becoming increasingly important in recent developments of emerging technologies?

Analysing knowledge flows between science and technology

The data analysis methodology derives its information from observed linkages between patents and scientific research publications. The main advantage of this empirical approach is the availability of comprehensive, long-term and internationally comparable data. This enables large-scale, systematic measurement of linkages and knowledge flows between (discovery-oriented) science and (patented) technology (S/T linkages). Part of these links represent genuine knowledge flows, part reflect other types of connections.

As for the statistical data, the S/T linkage table comprises of pairwise citation frequency counts. The S/T pairs are defined by the citing patents, that explicitly mention scientific research in their list of referenced sources, and the cited research publications. Because of time-lags involved between knowledge creation and knowledge utilization in technological development, the numbers of these S/T citation linkages will inevitably go down as one moves to the current date. Many results of science that will shape the future generation of technologies are yet to be published.

The citation-based S/T linkage analysis in this report was done at the aggregate-level of entire scientific disciplines to technology areas. The trend analysis of changes in the S/T linkage tables compares three consecutive time-periods: 2000-2004, 2005-2009 and 2010-2014.

Given the time-lagged nature of S/T data, the above key question cannot be addressed directly and unambiguously. Instead, a series of derivative research questions have been addressed that provide partial answers:

- *which technology areas exhibit high-growth rates in terms of S/T linkages? This trend analysis compares: 2005-2009 vs 2000-2004 and 2010-2014 vs 2005-2009.*

- *are there processes of S/T strengthening, where some scientific disciplines are becoming increasingly important, or intertwined, with technological development? This trend analysis compares: 2005-2009 and 2010-2014.*

- *which technology areas exhibit processes of S/T broadening or S/T narrowing, where an increasing or decreasing diversity of scientific disciplines are becoming major contributors of technological development? And what are the details in the case of 'Artificial Intelligence technology'.*

Generating an overview of general patterns and trends, the macro-level citation data were analysed for two geographical areas: (1) OECD area, covering the club of world's most advanced economies; (2) European Union (EU28) area, representing the European continent. The findings are compared to identify significant differences between Europe and globally.

Science/Technology links: patterns and trends in the OECD area

- *Four technology areas exhibit domains where S/T linkages have increased rapidly between 2000-2004 to 2005-2009: 'Nanotechnology'; 'Imaging and sound technology - imaging technique'; 'Imaging and sound technology - sound technique'; 'Large-capacity and high speed storage'. In the majority of the fast-growth scientific disciplines are either 'Energy science and technology', or 'Environmental sciences and technology'. Both disciplines seem to have strengthened their contribution to 'Nanotechnology' between 2000-2004 and 2005-2009. Very few other domains are found where S/T strengthening occurred.*

- *The number of disciplines involved in S/T broadening processes has increased. These where found mainly in the medical/health/life sciences domains, whereas S/T narrowing tended to occur in natural sciences, engineering sciences and computer science.*

- *The technology area of 'Security - Electronic payment' is interesting. It shows significant changes between 2005-2009 and 2010-2014, where 'Agriculture and food science' increased its share of S/T links from 2% to 6%, 'Basic life sciences'(from 2% to 6%) and chemistry and chemical engineering (from 3% to 7%). The two largest scientific disciplines of this technology area remain the* *same: 'Computer science' (28% in 2010-2014) and 'Electronic and electrical engineering' (21%).*

- *As for S/T narrowing, here we find several disciplines in decline as major contributor: 'Biomedical sciences'; 'Electrical engineering and telecommunications'; 'Mechanical engineering and aerospace'; and 'Physics and materials science'. The latter two disciplines have lost further ground since 2011.*

- *'Nanotechnology' is one of the dominant technology areas that have become more science-based during the last 15 years.*

- *The technology area of Artificial Intelligence ('AI technology') is marked by large differences between the contributions of disciplines as well as some significant changes over time. The no 1 'enabler' discipline in this area, 'Computer science', has lost ground as a major contributor in favour of 'Chemistry and chemical engineering', 'Biological sciences', and 'Agriculture and food science'. Overall, we observe a gradual shift towards more contributions from chemistry and the life sciences.*

- *The area covering the Internet of Things ('IoT and related technologies') shows a strong concentration of contributions from Electronic and electrical engineering and from Computer science. Together they account for 90% of the S/T links. The share of 'Electronic and electrical engineering' has increased, while 'Computer science' decreased.*

Science/Technology links: patterns and trends in the EU28 area

- *Analysing the changes between 2000-2004 and 2005-2009, no less than 25 technology areas contain at least one fast-growth scientific discipline. Three technology areas are prominent in that respect: 'Industrial biotechnology'; 'Advanced materials'; 'Pharmaceuticals'.*

- *Very few cases are found of S/T strengthening. Overall, the EU28 profile is quite different from the OECD findings. The main similarity between both geographical areas is the significant emergence of 'Energy science and technology' throughout those 15 years, and the rise of 'Environmental sciences and technology' in more recent years. The findings reveal continued strengthening of the links between the technology area 'Macromolecular chemistry, polymer' and the discipline 'Energy science and technology', as well as between 'Industrial biotechnology' and 'Energy science and technology'.*

- *Three technology areas show signs of S/T broadening, one of which is also on the OECD list: 'Large-capacity information analysis - data analysis simulation management'. In contrast, 'Nanotechnology', irrespective of how this area is delineated, is S/T narrowing; the same pattern occurs in the OECD area.*

- *As for the case study of 'Artificial Intelligence', again the data show a gradual decline of 'Computer science', and the rise of 'Chemistry and chemical engineering' and 'Energy science and technology'. However, several new EU28-specific features emerge: the rise of 'Physics and materials science'; the decline of 'Biomedical sciences' and 'Clinical medicine', the rise of 'Instruments and instrumentation'.*

- *The EU28's S/T profile in Internet of Things ('IoT and related technologies') is similarly to the OECD's profile, but with a smaller number of disciplines with a significant low-level contribution.*

Moving towards answers

- *This macro-level exploratory study provides indications of 'structural' changes in knowledge flows between scientific fields and some technology areas, where disciplinary composition of contributing science is changing; key 'enabling' fields are becoming less important, while other fields are on the rise.*

- *Changes seem depend in part on geography-related determinants or geopolitical factors. The many observed (small and large) differences when comparing 'OECD area' and the 'EU area' provide empirical evidence to this effect.*

- *The EU28 profile is quite different from the OECD findings, which requires further studies. Such studies should also be broken down at the level of separate countries (by patent applicant) provided the number of patents is sufficiently large to enable robust and reliable analysis.*

- *Some findings may also relate to possible biases in the information sources. Especially with regards to the patents, which are affected by changes in patenting policies and/or practices of national patent offices. Follow-up studies should distinguish the effects of new or changing patent legislation or IPR practices, or modifications in patent classification systems, from actual changes in technological development and the nature of S/T relationships.*

- *Concluding, this data-rich analytical approach describes macro-level patterns and trends that may help assess the 21st century evolution we are witnessing in S/T interactions and linkages.*

- *However the observed changes in S/T linkage patterns are gradual and extremely difficult to interpret unambiguously. It is impossible to determine whether or not contemporary science, as a whole, has become more important for technological development.*

- *The citation links between research publications and patents provide an information source for in-depth case studies that may help unravel and contextualize the macro-level findings described in this exploratory study.*

- *More work is needed to gain insights in processes. Innovation analysts should dig deeper to understand the specifics of how advances in science impact on technology, and how science-based technology may result in the new generations of innovative products and services. We need to move from the 'what & where' to the 'how & who' questions regarding economic productivity and the role of science and technology.*

1 Introduction

Productivity is expected to be the main driver of economic growth and well-being over the next 50 years, in part via investment in knowledge-based capital and technological innovation. However, findings of recent analyses suggest that innovation-related diffusion processes seem to have slowed down in several advanced economies, hampering their ability to support stronger productivity growth (OECD, 2015a). The slowdown in productivity over the past decade has added to concerns about long-term economic outlook. Understanding how progress in science is connected to technological development is crucial to get a better handle of the drivers and policy levers that can foster science-based innovation in a rapidly changing innovation ecosystems and knowledge-intensive economies.

One area of rising interest is understanding in more detail the role of basic and applied scientific research in driving new emerging technologies and related technological innovations. Science is an important source of novel ideas, tools, materials and prototypes in some areas of advanced technological development. The key question however is whether or not science has become increasingly important in recent technological developments. To address this question, in a broad systematic fashion, one needs to establish a stable frame of reference, appropriate empirical information, and a sufficiently long time-window.

The data analysis methodology is based on observed linkages between patents ('technology') and scientific research publications covered in bibliographic databases (discovery-oriented 'basic science'). The main advantage is availability of comprehensive, long-term and internationally comparable data (OECD, 2016). The next section presents more details on this methodological approach and its data sources.

2 Analytical approach

2.1 Science/Technology linkage data

The large majority of the patents worldwide are filed by business enterprises (a small minority are patents by public sector organisations such as universities).[1] Especially in the case of the R&D-intensive industries, one finds large quantities of patents that mention scientific and technical research literature in their 'prior art' reference lists. These literature references (or 'citations' as they are usually named) reflect the usage or 'impact' of science on technological development. These 'patent-to-publication citations' ('patent citations' for short) represent an explicit link between patented technical inventions ('technology') and published scientific and engineering research ('science'). Depending on the type of technology, a significant share of those citations include research articles in international scientific journals ('research publications').[2]

Figure 1a. Micro-level S/T linkages: patents and research publications

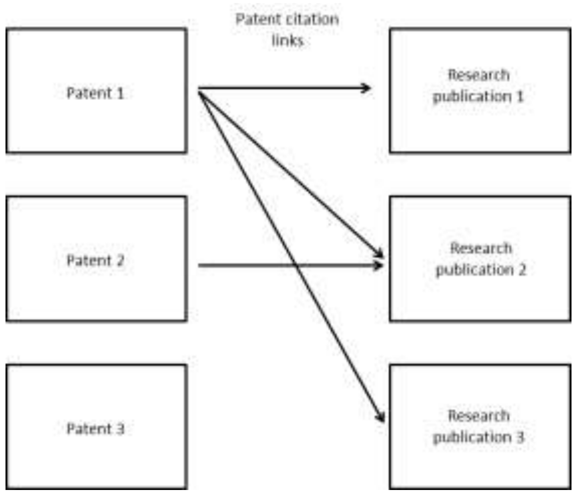

Figure 1a presents a graph of such citation patterns at the micro-level of individual patents and research publications, where the 'science-based' patent 1 cites several scientific research publications (within a specific period of time) while patent 3 has no explicit citation links to any of these three research publications. This illustrative,

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[1] The country of the patent filing business enterprise is not necessarily the same country where the technology was developed or corporate R&D was conducted - especially in the case of large multinationals where patent filing is often centralised in the country of the corporate (R&D) headquarters.

[2] Where each 'citing' patent is assigned to one or more 'technology areas', according to the International Patent Classification (IPC) codes, each 'cited' publication can be classified it its respective 'scientific discipline'. To the extent that such citations are sufficiently numerous, the S/T linkage table allows for a systematic, quantitative assessment of the relationship between the 'citing' technological areas and 'cited' scientific disciplines. The majority of the citing patents relate to two 'science-based' technology domains: computing/electronics and pharmaceuticals/biotechnology. Obviously, these disciplines are skewed towards those fields of science with strong links to these technology areas.

stylized example is limited to 3 documents on both sides. The reality there are millions of patents that cite one or more research publications.

These citation-based S/T linkages can be aggregated on either side of the S/T divide. Figure 1b exhibits the meso-level of patent domains (usually delineated in terms of International Patent Classification system codes assigned to a patent) and research domains (each delineated in terms of a set of scientific journals consisting of research publications). Patent domain 2 cites three domains but its strongest citation linkages are with research domain 2. Again, some patent 'science-extensive' domains may have no citations to research domains – see patent domain 3. Note that both selected types of delineation are one of several possible options to define domains.

The domains were further aggregated to the macro-level of 'technology area' and 'scientific discipline' (see Graph 1c). The terminology and associated delineations were decided in consultation with the EC and OECD. Here we find strong links between technology area 1 (say, Pharmaceuticals) and scientific discipline 1 (say, biomedical sciences). Technology area 3 cites some disciplines, but at relatively low levels. Also at this high level, some technology areas will include patents that do not cite research publications in specific scientific disciplines. The citation links can also be interpreted from the science side, where scientific discipline 2 has the broadest range of S/T links, covering three technology areas. Scientific discipline 1 is only cited by one area.

Figure 1b. Meso-level S/T linkages: patent domains and research domains

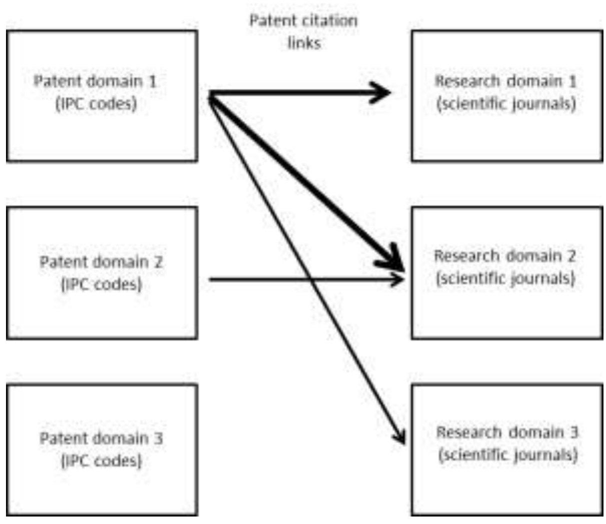
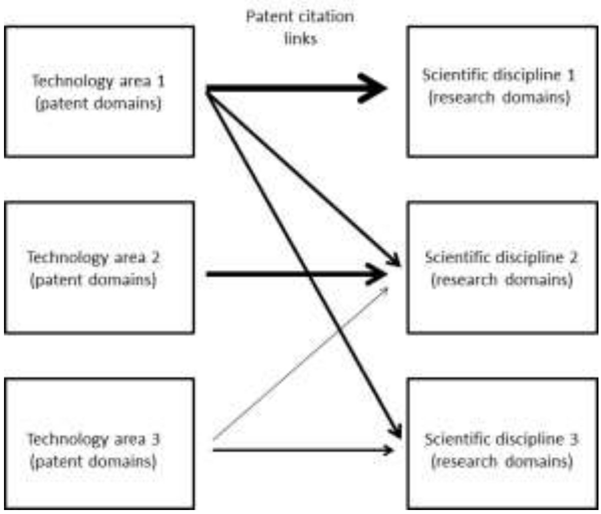


Figure 1c. Macro-level S/T linkages: technology areas and scientific disciplines



The S/T linkage data-analysis in this report will be at the macro-level, in the analytical tradition of many other studies of this kind that have been conducted during the last two decades.

Using the patent citations and citation frequency counts as an analytical lens, the results of various macro-level cases studies seem to imply that contributions of basic science in supporting the development of industrial innovations has been increasing – at least in volume - over the past two decades (see for example: Narin et al. 1997; Tijssen et al., 2000; Callaert et al., 2012; Ahmadpoor & Jones, 2017; Ranaei et al., 2017; Wang & Li 2018; Jefferson et al., 2018). However, inevitably patent-based analysis can only provide a 'blurred and partial' lens on the nature and intensity of S/T linkages (e.g. Funk, 2018).

The disciplinary origin of the contributing science is an important factor in influencing the pattern and intensity of knowledge transfer from technologies (McMillan et al. 2000; Bekkers and Bodas Freitas 2008). However, many other data-related factors or external determinants may have affected the numbers of citation frequencies; clearly further studies are required to ascertain the reliability and validity of those findings.

The main analytical goal is produce a series of data arrays ('S/T linkage tables') that connect technology areas to scientific disciplines. Each S/T linkage table consists of an array of pairwise data cells ('S/T pairs'), where each pair consists of a cited discipline and citing area. Each cell contains numerical information on the strength of the S/T link between the respective discipline and area. Citations to publications in journals that are assigned to multiple research domains and scientific disciplines will be counted as one link for each discipline. Similarly, patents spanning several technology domains and areas are also counted more than once in case of multiple occurrences.

2.2 *Technology areas and scientific disciplines*

The S/T linkage analysis is done at the level of 41 'technology areas' as presented in Table 1. Each area was delineated in terms International Patent Classification (IPC) codes. See Appendix A for details. Three variants of two areas (Industrial Biotechnology; Nanotechnology) were analysed to assess possible effects of slightly different delineations.

The science side of the S/T linkage table comprises of 35 'scientific disciplines' as developed by CWTS (Leiden University) – see Table 2. The selection includes STEM disciplines (Science, Technology, Engineering, Mathematics) as well as non-STEM disciplines in the social sciences and humanities. These disciplines are based on Clarivate Analytics' Journal Subject Categories, an internationally-used stable system with some 260 'subdisciplines', each containing a large set of scientific and technical journals (usually in the hundreds).

Some of these disciplines are far more likely to contribute to technological development that others. The share of the various technology areas and scientific fields in the S/T linkages is shown in subsection 3.1.

Table 1. Selected technology areas

TECHNOLOGY AREA	SUB-AREA	DELINEATION*
Nanotechnology		a; b; c
Industrial biotechnology		a; b; c
Photonics		a
Advanced materials		a
Micro- and nanoelectronics		a
Advanced manufacturing technologies		a
Chemical engineering		b
Computer technology		b
Digital communication		b
Environmental technology		b
Food chemistry		b
Optics		b
Pharmaceuticals		b
Macromolecular chemistry, polymers		b
AI technology		c
High speed network	digital communication technique	c
	exchange, selecting	c
	others	c
Mobile communication security	cyphering, authentication	c
	electronic payment	c
Sensor and device network	sensor network	c
	electronic tag	c
	others	c

High speed computing		c
Large-capacity and high speed storage		c
Large-capacity information analysis	database	c
	data analysis, simulation, management	c
Cognition and meaning understanding		c
Human interface		c
Imaging and sound technology	imaging technique	c
	sound technique	c
Information communication device	electronic circuit	c
	cable and conductor	c
	semiconductor	c
	optic device	c
	others	c
IoT and related technology		c
Electronic measurement		c
Others	computer input-output	c
	other related technique	c
Robotics and autonomous systems		c

* Source of delineation: (a) EC concordance table; (b) WIPO concordance table; (c) OECD concordance tables.

Table 2. Selected scientific disciplines

STEM DISCIPLINES	***NON-STEM DISCIPLINES***
Agriculture and Food Science Astronomy and Astrophysics Basic Life Sciences Basic Medical Sciences Biological Sciences Biomedical Sciences Chemistry and Chemical Engineering Civil Engineering and Construction Clinical Medicine Computer science Earth Sciences and Technology Electrical Engineering and Telecommunication Energy Science and Technology Environmental Sciences and Technology General and Industrial Engineering Health Sciences Instruments and Instrumentation Mathematics Mechanical Engineering and Aerospace Physics and Materials Science	Creative Arts, Culture and Music Economics and Business Educational Sciences History, Philosophy and Religion Information and Communication Sciences Language and Linguistics Law and Criminology Literature Management and Planning Political Science and Public Administration Psychology Social and Behavioral Sciences - Interdisciplinary Sociology and Anthropology Statistical Sciences ***Other:*** Multidisciplinary journals*

* General journals with a multidisciplinary content (e.g. *Nature*, *Science*, *PNAS*, etc.)

2.3 Data sources

Information on citing patents and cited publications is derived from databases at CWTS (Leiden University, Netherlands). The patents are extracted from the PATSTAT database, where only PCT/WIPO patents are selected thus creating a 'level playing field' to compare countries and geographical areas worldwide (the patents filed/granted in national patenting systems are removed). Our analysis relates to 'PCT patent families' only in order to remove duplicate patents; such a family consists of at least one PCT patent (among patents filed at other patent systems).

The research publications are extracted from the Clarivate Analytics owned and CWTS-licensed Web of Science (WoS) database, more specifically the Science Citation Index Expanded, Social Sciences Citation Index and Arts & Humanities Citation Index. As with patents, publication data are a fairly well-developed metric (comprehensive, long-term and internationally comparable data). See Appendix B for more technical information on how these two databases were matched in order to conduct S/T linkage analyses.

Having linked PATSTAT to the WoS, the CWTS 'Science/Technology information system' contains some 1.7 million unique micro-level citations at the level of individual (PCT) patents and cited WoS-indexed publications.3 The derivative, aggregate-level 'S/T pairs' relate to the number of patents in a citing technology area that are linked to a cited scientific discipline.

2.4 Trends analysis: methodology and presentation

In the line with the primary research question (is recent technological development benefitting more from science?), the analysis of S/T pairs is done from the perspective of citing patents and their related technology areas.

The trend analysis of 21st century S/T linkages comprise of three successive 5-year periods: 2000-2004, 2005-2009 and 2010-2014. Discerning patterns across these three year-blocks provides empirical evidence on how patented technologies interrelate to published scientific research and – by assumption - technological development is benefitting from scientific progress. This year-block approach captures 'structural' trends and avoids an emphasis on chance findings that emerge from volatile (bi)annual changes.

The data analysis compares two supranational geographical regions: 'OECD area' and EU28 area'. In each case, a patent is assigned to that area if it mentions at least one

[3] Many of those patents are cited subsequently by other patents. Large quantities of these 'forward citations' indicate the degree to which a citing patent in an S/T pair represents a 'highly cited' technological development. The same applies to the research publications: the extent to which it is cited in science by other publications may indicate a highly cited scientific breakthrough. Applying this 'highly cited' approach enables measures of 'R&D excellence' to compare countries and universities in terms of their level science-based innovativeness (Tijssen and Winnink, 2017). The countries and universities that produce the science that is cited in the world's most highly cited patents, tend to be research powerhouses of new inputs for advanced technological development.

country from that area in the address list of the patent applicants.4 The comparative results, presented in the next section of the report, will start with the OECD area, representing 'worldwide' S/T Linkage patterns, followed by the same set of outputs for the EU28 area, which represented 'European' S/T Linkage patterns. Significant differences between both areas will be highlighted in the accompanying text. The tables with the main findings will be numbered pairwise.

Most of the analysis relates to the S/T linkage patterns and trends – either at the level of citing technology areas, cited scientific disciplines, or individual S/T pairs. The computational analysis does not deal with the increases in absolute numbers of patent citation occurrences, which – because of the nature of the data – tend to decline significantly as one moves nearer to the present, but rather of changes in relative sense.

The rate of decline is taken as an S/T linkage indicator in the first trend analysis: 2005-2009 versus 2000-2004. S/T pairs with relatively low rates of decline (or even growth), in spite of overall decline across all areas and disciplines, are seen as becoming more strongly linked. Moving towards the present-day situation, a systematic comparative analysis of patent citation frequency data breaks down because of the low absolute numbers involved. What remains is a comparison of relative shares – the contribution of a scientific discipline to all disciplines cited by patents. If the share goes up, one may assume that – relatively speaking – that discipline has become more relevant for technological development. This S/T strengthening' analysis is presented in subsection 3.1.

The other part of the trend analysis captures general patterns across all three time-periods, by extracting data from two distributional processes within the portfolio of cited scientific disciplines per technology area. This analysis involves 'S/T broadening', where an increasing diversity of disciplines are becoming a major contributor to an area, or 'S/T narrowing' where the reverse happens (see subsection 3.2).

2.5 Cautionary notes

With S/T linkages now expressed in terms of these S/T pairs and the frequency of citation occurrence counts, it is technically feasible to gain some insight into longer-term trends in the relationships between science and technology. By looking at general trends that emerged in the early 2000s, that may have persisted in the recent past, it is possible to detect patterns that are likely to have continued up until the recent past.

However, these data should be handled with care. The analytical power of S/T linkage analysis is subject to several caveats and disclaimers. Particular attention shall be paid to the following inherent biases in patent and research publication data:

[4] The scarcity of the S/T linkage data, especially in the 2010-2014 period, prevents a reliable and meaningful analysis at the level of the individual countries, with the exception of the world's largest nations.

- Patents and research publications are both proxies; of technological development and scientific research respectively. Hence, one should be cautious when interpreting the data and drawing strong conclusions with regards to specific cells in the data table. Hence, data analysis should focus on identifying general patterns and trends.

- Rows, columns or cells in a S/T linkage tables may suffer from low frequency counts. Small changes, from year to year or across time-periods, may lead to significant but nonsensical growth/decline rates. The statistics can easily become unreliable. A robust analysis of trends should take this caveat into account; implementing lower thresholds for S/T linkages removes S/T pairs with insignificant numbers of patent citation occurrences which may also have occurred because of database biases or small-scale chance events.

- Not all science-related technological developed are (adequately) covered by patents, especially in technology areas that benefit only indirectly from 'basic' discovery-oriented science. In many cases the scientific inputs are from 'applied science' or from engineering research. The latter inputs are usually difficult to detect in patent reference lists because the associated publications cannot be matched to large international bibliographical databases such the Web of Science or Scopus. STEM disciplines are much better represented in the research literature cited by patents, due to the nature of technological development and the technologies that are protected by patents.

Focussing on the analysis of 21st century S/T trends, the key issue driving this analysis and the focus of this report, patent citation data come with several important restrictions:

- Not all science-related technological developments are (adequately) covered by patents, especially in technology areas that benefit only partially or indirectly from science.

- The research publications cited in patents and indexed in the Web of Science database tend to reflect 'basic' discovery-oriented or curiosity-driven research. Application-oriented research and applied (engineering) research are underrepresented.

- The collected empirical data on relationships and links between technology and science are time-dependent; as one moves to the current year the number of citations in patents to research publications declines rapidly because of 4 or 5-year time-delays in knowledge transfer and utilization processes, which constrains longitudinal analysis up until recent years (the time-window for reliable trend analyses closes, effectively, around 2013 or 2014).

3 Main empirical findings

3.1 Distribution of S/T links across technology areas and scientific disciplines

Collecting all patent citations across the 15-year time-period, Table 3 presents the percentage share of each technology area in the total number of patents citing the scientific research literature.5 Pharmaceuticals and Industrial biotechnology account for almost half of these S/T links. The other relatively large areas are: Advanced Manufacturing Technologies; Computer technology; Micro and nanoelectronics; Information communication device- Semiconductor; and Advanced materials. The 'Biopharmaceuticals' sector and 'Electronics/Semiconductors' sector account for three-quarters of all links between patented technologies and published science. The Chemicals sector is the third major sector (Chemical engineering; Food chemistry; Macromolecular chemistry, polymers). A split is made between the shares within patents from countries in the OECD area and those from EU28 member states. The results highlight some significant differences between the global and European distribution, notably the much larger share of Industrial biotechnology in Europe.

Table 4 exhibits the breakdown from the perspective of the cited scientific disciplines. The top seven disciplines also account for 80% of the S/T links, mirroring the above three sectors: Biopharmaceuticals (Basic life sciences; Biomedical sciences; Clinical medicine; Basic medical sciences); Electronics/Semiconductors (Physics and materials science; Electrical engineering and telecommunication; Computer sciences); Chemicals (Chemistry and chemical engineering; Agriculture and food science). The EU28 has a relatively large share of science links related to the Biopharmaceuticals and Chemicals.

Table 3. Share of technology areas in S/T linkages, 2000-2014 (%)

	OECD	EU28
Pharmaceuticals	22.67	23.27
Industrial biotechnology (EC delineation)	22.41	38.23
Advanced Manufacturing Technologies	5.76	3.47
Computer technology	5.16	3.69
Micro and nanoelectronics	4.07	2.26
Information communication device - semiconductor	3.57	1.89
Advanced materials	3.42	2.91
Imaging and sound technology - imaging technique	2.94	1.47
Chemical engineering	2.71	2.79
Food chemistry	2.61	2.79
Macromolecular chemistry, polymers	2.15	2.03
Photonics	1.90	1.29
Large-capacity information analysis - data analysis simulation management	1.88	1.19

[5] To compute these shares two of the three delineations of 'Industrial biotechnology' and 'Nanotechnology' (WIPO, EC and OECD) were removed. Somewhat arbitrarily the EC delineation was kept for calculations. Sensitivity analysis, i.e. removing either one of the three delineations, has no significant effects on the outcome.

Human interface	1.81	1.18
Optics	1.80	1.34
High speed network - digital communication techniques	1.65	1.33
Cognition and meaning understanding	1.60	1.32
Digital communication	1.27	1.27
Nanotechnology (EC delineation)	1.13	0.65
High speed computing	1.07	0.25
Information communication device - optic device	0.90	0.59
Environmental technology	0.89	1.01
Large-capacity and high speed storage	0.78	0.21
High speed network - others	0.73	0.40
AI technology	0.71	0.25
IoT and related technology	0.60	0.45
Others - other related techniques	0.60	0.20
Mobile communication	0.52	0.50
Large-capacity information analysis - database	0.50	0.26
Information communication device - others	0.35	0.21
Electronic measurement	0.35	0.31
Security - Cyphering authentication	0.34	0.25
Information communication device - electronic circuit	0.32	0.16
Imaging and sound technology - sound technique	0.26	0.26
Sensor and device network - electronic tag	0.14	0.06
High speed network - exchange selecting	0.12	0.10
Sensor and device network - sensor network	0.11	0.07
Security - electronic payment	0.08	0.04
Others - computer input output	0.06	0.01
Sensor and device network - others	0.05	0.00
Robotics and Autonomous Systems	0.04	0.04

Table 4. Share of scientific disciplines in S/T linkages, 2000-2014 (%)

	OECD	EU28
Basic life sciences	16.22	16.97
Physics and materials science	13.13	9.07
Chemistry and chemical engineering	12.83	13.77
Biomedical sciences	11.92	15.29
Clinical medicine	11.06	13.45
Electrical engineering and telecommunication	10.35	6.33
Computer sciences	6.34	4.37
Multidisciplinary journals	4.71	4.23
Basic medical sciences	3.37	5.79
Biological sciences	2.40	2.37
Agriculture and food science	1.97	2.55
Instruments and instrumentation	0.93	0.90
Energy science and technology	0.91	1.17
Environmental sciences and technology	0.73	0.97

Mechanical engineering and aerospace	0.71	0.59
Earth sciences and technology	0.62	0.50
General and industrial engineering	0.39	0.33
Health sciences	0.31	0.47
Mathematics	0.26	0.21
Statistical sciences	0.25	0.18
Psychology	0.13	0.15
Civil engineering and construction	0.11	0.11
Information and communication sciences	0.08	0.03
Economics and business	0.06	0.02
Management and planning	0.05	0.01
Law and criminology	0.04	0.05
Educational sciences	0.03	0.02
Astronomy and astrophysics	0.02	0.03
Language and linguistics	0.02	0.01
Sociology and anthropology	0.01	0.01
Social and behavioral sciences - interdisciplinary	0.01	0.01
Creative arts, culture and music	0.01	0.01
History, philosophy and religion	0.01	0.01
Political science and public administration	0.01	0.00
Literature	0.00	0.00

3.2 Trends analysis – part 1: S/T strengthening

3.2.1. Patterns and trends in the OECD area

As a result of inherent time-lags in patenting procedures and delays in knowledge dissemination processes, the total number of citations from patents to STEM scientific disciplines declines as we approach the current era. This 'attrition rate' is quite high within the OECD area, where the number of patents that cite scientific research almost halved from 1.974.586 in the years 2000-2004 to 1.062.045 in 2005-2009, and dropped further still to 325.726 in 2010-2014.

As the total number of S/T links within the OECD area having declined by almost 50% between the first two periods, any S/T pair with a significant positive growth rate in 2005-2009, relative to the number of citation links in 2000-2004, is considered a 'fast-growth' pair. Adopting a more stringent criterion, set at 50% growth of the 2000-2004 level, and applying lower threshold of at least 50 patent citations per S/T pair in 2005-2009, only four technology areas contain 'fast-growth' scientific discipline in terms of citation increase: Imaging and sound technology - imaging technique (20 disciplines); Nanotechnology - all three delineations (3 disciplines); Imaging and sound technology - sound technique (1 discipline); Large-capacity and high speed storage (1 discipline). The S/T pair with the largest growth rate (127%) is patents in the area Imaging and sound technology - imaging technique which is citing research in Civil Engineering and Construction.

Further analysis is required to ascertain the reasons for this outcome. Why, for example, only these four areas? And what explains the remarkable position of

Imaging and sound technology - imaging technique. An in-depth follow-up study should distinguish the effects of possible modifications in patenting legislation, IPR practices, or patent classification systems from actual changes in S/T relationships. Table 5 lists the S/T pairs mentioned above in the OECD area, the majority of which are concentrated in just two technology areas: Imaging and sound technology - imaging technique; Nanotechnology. On the science side, Energy science and technology is prominent.

The analysis of noticeable trends between 2005-2009 and 2010-2014 is restricted to those technology areas cases where at least one scientific discipline became significantly more important as compared to other disciplines. More specifically, where the 'strength' of the S/T pair - the share of a scientific discipline in the total number of patent citations from a technology area - increased by more than 50%. For example, an increase from a 2% share to 3%, or from 10% to a 15% share. Again, the analysis is anchored to sizeable S/T pairs with at least 50 citations in 2010-2014.

A total of 23 S/T pairs meet these two selection criteria – see Table 6 for the OECD area.6 Again, more than half of these 'relative' fast grower pairs are concentrated in Energy science and technology, and in Environmental sciences and technology; 18 cases in all. The rise of these two disciplines in technological development, indicated in the previous subsection, has continued in more recent years. The third domain on the rise is Instruments and instrumentation. The vast majority of these pairs have growth rates between 50% and 100%. The largest growth rates, more than a doubling, occurred in three cases: Environmental sciences and technology/Information communication device – semiconductor, and Environmental sciences and technology/Micro and nanoelectronics, Electrical engineering and telecommunication/Sensor and device network - electronic tag.

Table 5. Selected high-growth technology areas between 2000-04 and 2005-09: OECD area*

TECHNOLOGY AREA	SCIENTIFIC DISCIPLINE
Imaging and sound techn. - imaging technique	Agriculture and food science
	Basic life sciences
	Basic medical sciences
	Biological sciences
	Biomedical sciences
	Clinical medicine
	Basic medical sciences
	Chemistry and chemical engineering
	Civil engineering and construction
	Computer science
	Electrical engineering and telecommunication
	Energy science and technology

[6] The three delineations of 'Nanotechnology' and of 'Industrial Biotechnology' are counted as a single area.

	Environmental sciences and technology
	Earth sciences and technology
	General and industrial engineering
	Instruments and instrumentation
	Mechanical engineering and aerospace
	Mathematics
	Statistical sciences
	Psychology
Nanotechnology (all three delineations)	Energy science and technology
	Environmental sciences and technology
	General and industrial engineering
Imaging and sound techn. - sound technique	Chemistry and chemical engineering
Large-capacity and high speed storage	Energy science and technology

*** Data analysis parameters: countries in the OECD area; 2005-2009 vs 2000-2004; S/T pairs with minimum of 50 patent citations in 2005-2009.**

Have some scientific disciplines becoming increasingly important for a particular technological area? The large observed growth rates suggest processes of 'S/T strengthening', where scientific disciplines that are becoming increasingly intertwined with a particular technological area. Such a case of S/T strengthening is operationalized here in terms of increasingly large share of patent citations since the years 2000-2004. Comparing the lists of S/T pairs in tables 5 and 6, only one pair hints of such a possible process: we find that both Energy science and technology, and Environmental sciences and technology have increased their presence as contributing knowledge-production domains to Nanotechnology patents. The contribution increased by 50-60% between 2000-2005 and 2005-2009. But that share was still at very low level: between 1 and 2% in 2005-2009. The latter period, in 2010-2014, saw further growth (see Table 6), but clearly the contribution of these two is still small compared to the two dominant disciplines that contribute most to Nanotechnology: Chemistry and chemical engineering, and Physics and materials science (both with 30-35% shares of the total).

Table 6. High-growth S/T pairs between 2005-2009 and 2010-2014: OECD area*

TECHNOLOGY AREA	SCIENTIFIC DISCIPLINE
Advanced manufacturing technologies	Energy science and technology
Advanced materials	Energy science and technology
AI technology	Agriculture and food science
	Physics and materials science
Cognition and meaning understanding	Instruments and instrumentation
Digital communication	Instruments and instrumentation
Electronic measurement	Instruments and instrumentation
Food chemistry	Energy science and technology
High speed network - digital comm. techniques	Instruments and instrumentation
High speed network - exchange selecting	Physics and materials science

High speed network - others	Instruments and instrumentation
Human interface	Instruments and instrumentation
Industrial biotechnology (all three delineations)	Energy science and technology
Information communication device – semiconductor	Energy science and technology
Large-capacity information analysis - database	Chemistry and chemical engineering
Macromolecular chemistry, polymers	Energy science and technology
	Environmental sciences and technology
Micro and nanoelectronics	Energy science and technology
	Environmental sciences and technology
Nanotechnology	Energy science and technology
	Environmental sciences and technology
Optics	Basic medical sciences
Sensor and device network - electronic tag	Energy science and technology

*** Data analysis parameters: countries in the OECD area; 2005-2009 vs 2010-2014; S/T pairs with minimum of 50 patent citations in 2005-2009.**

3.2.2 Patterns and trends in the EU28 area

The decline in number citations from patents to STEM research publications is less dramatic in the case of the European Union, where the total dropped from 194.321 in 2000-2004 to 178.574 in 2005-2009, and down to 84.748 in 2010-2014. Clearly the EU area is subject to a much less severe attrition process as compared to the steep decline observed in the OECD area.[7]

Although the total number of S/T links within the EU28 have declined by only 11% between the first two periods, the same selection criterion is adopted as in the previous analysis of the OECD area: only those S/T pairs are taken into consideration if they exhibit a 50% growth rate between 2000-2004 and 2005-2009, and consist of at least 50 patent citations in 2005-2009. In the case of the EU28 one finds no less than 25 technology areas that contain at least one fast-growth scientific discipline. The following four areas have 4 or more of those fast-growers: Industrial biotechnology – OECD delineation (5 disciplines); Advanced materials (4 disciplines); Pharmaceuticals (4 disciplines); Industrial biotechnology – WIPO delineation (4 disciplines). The S/T pair with the largest growth rate (216%) is the technology area 'Industrial biotechnology – OECD delineation' citing research in 'Energy Science and Technology'.

[7] Over time, the relative quantity of citing patents from the EU28 countries has, as compared to the OECD total, steadily increased: from 9% in 2000-2004 to 24% in 2010-2014. A comprehensive explanation for this growth requires further research, which is beyond the scope of this exploratory study.

Covering all technology areas, contrary to the OECD analysis in Table 5, Table 7 lists the S/T pairs with growth rates of 75% or more. The overview shows a diversity of technology areas and disciplines. Some scientific disciplines have become more prominent as cited sources - three scientific disciplines in particular: Energy science and technology; Mechanical engineering and aerospace; Basic life sciences.

Table 7. High-growth S/T pairs between 2000-04 and 2005-09: EU28 area*

TECHNOLOGY AREA	SCIENTIFIC DISCIPLINE
Advanced manufacturing technologies	Mechanical engineering and aerospace
Advanced materials	Mechanical engineering and aerospace
	Physics and materials science
Chemical engineering	Mechanical engineering and aerospace
Cognition and meaning understanding	Earth sciences and technology
Electronic measurement	Computer science
Environmental technology	Agriculture and food science
Food chemistry	Energy science and technology
Industrial biotechnology (all three delineations)	Energy science and technology
Industrial biotechnology (two delineations)	Basic medical sciences
Information communication device - semiconductor	Energy science and technology
Macromolecular chemistry, polymers	Energy science and technology
Nanotechnology (all three delineations)	Basic life sciences
Optics	Basic life sciences
Nanotechnology (all three delineations)	Chemistry and chemical engineering
Nanotechnology (OECD delineation)	Physics and materials science
Pharmaceuticals	Agriculture and food science
	Computer science

*** Data analysis parameters: countries in the EU28 area; 2005-2009 vs 2000-2004; S/T pairs with minimum of 50 patent citations in 2005-2009.**

Extending the trend analysis to changes between 2005-2009 and 2010-2014, Table 8 compares the last pair of time-periods. Similarly to the OECD case, the analysis is restricted to those technology areas where the 'strength' of the S/T pair (share of a scientific discipline in the total number of patent citations from a technology area) increased by 50% or more. Eight S/T pairs meet these two selection criteria.

As in the OECD area, more than half of these fast grower pairs are concentrated in Energy science and technology, and in Environmental sciences and technology. Only Energy science and technology has continued to rise in more recent years. The vast majority of these pairs have growth rates between 50% and 100%. The largest growth rate, more than a doubling (110%), happened in the pair Macromolecular chemistry, polymers/Energy science and technology.

Table 8. High-growth S/T pairs between 2005-2009 and 2010-2014: EU28 area*

TECHNOLOGY AREA	SCIENTIFIC DISCIPLINE
Advanced materials	Environmental sciences and technology
Cognition and meaning understanding	Basic life sciences
Environmental technology	Agriculture and food science
Food chemistry	Energy science and technology
Industrial biotechnology (all three delineations)	Energy science and technology
	Environmental sciences and technology
Macromolecular chemistry, polymers	Energy science and technology
	Environmental sciences and technology

*** Data analysis parameters: countries in the OECD area; 2005-2009 vs 2010-2014; S/T pairs with minimum of 50 patent citations in 2005-2009.**

Overall, the EU28 ‘S/T strengthening’ profile is quite different from the OECD findings. There are some similarities of course (since several EU members are also OECD member): the significant emergence of Energy science and technology throughout those 15 years, and the rise of Environmental sciences and technology in more recent years. The findings reveal continued strengthening of the links between Macromolecular chemistry, polymer and Energy science and technology, as well as between Industrial biotechnology and Energy science and technology.

3.3 Trends analysis – part 2: S/T broadening or S/T narrowing

3.3.1 Introduction

As emerging technologies start to mature, some may increase their technical complexity or broaden their scope of application. Such processes may result in a growing need for a diversity of inputs from scientific research. Some technologies may require innovative, interdisciplinary research. In those cases one would expect to see a larger number of scientific disciplines being cited in patents as years go by. Conversely, some maturing ‘specialised’ technologies may develop trajectories where their existing ‘core disciplines’ become increasingly important, while other ‘fringe disciplines’ gradually fade away as contributors.

Take for example the four technology areas in Table 3a that show increased activity in multiple scientific disciplines: AI technology has increasingly tight links to Agriculture and food science, and to Physics and materials science. Three other areas (Macromolecular chemistry and polymers, Micro and nanoelectronics, and Nanotechnology) share increasing contributions from Energy science and technology, and from Environmental sciences and technology. Has science-based technological development in these cases become more ‘broader’ in terms of their science base? Is that source of information becoming more ‘multi-disciplinarity’ or ‘cross-disciplinarity’?

A close look at the disciplinary distribution of citations by the patents of a technological area may reveal interesting clues about such 'S/T broadening' effects. To address this issue, the trend analysis examined such changes across the three time-periods (2000-2004, 2005-2009 and 2010-2014). The measurement method counts the number of 'major cited scientific disciplines' per citing technology area, that is those STEM disciplines take account for at least 5% of the S/T links per area and per time-period.

S/T broadening then entails an increasingly large number of such 'major' scientific disciplines. Starting from the baseline in 2000-2004, technology areas characterised by S/T broadening would exhibit consistent significant growth of disciplines in 2005-2009 and/or 2010-2014, where 'consistent significant growth' is operationalised as having at least two major disciplines more than the 2000-2004 benchmark value. Conversely, those technology areas affected by 'S/T narrowing' show a declining number of citing disciplines.

3.3.2 Patterns and trends in the OECD area

Table 9 presents the list of technology areas where either process has occurred within the OECD area, along with the number of associated STEM disciplines per time period. Interestingly, we find similar levels of broadening and narrowing across all technology areas. The number of scientific disciplines involved in broadening processes has increased. Where the 2000-2004 period consisted of nine major contributing scientific disciplines, the number went up to 10 in 2005-2009, and further increased to 13 in 2010-2014. Note that the disciplines involved in broadening where found mainly in the medical/health/life sciences domains, whereas narrowing tends to occur in natural sciences, engineering sciences and Computer science.

Comparing the 2000-2004 and 2005-2009 data we find three new entrants: Clinical medicine (in the technology area 'Human interface'), Environmental sciences and technology (in Chemical engineering), Physics and materials science (in 'Large-capacity information analysis - data analysis simulation management' and in 'Digital communication'). As for changes between 2005-2009 and 2010-2014, 'Security - Electronic payment' presents an interesting case with increases in Agriculture and food science (from 2% to 6% in 2010-2014), Basic life sciences (from 2% to 6%) and chemistry and chemical engineering (from 3% to 7%). The two largest scientific disciplines of this technology area remain the same: Computer science (28% in 2010-2014) and Electronic and electrical engineering (21%).

As for S/T narrowing trends within the OECD, also afflicting six technology areas, here we find six scientific disciplines 'in retreat' as major contributors and being replaced by other scientific disciplines. While Chemistry and chemical engineering gained importance in some technology areas during the period 2001-2010, the share of several other disciplines declined: Biomedical sciences; Electrical engineering and telecommunications; Mechanical engineering and aerospace; and Physics and materials science. Since 2011, the latter two disciplines have lost further ground.

Table 9. Technology areas engaged in S/T broadening or S/T narrowing: OECD area*

	NUMBER OF MAJOR CITED SCIENTIFIC DISCIPLINES		
	2000-2004	2005-2009	2010-2014
S/T broadening:			
Large-capacity information analysis - data analysis simulation management	6	7	7
Sensor and device network - electronic tag	6	6	7
Security - electronic payment	2	3	6
Chemical engineering	3	4	5
Human interface	4	5	5
Digital communication	2	3	3
S/T narrowing:			
Sensor and device network - sensor network	3	2	2
Macromolecular chemistry, polymers	4	3	3
Nanotechnology (all three delineations)	4	3	3
Advanced manufacturing technologies	5	4	4
Imaging and sound technology - sound technique	5	5	4
Electronic measurement	7	7	6

*** Data analysis parameters: countries in the OECD area; major cited scientific disciplines with a share of at least 5% per technology area; STEM disciplines only.**

3.3.3 Patterns and trends in the EU28 area

The EU28 overview in Table 10 shows much less technology areas engaged in broadening or narrowing. Patents from Europe seem to be less dynamic (volatile?) in terms of their changing citation links to science. Of the three technology area that show signs of broadening, one is also on the OECD list (see Table 7): Large-capacity information analysis - data analysis simulation management. Nanotechnology, irrespective of how this area is delineated, is narrowing; the same pattern occurs in the OECD area.

Table 10. Technology areas engaged in S/T broadening or S/T narrowing: EU28 area*

	NUMBER OF MAJOR CITED SCIENTIFIC DISCIPLINES		
	2000-2004	2005-2009	2010-2014
S/T broadening:			
Large-capacity information analysis - data analysis simulation management	6	8	9
Cognition and meaning understanding	4	6	6
Robotics and autonomous systems	3	4	5
S/T narrowing:			
Nanotechnology (WIPO delineation)	6	5	3
Nanotechnology (EC delineation)	6	4	3
Nanotechnology (OCED delineation)	5	3	3

*** Data analysis parameters: countries in the EU28 area; major cited scientific disciplines with a share of at least 5% per technology area; STEM disciplines only.**

The most remarkable outcome are the two technology areas (Cognition and meaning understanding, Robotics and autonomous systems) where Europe differs from worldwide trends. Comparing 2000-2004 to 2005-2009 in the case of Cognition and meaning understanding, the two new scientific disciplines represent minor increases in relevance: Clinical Medicine (from 4.6% to 6.4%) and Physics and materials science (from 4.6% to 5.3%). As for Robotics and autonomous systems, this area produces low number of citations of research publications in (less than 100 per 5 years) which renders these data unreliable for trend analysis.

3.4 Special case studies

3.4.1 Artificial Intelligence

Artificial Intelligence (AI) is usually defined as the branch of computer science that is concerned with the automation of intelligent behaviour (Luger & Stubblefield, 1993). It is sometimes referred to as machine intelligence; intelligence demonstrated by machines. AI is a research area and a field of technology that creates both software and hardware sophisticated features in order to include virtual artificial agents. 21st century development in AI has experienced a resurgence following concurrent advances in computer power, large amounts of data, and theoretical understanding. As such, advanced AI technologies have become an essential part of the technology industries, helping to solve many challenging problems in computer science.

Looking at those 21st century developments from the perspective of S/T linkages and patent citations from the OECD area, the share of the technology area 'AI technology' in the total number of patents that cite scientific research literature has gradually decreased from 0.78% in 2000-2004, to 0.63% in 2005-2009, to 0.51% in 2010-2014.8 It seems that AI technology is becoming less linked to science, relative to the general worldwide trend across all technology areas, as time progresses. The EU28 picture is different: is shows the same share (around 0.25%) throughout the entire 15 years.

Following the above analytical design (in subsections 3.2 and 3.3), Table 11 summarizes the share of the scientific disciplines in the patent citations from this technology area. The findings, from the OECD area, show large differences between the contributions of disciplines. Some disciplines have lost some ground as a contributor, including the no 1 source: Computer science. Some disciplines seem to have gained importance. Notably Chemistry and chemical engineering, Biological sciences, and Agriculture and food science. But to a lesser extend also: Energy science and technology, and Civil engineering and construction. Overall, there are signs of a gradual shift towards more contributions from the chemistry and the life sciences.

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[8] In the computation of the total number of citing patents, across all technology areas, a choice had to be made with regards to removing delineations of 'Industrial biotechnology' and 'Nanotechnology' (WIPO, EC and OECD). Somewhat arbitrarily the EC delineation was kept for calculations. Sensitivity analysis, i.e. removing either one of the three delineations, has no significant impact on the share of 'AI technology' in the total number of citing patents.

Table 11. S/T broadening or S/T narrowing in 'AI technology': OECD area*

	SHARE OF TOTAL CITING PATENTS		
	2010-2014	2005-2009	2000-2004
Computer science	29.2%	29.5%	36.8%
Electrical engineering and telecommunications	20.2%	18.8%	20.2%
Physics and materials science	7.7%	5.1%	5.3%
Biomedical sciences	6.7%	7.6%	5.3%
Basic life sciences	4.8%	5.0%	4.4%
Chemistry and chemical engineering	4.4%	3.4%	2.7%
Biological sciences	3.4%	2.8%	1.7%
Statistical sciences	2.3%	3.3%	2.3%
Clinical medicine	2.1%	4.0%	3.7%
Agriculture and food science	2.0%	1.1%	0.4%
Basic medical sciences	1.9%	2.4%	2.0%
Instruments & instrumentation	1.3%	1.4%	1.1%
Mathematics	1.3%	1.6%	1.3%
General and industrial engineering	1.2%	1.7%	1.9%
Mechanical engineering and aerospace	1.2%	1.5%	1.4%
Energy science and technology	1.0%	0.7%	0.5%
Civil engineering and construction	0.9%	0.7%	0.3%
Earth sciences and technology	0.8%	1.2%	1.2%
Psychology	0.7%	0.8%	0.8%
Health sciences	0.7%	1.1%	0.7%

* Includes scientific disciplines that account for 0.5% or more in 2010-2014.

Table 12 presents the overview for the EU28 area, with the same gradual decline of Computer science, and the rise of Chemistry and chemical engineering and of Energy science and technology. However, several new features emerge, as compared to the OECD pattern: the rise of Physics and materials science; the decline of Biomedical sciences and of Clinical medicine, the rise of Instruments and instrumentation, and citations to a wider range of non-STEM disciplines in the lower regions of the distribution (Psychology; History, philosophy and religion; Sociology and anthropology). As far as the major contributing disciplines are concerned, the European picture is fairly similar to the OECD counterpart.

Table 12. S/T broadening or S/T narrowing in 'AI technology': EU28 area*

	SHARE OF TOTAL CITING PATENTS		
	2010-2014	2005-2009	2000-2004
Computer science	25.5%	29.4%	34.3%
Electrical engineering and telecommunication	18.6%	20.1%	16.5%
Physics and materials science	11.8%	6.0%	8.7%
Biomedical sciences	5.0%	6.6%	7.2%
Chemistry and chemical engineering	5.0%	4.6%	3.9%
Basic life sciences	3.6%	4.2%	5.2%
Biological sciences	2.7%	2.2%	2.2%
Instruments and instrumentation	2.7%	1.8%	0.9%
Statistical sciences	2.7%	3.3%	1.1%

Earth sciences and technology	2.3%	2.7%	0.4%
Energy science and technology	2.3%	1.1%	0.9%
Mathematics	2.3%	1.5%	1.1%
Basic medical sciences	1.8%	3.3%	3.0%
Civil engineering and construction	1.8%	1.3%	0.4%
Clinical medicine	1.8%	2.0%	3.3%
General and industrial engineering	1.4%	2.7%	1.3%
Environmental sciences and technology	0.9%	1.1%	0.9%
Mechanical engineering and aerospace	0.9%	1.3%	1.5%
History, philosophy and religion	0.5%	0.0%	0.4%
Psychology	0.5%	0.7%	0.9%
Sociology and anthropology	0.5%	0.0%	0.0%

*** Includes scientific disciplines that account for 0.5% or more in 2010-2014.**

3.5 Internet of Things

Internet of Things (IoT) is seen by many as a new paradigm of information networks with the aim of expanding the scope of Web-based services. IoT focusses on interactions and information processing that occur predominantly between physical objects rather than between people. Web-based household appliances are a key example. IoT is at the center of attention in several political and economic debates (European Commission, 2009; OECD, 2015b), owing to its potential to boost business opportunities within and beyond the ICT sector.

Table 13. S/T broadening or S/T narrowing in 'IoT and related technology': OECD area*

	SHARE OF TOTAL CITING PATENTS		
	2010-2014	2005-2009	2000-2004
Electrical engineering and telecommunication	51.5%	49.2%	46.4%
Computer science	36.9%	38.2%	42.0%
Physics and materials science	1.4%	1.7%	2.1%
General and industrial engineering	1.3%	1.2%	0.9%
Instruments and instrumentation	1.3%	0.8%	0.5%
Statistical sciences	1.2%	1.0%	0.9%
Chemistry and chemical engineering	0.8%	0.5%	0.4%
Basic medical sciences	0.6%	0.8%	0.6%
Mathematics	0.6%	0.6%	0.7%
Civil engineering and construction	0.5%	0.2%	0.1%
Language and linguistics	0.5%	0.0%	0.0%

*** Includes scientific disciplines that account for 0.5% or more in 2010-2014.**

The share of the technology area 'IoT and related technology' in the total number of patents that cite scientific research literature has gradually decreased within the

OECD area – from 0.63% during the years 2000-2004 to 0.53% in 2010-2014. 9 In contrast, the share in EU28 area shows a similar degree of stability (around 0.45%) throughout the entire period. Table 13 summarizes the share of the scientific disciplines in the patent citations from this technology area. These findings from the OCED area clearly indicate that the contribution from science is highly concentrated; two disciplines (Electrical engineering and telecommunication, and Computer science) account for almost 90% of the patent citations. The relative contribution of Electrical engineering and telecommunication has increased slightly. Several of the other 'minor' disciplines have also increased their share.

The EU28 pattern, in Table 14, shows same dominance of the two 'major' disciplines, but a smaller number of disciplines with a significant yet low-level contribution. Similarly to patents from the OECD area, the share of Computer science is also in decline.

Table 14. S/T broadening or S/T narrowing in 'IoT and related technology': EU28 area*

	SHARE OF TOTAL CITING PATENTS		
	2010-2014	2005-2009	2000-2004
Electrical engineering and telecommunication	54.3%	49.8%	51.0%
Computer science	39.5%	41.7%	42.2%
Instruments and instrumentation	1.6%	0.5%	0.1%
General and industrial engineering	0.8%	1.3%	1.0%
Physics and materials science	0.8%	1.2%	0.6%
Chemistry and chemical engineering	0.5%	0.4%	0.6%
Statistical sciences	0.5%	0.8%	0.5%

*** Includes scientific disciplines that account for 0.5% or more in 2010-2014.**

[9] See footnote 8.

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Appendix A – Sources of delineation of technology areas

A.1 EC concordance table

KETs	IPC classes
Nano-technology	B82Y (previously Y01N), B81C, B82B
Photonics	F21K, F21V, F21Y, G01D 5/26, G01D 5/58, G01D 15/14, G01G 23/32, G01J, G01L 1/24, G01L 3/08, G01L 11/02, G01L 23/06, G01M 11, G01P 3/36, G01P 3/38, G01P 3/68, G01P 5/26, G01Q 20/02, G01Q 30/02, G01Q 60/06, G01Q 60/18, G01R 15/22, G01R 15/24, G01R 23/17, G01R 31/308, G01R 33/032, G01R 33/26, G01S 7/481, G01V 8, G02B 5, G02B 6 (excl. subclasses 1, 3, 6/36, 6/38, 6/40, 6/44, 6/46), G02B 13/14, G03B 42, G03G 21/08, G06E, G06F 3/042, G06K 9/58, G06K 9/74, G06N 3/067, G08B 13/186, G08C 19/36, G08C 23/04, G08C 23/06, G08G 1/04, G11B 7/12, G11B 7/125, , G11B 7/13, , G11B 7/135, G11B 11/03, G11B 11/12, G11B 11/18, G11C 11/42, G11C 13/04, G11C 19/30, H01J 3, H01J 5/16, H01J 29/46, H01J 29/82, H01J 29/89, H01J 31/50, H01J 37/04, H01J 37/05, H01J 49/04, H01J 49/06, H01L 31/052, H01L 31/055, H01L 31/10, H01L 33/06, H01L 33/08, H01L 33/10, H01L 33/18, H01L 51/50, H01L 51/52, H01S 3, H01S 5, H02N 6, H05B 33
Industrial bio-technology	C02F 3/34, C07C 29, C07D 475, C07K 2, C08B 3, C08B 7, C08H 1, C08L 89, C09D 11, C09D 189, C09J 189, C12M, C12P, C12Q, C12S, G01N 27/327 except for co-occurrence with A01, A61, C07K 14/435, C07K 14/47, C07K 14/705, C07K 16/18, C07K 16/28, C12N 15/09, C12N 15/11, C12N 15/12, C12N 5/10, C12P 21/08, C12Q 1/68, G01N 33/15, G01N 33/50, G01N 33/53, G01N 33/68, G01N 33/566, C12N 1/19, C12N 1/21, C12N 1/15, C12N 15/00, C12N 15/10, C12P 21/02.
Advanced materials	B32B 9, B32B 15, B32B 17, B32B 18, B32B 19, B32B 25, B32B 27, B82Y 30, C01B 31, C01D 15, C01D 17, C01F 13, C01F 15, C01F 17, C03C, C04B 35, C08F, C08J 5, C08L, C22C, C23C, D21H 17, G02B 1, H01B 3, H01F 1/0, H01F 1/12, H01F 1/34, H01F 1/42, H01F 1/44, H01L 51/30, H01L 51/46, H01L 51/54.
Micro- and nanoelectronics	G01R 31/26, G01R 31/27 , G01R 31/28 , G01R 31/303 , G01R 31/304, G01R 31/317, G01R 31/327, G09G 3/14, G09G 3/32, H01F 1/40, H01F 10/193, H01G 9/028, H01G 9/032, H01H 47/32, H01H 57, H01S 5, H01L, H03B 5/32, H03C 3/22, H03F 3/04, H03F 3/06, H03F 3/08, H03F 3/10, H03F 3/12, H03F 3/14, H03F 3/16, H03F 3/183, H03F 3/21, H03F 3/343, H03F 3/387, H03F 3/55, H03K 17/72, H05K 1, B82Y 25 (certain overlap to nanotechnology).
Advanced Manufacturing Technologies	B01D 15, B01D 67, B01J 10, B01J 12, B01J 13, B01J 14, B01J 15, B01J 16, B01J 19/02, B01J 19/08, B01J 19/18, B01J 19/20, B01J 19/22, B01J 19/24, B01J 19/26, B01J 19/28, B01J 20/30, B01J 21/20, B01J 23/90, B01J 23/92, B01J 23/94, B01J 23/96, B01J 25/04, B01J 27/28, B01J 27/30, B01J 27/32, B01J 29/90, B01J 31/40, B01J 38, B01J 39/26, B01J 41/20, B01J 47, B01J 49, B01J 8/06, B01J 8/14, B01J 8/24, B01J 10, B01L , B04B , B04C , B32B 37, B32B 38, B32B 39, B32B 41, B81C 3, B82B 3, B82Y 35, B82Y 40, C01B 17/20, C01B 17/62, C01B 17/80, C01B 17/96, C01B 21/28, C01B 21/32, C01B 21/48, C01B 25/232, C01B 31/24, C01B 9, C01C 1/28, C01D 1/28, C01D 3/14, C01D 5/16, C01D 7/22, C01D 9/16, C01F 1, C01G 1, C02F 11/02, C02F 11/04, C02F 3, C03B 20, C03B 5/24, C03B 5/173, C03B 5/237, C03B 5/02, C03C 21, , C03C 29, C04B 11/028, C04B 35/622, C04B 35/624, C04B 35/626, C04B 35/653, C04B 35/657, C04B 37, C04B 38/02, C04B 38/10, C04B 40, C04B 7/60, C04B 9/20, C07C 17/38, C07C 2/08, C07C 2/46, C07C 2/52, C07C 2/58, C07C 2/80, C07C 201/16, C07C 209/82, C07C 213/10, C07C 227/38, C07C 231/22, C07C 249/14, C07C 253/32, C07C 263/18, C07C 269/08, C07C 273/14, C07C 277/06, C07C 29/74, C07C 303/42, C07C 315/06, C07C 319/26, C07C 37/68, C07C 4/04, C07C 4/06, C07C 4/16, C07C 4/18, C07C 41/34, C07C 41/58, C07C 45/78, C07C 45/90, C07C 46/10, C07C 47/058, C07C 47/09, C07C 5/333, C07C 5/41, C07C 51/42, C07C 51/573, C07C 51/64, C07C 57/07, C07C 67/48, C07C 68/08, C07C 7, C07D 201/16, C07D 209/84, C07D 213/803, C07D 251/62, C07D 301/32, C07D 311/40, C07D 499/18, C07D 501/12, C07F 7/20, C07H 1/06, C07K 1, C08B 1/10, C08B 17, C08B 30/16, C08C , C08F 2/01, , C09B 41, C09B 67/54, C09D 7/14, C09J 5, C12M, C12S , C21C 5/52, C21C 5/54, C21C 5/56, C21C 7, C21D , C22B 11, C22B 21, C22B 26, C22B 4, C22B 59, C22B 9, C22C 1, C22C 3, C22C 33, C22C 35, C22C 47, C22F , C23C 14/56, C23C 16/54, C25B 9, C25B 15/02, C25C , C25D 1, C30B 15/20, C30B 35, C40B 60, D01D 10, D01D 11, D01D 13, D01F 9/133, D01F 9/32, D06B 23/20, D21H 23/20, D21H 23/70, D21H 23/74, D21H 23/78, D21H 27/22, F24J 1, F25J 3, F25J 5, F27B 17, F27B 19, F27D 19, F27D 7/06, G01C 19/5628, G01C 19/5663, G01C 19/5769, G01C 25, G01R 3, G11B 7/22, H01L 21, H01L 31/18, H01L 35/34, H01L 39/24, H01L 41/22, H01L 43/12, H01L 51/40, H01L 51/48, H01L 51/56, H01S 3/08, H01S 3/09, H01S 5/04, H01S 5/06, H01S 5/10, H05B 33/10, H05K 13, H05K 3

Source: KETs Observatory (van de Velde et al. 2013).

A.2 WIPO concordance table

IPC8 -Technology Concordance

Note: In this update, code “G04R” had been added. Methodology available at: http://www.wipo.int/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf
Source: WIPO Statistics Database

Last update: March 2018

Field_number	Field_en	IPC_code	Updated_on
1	Electrical machinery, apparatus, energy	F21H%	
1	Electrical machinery, apparatus, energy	F21K%	
1	Electrical machinery, apparatus, energy	F21L%	
1	Electrical machinery, apparatus, energy	F21S%	
1	Electrical machinery, apparatus, energy	F21V%	
1	Electrical machinery, apparatus, energy	F21W%	
1	Electrical machinery, apparatus, energy	F21Y%	
1	Electrical machinery, apparatus, energy	H01B%	
1	Electrical machinery, apparatus, energy	H01C%	
1	Electrical machinery, apparatus, energy	H01F%	
1	Electrical machinery, apparatus, energy	H01G%	
1	Electrical machinery, apparatus, energy	H01H%	
1	Electrical machinery, apparatus, energy	H01J%	
1	Electrical machinery, apparatus, energy	H01K%	
1	Electrical machinery, apparatus, energy	H01M%	
1	Electrical machinery, apparatus, energy	H01R%	
1	Electrical machinery, apparatus, energy	H01T%	
1	Electrical machinery, apparatus, energy	H02B%	
1	Electrical machinery, apparatus, energy	H02G%	
1	Electrical machinery, apparatus, energy	H02H%	
1	Electrical machinery, apparatus, energy	H02J%	

1	Electrical machinery, apparatus, energy	H02K%	
1	Electrical machinery, apparatus, energy	H02M%	
1	Electrical machinery, apparatus, energy	H02N%	
1	Electrical machinery, apparatus, energy	H02P%	
1	Electrical machinery, apparatus, energy	H02S%	June 10, 2014
1	Electrical machinery, apparatus, energy	H05B%	
1	Electrical machinery, apparatus, energy	H05C%	
1	Electrical machinery, apparatus, energy	H05F%	
1	Electrical machinery, apparatus, energy	H99Z%	
2	Audio-visual technology	G09F%	
2	Audio-visual technology	G09G%	
2	Audio-visual technology	G11B%	
2	Audio-visual technology	H04N 3%	
2	Audio-visual technology	H04N 5%	
2	Audio-visual technology	H04N 7%	
2	Audio-visual technology	H04N 9%	
2	Audio-visual technology	H04N 11%	
2	Audio-visual technology	H04N 13%	
2	Audio-visual technology	H04N 15%	
2	Audio-visual technology	H04N 17%	
2	Audio-visual technology	H04N 19%	June 10, 2014
2	Audio-visual technology	H04N 101%	
2	Audio-visual technology	H04R%	
2	Audio-visual technology	H04S%	
2	Audio-visual technology	H05K%	
3	Telecommunications	G08C%	
3	Telecommunications	H01P%	
3	Telecommunications	H01Q%	
3	Telecommunications	H04B%	
3	Telecommunications	H04H%	
3	Telecommunications	H04J%	
3	Telecommunications	H04K%	
3	Telecommunications	H04M%	
3	Telecommunications	H04N 1%	
3	Telecommunications	H04Q%	
4	Digital communication	H04L%	
4	Digital communication	H04N 21%	
4	Digital communication	H04W%	
5	Basic communication processes	H03B%	

5	Basic communication processes	H03C%	
5	Basic communication processes	H03D%	
5	Basic communication processes	H03F%	
5	Basic communication processes	H03G%	
5	Basic communication processes	H03H%	
5	Basic communication processes	H03J%	
5	Basic communication processes	H03K%	
5	Basic communication processes	H03L%	
5	Basic communication processes	H03M%	
6	Computer technology	G06C%	
6	Computer technology	G06D%	
6	Computer technology	G06E%	
6	Computer technology	G06F%	
6	Computer technology	G06G%	
6	Computer technology	G06J%	
6	Computer technology	G06K%	
6	Computer technology	G06M%	
6	Computer technology	G06N%	
6	Computer technology	G06T%	
6	Computer technology	G10L%	
6	Computer technology	G11C%	
7	IT methods for management	G06Q%	
8	Semiconductors	H01L%	
9	Optics	G02B%	
9	Optics	G02C%	
9	Optics	G02F%	
9	Optics	G03B%	
9	Optics	G03C%	
9	Optics	G03D%	
9	Optics	G03F%	
9	Optics	G03G%	
9	Optics	G03H%	
9	Optics	H01S%	
10	Measurement	G01B%	
10	Measurement	G01C%	
10	Measurement	G01D%	
10	Measurement	G01F%	
10	Measurement	G01G%	
10	Measurement	G01H%	
10	Measurement	G01J%	
10	Measurement	G01K%	
10	Measurement	G01L%	
10	Measurement	G01M%	
10	Measurement	G01N 1%	
10	Measurement	G01N 3%	
10	Measurement	G01N 5%	
10	Measurement	G01N 7%	
10	Measurement	G01N 9%	

10	Measurement	G01N 11%	
10	Measurement	G01N 13%	
10	Measurement	G01N 15%	
10	Measurement	G01N 17%	
10	Measurement	G01N 19%	
10	Measurement	G01N 21%	
10	Measurement	G01N 22%	
10	Measurement	G01N 23%	
10	Measurement	G01N 24%	
10	Measurement	G01N 25%	
10	Measurement	G01N 27%	
10	Measurement	G01N 29%	
10	Measurement	G01N 30%	
10	Measurement	G01N 31%	
10	Measurement	G01N 35%	
10	Measurement	G01N 37%	
10	Measurement	G01P%	
10	Measurement	G01Q%	
10	Measurement	G01R%	
10	Measurement	G01S%	
10	Measurement	G01V%	
10	Measurement	G01W%	
10	Measurement	G04B%	
10	Measurement	G04C%	
10	Measurement	G04D%	
10	Measurement	G04F%	
10	Measurement	G04G%	
10	Measurement	G04R%	January 1, 2013
10	Measurement	G12B%	
10	Measurement	G99Z%	
11	Analysis of biological materials	G01N 33%	
12	Control	G05B%	
12	Control	G05D%	
12	Control	G05F%	
12	Control	G07B%	
12	Control	G07C%	
12	Control	G07D%	
12	Control	G07F%	
12	Control	G07G%	
12	Control	G08B%	
12	Control	G08G%	
12	Control	G09B%	
12	Control	G09C%	
12	Control	G09D%	
13	Medical technology	A61B%	
13	Medical technology	A61C%	
13	Medical technology	A61D%	

13	Medical technology	A61F%	
13	Medical technology	A61G%	
13	Medical technology	A61H%	
13	Medical technology	A61J%	
13	Medical technology	A61L%	
13	Medical technology	A61M%	
13	Medical technology	A61N%	
13	Medical technology	H05G%	
13	Medical technology	G16H%	January 1, 2018
14	Organic fine chemistry	A61K 8%	
14	Organic fine chemistry	A61Q%	
14	Organic fine chemistry	C07B%	
14	Organic fine chemistry	C07C%	
14	Organic fine chemistry	C07D%	
14	Organic fine chemistry	C07F%	
14	Organic fine chemistry	C07H%	
14	Organic fine chemistry	C07J%	
14	Organic fine chemistry	C40B%	
15	Biotechnology	C07G%	
15	Biotechnology	C07K%	
15	Biotechnology	C12M%	
15	Biotechnology	C12N%	
15	Biotechnology	C12P%	
15	Biotechnology	C12Q%	
15	Biotechnology	C12R%	
15	Biotechnology	C12S%	
16	Pharmaceuticals	A61K 6%	
16	Pharmaceuticals	A61K 9%	
16	Pharmaceuticals	A61K 31%	
16	Pharmaceuticals	A61K 33%	
16	Pharmaceuticals	A61K 35%	
16	Pharmaceuticals	A61K 36%	
16	Pharmaceuticals	A61K 38%	
16	Pharmaceuticals	A61K 39%	
16	Pharmaceuticals	A61K 41%	
16	Pharmaceuticals	A61K 45%	
16	Pharmaceuticals	A61K 47%	
16	Pharmaceuticals	A61K 48%	
16	Pharmaceuticals	A61K 49%	
16	Pharmaceuticals	A61K 50%	
16	Pharmaceuticals	A61K 51%	
16	Pharmaceuticals	A61K 101%	
16	Pharmaceuticals	A61K 103%	
16	Pharmaceuticals	A61K 125%	
16	Pharmaceuticals	A61K 127%	
16	Pharmaceuticals	A61K 129%	
16	Pharmaceuticals	A61K 131%	

16	Pharmaceuticals	A61K 133%	
16	Pharmaceuticals	A61K 135%	
16	Pharmaceuticals	A61P%	
17	Macromolecular chemistry, polymers	C08B%	
17	Macromolecular chemistry, polymers	C08C%	
17	Macromolecular chemistry, polymers	C08F%	
17	Macromolecular chemistry, polymers	C08G%	
17	Macromolecular chemistry, polymers	C08H%	
17	Macromolecular chemistry, polymers	C08K%	
17	Macromolecular chemistry, polymers	C08L%	
18	Food chemistry	A01H%	
18	Food chemistry	A21D%	
18	Food chemistry	A23B%	
18	Food chemistry	A23C%	
18	Food chemistry	A23D%	
18	Food chemistry	A23F%	
18	Food chemistry	A23G%	
18	Food chemistry	A23J%	
18	Food chemistry	A23K%	
18	Food chemistry	A23L%	
18	Food chemistry	C12C%	
18	Food chemistry	C12F%	
18	Food chemistry	C12G%	
18	Food chemistry	C12H%	
18	Food chemistry	C12J%	
18	Food chemistry	C13B 10%	August 15, 2011
18	Food chemistry	C13B 20%	August 15, 2011
18	Food chemistry	C13B 30%	August 15, 2011
18	Food chemistry	C13B 35%	August 15, 2011
18	Food chemistry	C13B 40%	August 15, 2011
18	Food chemistry	C13B 50%	August 15, 2011
18	Food chemistry	C13B 99%	August 15, 2011
18	Food chemistry	C13D%	
18	Food chemistry	C13F%	
18	Food chemistry	C13J%	
18	Food chemistry	C13K%	

19	Basic materials chemistry	A01N%		
19	Basic materials chemistry	A01P%		
19	Basic materials chemistry	C05B%		
19	Basic materials chemistry	C05C%		
19	Basic materials chemistry	C05D%		
19	Basic materials chemistry	C05F%		
19	Basic materials chemistry	C05G%		
19	Basic materials chemistry	C06B%		
19	Basic materials chemistry	C06C%		
19	Basic materials chemistry	C06D%		
19	Basic materials chemistry	C06F%		
19	Basic materials chemistry	C09B%		
19	Basic materials chemistry	C09C%		
19	Basic materials chemistry	C09D%		
19	Basic materials chemistry	C09F%		
19	Basic materials chemistry	C09G%		
19	Basic materials chemistry	C09H%		
19	Basic materials chemistry	C09J%		
19	Basic materials chemistry	C09K%		
19	Basic materials chemistry	C10B%		
19	Basic materials chemistry	C10C%		
19	Basic materials chemistry	C10F%		
19	Basic materials chemistry	C10G%		
19	Basic materials chemistry	C10H%		
19	Basic materials chemistry	C10J%		
19	Basic materials chemistry	C10K%		
19	Basic materials chemistry	C10L%		
19	Basic materials chemistry	C10M%		
19	Basic materials chemistry	C10N%		
19	Basic materials chemistry	C11B%		
19	Basic materials chemistry	C11C%		
19	Basic materials chemistry	C11D%		
19	Basic materials chemistry	C99Z%		
20	Materials, metallurgy	B22C%		
20	Materials, metallurgy	B22D%		
20	Materials, metallurgy	B22F%		
20	Materials, metallurgy	C01B%		
20	Materials, metallurgy	C01C%		
20	Materials, metallurgy	C01D%		
20	Materials, metallurgy	C01F%		
20	Materials, metallurgy	C01G%		
20	Materials, metallurgy	C03C%		
20	Materials, metallurgy	C04B%		
20	Materials, metallurgy	C21B%		
20	Materials, metallurgy	C21C%		
20	Materials, metallurgy	C21D%		
20	Materials, metallurgy	C22B%		
20	Materials, metallurgy	C22C%		

20	Materials, metallurgy	C22F%	
21	Surface technology, coating	B05C%	
21	Surface technology, coating	B05D%	
21	Surface technology, coating	B32B%	
21	Surface technology, coating	C23C%	
21	Surface technology, coating	C23D%	
21	Surface technology, coating	C23F%	
21	Surface technology, coating	C23G%	
21	Surface technology, coating	C25B%	
21	Surface technology, coating	C25C%	
21	Surface technology, coating	C25D%	
21	Surface technology, coating	C25F%	
21	Surface technology, coating	C30B%	
22	Micro-structural and nano-technology	B81B%	
22	Micro-structural and nano-technology	B81C%	
22	Micro-structural and nano-technology	B82B%	
22	Micro-structural and nano-technology	B82Y%	August 15, 2011
23	Chemical engineering	B01B%	
23	Chemical engineering	B01D 1%	
23	Chemical engineering	B01D 3%	
23	Chemical engineering	B01D 5%	
23	Chemical engineering	B01D 7%	
23	Chemical engineering	B01D 8%	
23	Chemical engineering	B01D 9%	
23	Chemical engineering	B01D 11%	
23	Chemical engineering	B01D 12%	
23	Chemical engineering	B01D 15%	
23	Chemical engineering	B01D 17%	
23	Chemical engineering	B01D 19%	
23	Chemical engineering	B01D 21%	
23	Chemical engineering	B01D 24%	
23	Chemical engineering	B01D 25%	
23	Chemical engineering	B01D 27%	
23	Chemical engineering	B01D 29%	
23	Chemical engineering	B01D 33%	
23	Chemical engineering	B01D 35%	
23	Chemical engineering	B01D 36%	
23	Chemical engineering	B01D 37%	
23	Chemical engineering	B01D 39%	
23	Chemical engineering	B01D 41%	
23	Chemical engineering	B01D 43%	
23	Chemical engineering	B01D 57%	
23	Chemical engineering	B01D 59%	
23	Chemical engineering	B01D 61%	

23	Chemical engineering	B01D 63%	
23	Chemical engineering	B01D 65%	
23	Chemical engineering	B01D 67%	
23	Chemical engineering	B01D 69%	
23	Chemical engineering	B01D 71%	
23	Chemical engineering	B01F%	
23	Chemical engineering	B01J%	
23	Chemical engineering	B01L%	
23	Chemical engineering	B02C%	
23	Chemical engineering	B03B%	
23	Chemical engineering	B03C%	
23	Chemical engineering	B03D%	
23	Chemical engineering	B04B%	
23	Chemical engineering	B04C%	
23	Chemical engineering	B05B%	
23	Chemical engineering	B06B%	
23	Chemical engineering	B07B%	
23	Chemical engineering	B07C%	
23	Chemical engineering	B08B%	
23	Chemical engineering	C14C%	
23	Chemical engineering	D06B%	
23	Chemical engineering	D06C%	
23	Chemical engineering	D06L%	
23	Chemical engineering	F25J%	
23	Chemical engineering	F26B%	
23	Chemical engineering	H05H%	
24	Environmental technology	A62C%	
24	Environmental technology	B01D 45%	
24	Environmental technology	B01D 46%	
24	Environmental technology	B01D 47%	
24	Environmental technology	B01D 49%	
24	Environmental technology	B01D 50%	
24	Environmental technology	B01D 51%	
24	Environmental technology	B01D 52%	
24	Environmental technology	B01D 53%	
24	Environmental technology	B09B%	
24	Environmental technology	B09C%	
24	Environmental technology	B65F%	
24	Environmental technology	C02F%	
24	Environmental technology	E01F 8%	
24	Environmental technology	F01N%	
24	Environmental technology	F23G%	
24	Environmental technology	F23J%	
24	Environmental technology	G01T%	
25	Handling	B25J%	
25	Handling	B65B%	
25	Handling	B65C%	
25	Handling	B65D%	

25	Handling	B65G%		
25	Handling	B65H%		
25	Handling	B66B%		
25	Handling	B66C%		
25	Handling	B66D%		
25	Handling	B66F%		
25	Handling	B67B%		
25	Handling	B67C%		
25	Handling	B67D%		
26	Machine tools	A62D%		
26	Machine tools	B21B%		
26	Machine tools	B21C%		
26	Machine tools	B21D%		
26	Machine tools	B21F%		
26	Machine tools	B21G%		
26	Machine tools	B21H%		
26	Machine tools	B21J%		
26	Machine tools	B21K%		
26	Machine tools	B21L%		
26	Machine tools	B23B%		
26	Machine tools	B23C%		
26	Machine tools	B23D%		
26	Machine tools	B23F%		
26	Machine tools	B23G%		
26	Machine tools	B23H%		
26	Machine tools	B23K%		
26	Machine tools	B23P%		
26	Machine tools	B23Q%		
26	Machine tools	B24B%		
26	Machine tools	B24C%		
26	Machine tools	B24D%		
26	Machine tools	B25B%		
26	Machine tools	B25C%		
26	Machine tools	B25D%		
26	Machine tools	B25F%		
26	Machine tools	B25G%		
26	Machine tools	B25H%		
26	Machine tools	B26B%		
26	Machine tools	B26D%		
26	Machine tools	B26F%		
26	Machine tools	B27B%		
26	Machine tools	B27C%		
26	Machine tools	B27D%		
26	Machine tools	B27F%		
26	Machine tools	B27G%		
26	Machine tools	B27H%		
26	Machine tools	B27J%		
26	Machine tools	B27K%		

26	Machine tools	B27L%	
26	Machine tools	B27M%	
26	Machine tools	B27N%	
26	Machine tools	B30B%	
27	Engines, pumps, turbines	F01B%	
27	Engines, pumps, turbines	F01C%	
27	Engines, pumps, turbines	F01D%	
27	Engines, pumps, turbines	F01K%	
27	Engines, pumps, turbines	F01L%	
27	Engines, pumps, turbines	F01M%	
27	Engines, pumps, turbines	F01P%	
27	Engines, pumps, turbines	F02B%	
27	Engines, pumps, turbines	F02C%	
27	Engines, pumps, turbines	F02D%	
27	Engines, pumps, turbines	F02F%	
27	Engines, pumps, turbines	F02G%	
27	Engines, pumps, turbines	F02K%	
27	Engines, pumps, turbines	F02M%	
27	Engines, pumps, turbines	F02N%	
27	Engines, pumps, turbines	F02P%	
27	Engines, pumps, turbines	F03B%	
27	Engines, pumps, turbines	F03C%	
27	Engines, pumps, turbines	F03D%	
27	Engines, pumps, turbines	F03G%	
27	Engines, pumps, turbines	F03H%	
27	Engines, pumps, turbines	F04B%	
27	Engines, pumps, turbines	F04C%	
27	Engines, pumps, turbines	F04D%	
27	Engines, pumps, turbines	F04F%	
27	Engines, pumps, turbines	F23R%	
27	Engines, pumps, turbines	F99Z%	
27	Engines, pumps, turbines	G21B%	
27	Engines, pumps, turbines	G21C%	
27	Engines, pumps, turbines	G21D%	
27	Engines, pumps, turbines	G21F%	
27	Engines, pumps, turbines	G21G%	
27	Engines, pumps, turbines	G21H%	
27	Engines, pumps, turbines	G21J%	
27	Engines, pumps, turbines	G21K%	
28	Textile and paper machines	A41H%	
28	Textile and paper machines	A43D%	
28	Textile and paper machines	A46D%	
28	Textile and paper machines	B31B%	
28	Textile and paper machines	B31C%	
28	Textile and paper machines	B31D%	
28	Textile and paper machines	B31F%	
28	Textile and paper machines	B41B%	
28	Textile and paper machines	B41C%	

28	Textile and paper machines	B41D%		
28	Textile and paper machines	B41F%		
28	Textile and paper machines	B41G%		
28	Textile and paper machines	B41J%		
28	Textile and paper machines	B41K%		
28	Textile and paper machines	B41L%		
28	Textile and paper machines	B41M%		
28	Textile and paper machines	B41N%		
28	Textile and paper machines	C14B%		
28	Textile and paper machines	D01B%		
28	Textile and paper machines	D01C%		
28	Textile and paper machines	D01D%		
28	Textile and paper machines	D01F%		
28	Textile and paper machines	D01G%		
28	Textile and paper machines	D01H%		
28	Textile and paper machines	D02G%		
28	Textile and paper machines	D02H%		
28	Textile and paper machines	D02J%		
28	Textile and paper machines	D03C%		
28	Textile and paper machines	D03D%		
28	Textile and paper machines	D03J%		
28	Textile and paper machines	D04B%		
28	Textile and paper machines	D04C%		
28	Textile and paper machines	D04G%		
28	Textile and paper machines	D04H%		
28	Textile and paper machines	D05B%		
28	Textile and paper machines	D05C%		
28	Textile and paper machines	D06G%		
28	Textile and paper machines	D06H%		
28	Textile and paper machines	D06J%		
28	Textile and paper machines	D06M%		
28	Textile and paper machines	D06P%		
28	Textile and paper machines	D06Q%		
28	Textile and paper machines	D21B%		
28	Textile and paper machines	D21C%		
28	Textile and paper machines	D21D%		
28	Textile and paper machines	D21F%		
28	Textile and paper machines	D21G%		
28	Textile and paper machines	D21H%		
28	Textile and paper machines	D21J%		
28	Textile and paper machines	D99Z%		
29	Other special machines	A01B%		
29	Other special machines	A01C%		
29	Other special machines	A01D%		
29	Other special machines	A01F%		
29	Other special machines	A01G%		
29	Other special machines	A01J%		
29	Other special machines	A01K%		

29	Other special machines	A01L%	
29	Other special machines	A01M%	
29	Other special machines	A21B%	
29	Other special machines	A21C%	
29	Other special machines	A22B%	
29	Other special machines	A22C%	
29	Other special machines	A23N%	
29	Other special machines	A23P%	
29	Other special machines	B02B%	
29	Other special machines	B28B%	
29	Other special machines	B28C%	
29	Other special machines	B28D%	
29	Other special machines	B29B%	
29	Other special machines	B29C%	
29	Other special machines	B29D%	
29	Other special machines	B29K%	
29	Other special machines	B29L%	
29	Other special machines	B33Y%	January 1, 2015
29	Other special machines	B99Z%	
29	Other special machines	C03B%	
29	Other special machines	C08J%	
29	Other special machines	C12L%	
29	Other special machines	C13B 5%	August 15, 2011
29	Other special machines	C13B 15%	August 15, 2011
29	Other special machines	C13B 25%	August 15, 2011
29	Other special machines	C13B 45%	August 15, 2011
29	Other special machines	C13C%	
29	Other special machines	C13G%	
29	Other special machines	C13H%	
29	Other special machines	F41A%	
29	Other special machines	F41B%	
29	Other special machines	F41C%	
29	Other special machines	F41F%	
29	Other special machines	F41G%	
29	Other special machines	F41H%	
29	Other special machines	F41J%	
29	Other special machines	F42B%	
29	Other special machines	F42C%	
29	Other special machines	F42D%	
30	Thermal processes and apparatus	F22B%	
30	Thermal processes and apparatus	F22D%	
30	Thermal processes and	F22G%	

	apparatus		
30	Thermal processes and apparatus	F23B%	
30	Thermal processes and apparatus	F23C%	
30	Thermal processes and apparatus	F23D%	
30	Thermal processes and apparatus	F23H%	
30	Thermal processes and apparatus	F23K%	
30	Thermal processes and apparatus	F23L%	
30	Thermal processes and apparatus	F23M%	
30	Thermal processes and apparatus	F23N%	
30	Thermal processes and apparatus	F23Q%	
30	Thermal processes and apparatus	F24B%	
30	Thermal processes and apparatus	F24C%	
30	Thermal processes and apparatus	F24D%	
30	Thermal processes and apparatus	F24F%	
30	Thermal processes and apparatus	F24H%	
30	Thermal processes and apparatus	F24J%	
30	Thermal processes and apparatus	F24S%		January 1, 2018
30	Thermal processes and apparatus	F24T%		January 1, 2018
30	Thermal processes and apparatus	F24V%		January 1, 2018
30	Thermal processes and apparatus	F25B%	
30	Thermal processes and apparatus	F25C%	
30	Thermal processes and apparatus	F27B%	
30	Thermal processes and apparatus	F27D%	
30	Thermal processes and apparatus	F28B%	
30	Thermal processes and apparatus	F28C%	
30	Thermal processes and apparatus	F28D%	

30	Thermal processes and apparatus	F28F%	
30	Thermal processes and apparatus	F28G%	
31	Mechanical elements	F15B%	
31	Mechanical elements	F15C%	
31	Mechanical elements	F15D%	
31	Mechanical elements	F16B%	
31	Mechanical elements	F16C%	
31	Mechanical elements	F16D%	
31	Mechanical elements	F16F%	
31	Mechanical elements	F16G%	
31	Mechanical elements	F16H%	
31	Mechanical elements	F16J%	
31	Mechanical elements	F16K%	
31	Mechanical elements	F16L%	
31	Mechanical elements	F16M%	
31	Mechanical elements	F16N%	
31	Mechanical elements	F16P%	
31	Mechanical elements	F16S%	
31	Mechanical elements	F16T%	
31	Mechanical elements	F17B%	
31	Mechanical elements	F17C%	
31	Mechanical elements	F17D%	
31	Mechanical elements	G05G%	
32	Transport	B60B%	
32	Transport	B60C%	
32	Transport	B60D%	
32	Transport	B60F%	
32	Transport	B60G%	
32	Transport	B60H%	
32	Transport	B60J%	
32	Transport	B60K%	
32	Transport	B60L%	
32	Transport	B60M%	
32	Transport	B60N%	
32	Transport	B60P%	
32	Transport	B60Q%	
32	Transport	B60R%	
32	Transport	B60S%	
32	Transport	B60T%	
32	Transport	B60V%	
32	Transport	B60W%	
32	Transport	B61B%	
32	Transport	B61C%	
32	Transport	B61D%	
32	Transport	B61F%	
32	Transport	B61G%	

32	Transport	B61H%	
32	Transport	B61J%	
32	Transport	B61K%	
32	Transport	B61L%	
32	Transport	B62B%	
32	Transport	B62C%	
32	Transport	B62D%	
32	Transport	B62H%	
32	Transport	B62J%	
32	Transport	B62K%	
32	Transport	B62L%	
32	Transport	B62M%	
32	Transport	B63B%	
32	Transport	B63C%	
32	Transport	B63G%	
32	Transport	B63H%	
32	Transport	B63J%	
32	Transport	B64B%	
32	Transport	B64C%	
32	Transport	B64D%	
32	Transport	B64F%	
32	Transport	B64G%	
33	Furniture, games	A47B%	
33	Furniture, games	A47C%	
33	Furniture, games	A47D%	
33	Furniture, games	A47F%	
33	Furniture, games	A47G%	
33	Furniture, games	A47H%	
33	Furniture, games	A47J%	
33	Furniture, games	A47K%	
33	Furniture, games	A47L%	
33	Furniture, games	A63B%	
33	Furniture, games	A63C%	
33	Furniture, games	A63D%	
33	Furniture, games	A63F%	
33	Furniture, games	A63G%	
33	Furniture, games	A63H%	
33	Furniture, games	A63J%	
33	Furniture, games	A63K%	
34	Other consumer goods	A24B%	
34	Other consumer goods	A24C%	
34	Other consumer goods	A24D%	
34	Other consumer goods	A24F%	
34	Other consumer goods	A41B%	
34	Other consumer goods	A41C%	
34	Other consumer goods	A41D%	
34	Other consumer goods	A41F%	
34	Other consumer goods	A41G%	

34	Other consumer goods	A42B%	
34	Other consumer goods	A42C%	
34	Other consumer goods	A43B%	
34	Other consumer goods	A43C%	
34	Other consumer goods	A44B%	
34	Other consumer goods	A44C%	
34	Other consumer goods	A45B%	
34	Other consumer goods	A45C%	
34	Other consumer goods	A45D%	
34	Other consumer goods	A45F%	
34	Other consumer goods	A46B%	
34	Other consumer goods	A62B%	
34	Other consumer goods	A99Z%	
34	Other consumer goods	B42B%	
34	Other consumer goods	B42C%	
34	Other consumer goods	B42D%	
34	Other consumer goods	B42F%	
34	Other consumer goods	B43K%	
34	Other consumer goods	B43L%	
34	Other consumer goods	B43M%	
34	Other consumer goods	B44B%	
34	Other consumer goods	B44C%	
34	Other consumer goods	B44D%	
34	Other consumer goods	B44F%	
34	Other consumer goods	B68B%	
34	Other consumer goods	B68C%	
34	Other consumer goods	B68F%	
34	Other consumer goods	B68G%	
34	Other consumer goods	D04D%	
34	Other consumer goods	D06F%	
34	Other consumer goods	D06N%	
34	Other consumer goods	D07B%	
34	Other consumer goods	F25D%	
34	Other consumer goods	G10B%	
34	Other consumer goods	G10C%	
34	Other consumer goods	G10D%	
34	Other consumer goods	G10F%	
34	Other consumer goods	G10G%	
34	Other consumer goods	G10H%	
34	Other consumer goods	G10K%	
35	Civil engineering	E01B%	
35	Civil engineering	E01C%	
35	Civil engineering	E01D%	
35	Civil engineering	E01F 1%	
35	Civil engineering	E01F 3%	
35	Civil engineering	E01F 5%	
35	Civil engineering	E01F 7%	
35	Civil engineering	E01F 9%	

35	Civil engineering	E01F 11%	
35	Civil engineering	E01F 13%	
35	Civil engineering	E01F 15%	
35	Civil engineering	E01H%	
35	Civil engineering	E02B%	
35	Civil engineering	E02C%	
35	Civil engineering	E02D%	
35	Civil engineering	E02F%	
35	Civil engineering	E03B%	
35	Civil engineering	E03C%	
35	Civil engineering	E03D%	
35	Civil engineering	E03F%	
35	Civil engineering	E04B%	
35	Civil engineering	E04C%	
35	Civil engineering	E04D%	
35	Civil engineering	E04F%	
35	Civil engineering	E04G%	
35	Civil engineering	E04H%	
35	Civil engineering	E05B%	
35	Civil engineering	E05C%	
35	Civil engineering	E05D%	
35	Civil engineering	E05F%	
35	Civil engineering	E05G%	
35	Civil engineering	E06B%	
35	Civil engineering	E06C%	
35	Civil engineering	E21B%	
35	Civil engineering	E21C%	
35	Civil engineering	E21D%	
35	Civil engineering	E21F%	
35	Civil engineering	E99Z%	

A.3 OECD concordance table

The “J tag”: a new IPC-based taxonomy of ICT technologies

Technology area	Sub area	IPC codes
1. High speed network	Digital communication technique	H03K, H03L, H03M, H04B1/69-1/719, H04J, H04L (excluding H04L9, H04L12/14) *H04L9, *H04L12/14
	Exchange, selecting	H04M3-13,19,99, H04Q
	Others	H04B1/00-1/68, H04B1/72-1/76, H04B3-17 (excluding H04B1/59, H04B5, H04B7), H04H *H04B1/59, *H04B5, *H04B7
2. Mobile communication		H04B7, H04W (excluding H04W4/24, H04W12) *H04W4/24, *H04W12
3. Security	Cyphering, authentication	G06F12/14, G06F21, G06K19, G09C, G11C8/20, H04K, H04L9, H04M1/66-665, H04M1/667-675, H04M1/68-70, H04M1/727, H04N7/167-7/171, H04W12
	Electronic payment	G06Q20, G07F7/08-12, G07G1/12-1/14, H04L12/14, H04W4/24 *G06Q30/02
4. Sensor and device network	Sensor network	G08B1/08, G08B3/10, G08B5/22-38, G08B7/06, G08B13/18-13/196, G08B13/22-26, G08B25, G08B26, G08B27, G08C, G08G1/01-065 *G06F17/40, *H04W84/18
	Electronic tag	H04B1/59, H04B5 *G01S13/74-84, *G01V3, *G01V15
	Others	*H04W84/10
5. High speed computing		G06F5, G06F7, G06F9, G06F11, G06F13, G06F15/00, G06F15/16-15/177, G06F15/18, G06F 15/76-15/82

6. Large-capacity and high speed storage		G06F3/06–3/08, G06F12 (exclude G06F12/14), G06K1-7, G06K13, G11B, G11C(exclude G11C8/20), H04N5/78-5/907 *G06F12/14, *G11C8/20
7. Large-capacity information analysis	Database	G06F17/30, G06F17/40
	Data analysis, simulation, management	G06F17/00, G06F17/10-17/18, G06F17/50, G06F19, G06Q10, G06Q30, G06Q40,G06Q50, G06Q90, G06Q99, G08G (exclude G08G1/01-065, G08G1/0962-0969) *G08G1/01-065, *G08G1/0962-0969
8. Cognition and meaning understanding		G06F17/20-17/28, G06K9, G06T7, G10L13/027, G10L15, G10L17, G10L25/63,66 *G06F15/18
9. Human interface		H04M1 (exclude H04M1/66-665, H04M1/667-675, H04M1/68-70, H04M1/727), G06F3/01-3/0489, G06F3/14-3/153, G06F3/16, G06K11, G06T11/80, G08G1/0962-0969, G09B5, G09B7, G09B9 *H04M1/66-665, *H04M1/667-675, *H04M1/68-70, *H04M1/727, *G06F17/50, *G06K9, *G06T11, *G06T13, *G06T15, *G06T17-19
10. Imaging and sound technology	Imaging technique	H04N (excluding H04N5/78-5/907, H04N7/167-7/171), G06T1-9 (excluding G06T7), G06T11 (excluding G06T11/80), G06T13, G06T15, G06T17-19, G09G *H04N5/78-5/907, *H04N7/167-7/171, *G06T7, *G06T11/80
	Sound technique	H04R, H04S, G10L (excluding G10L13/027, G10L15, G10L17, G10L25/63,66) *G10L13/027,* G10L15, *G10L17, *G10L25/63,66
11. Information communication device	Electronic circuit	H03B, H03C, H03D, H03F, H03G, H03H, H03J
	Cable and conductor	H01B11

	Semiconductor	H01L29-33, H01L21, 25, 27, 43-51
	Optic device	G02B6, G02F, H01S5
	Others	B81B7/02, B82Y10, H01P, H01Q
12. Electronic measurement		G01S, G01V3, G01V8, G01V15
13. Others	Computer input-output	G06F3/00, G06F3/05, G06F3/09, G06F3/12, G06F3/13, G06F3/18
	Other related technique	G06E, G06F1, G06F15/02, G06F15/04, G06F15/08-15/14, G06G7, G06J, G06K15, G06K17, G06N, H04M15, H04M17

Legend: An asterisk (*) precedes those IPC codes that are relevant, although of secondary importance, for the technology area considered, and that may conversely be key in other ICT areas.

Technology area	Sub area	IPC
11. Information communication device	Others	B81B7/02
11. Information communication device	Others	B82Y10
12. Electronic measurement		GO1S
12. Electronic measurement		G01V15
12. Electronic measurement		G01V3
12. Electronic measurement		G01V8
11. Information communication device	Optic device	G02B6
11. Information communication device	Optic device	G02F
13. Others	Other related technique	G06E
5. High speed computing		G06F 15/16-15/177
5. High speed computing		G06F 15/76-15/82
13. Others	Other related technique	G06F1
5. High speed computing		G06F11
6. Large-capacity and high speed storage		G06F12 (exclude G06F12/14)
3. Security	Cyphering, authentication	G06F12/14
5. High speed computing		G06F13
5. High speed computing		G06F15/00
13. Others	Other related technique	G06F15/02
13. Others	Other related technique	G06F15/04
13. Others	Other related technique	G06F15/08-15/14
5. High speed computing		G06F15/18
7. Large-capacity information analysis	Data analysis, simulation, management	G06F17/00
7. Large-capacity information analysis	Data analysis, simulation, management	G06F17/10-17/18
8. Cognition and meaning understanding		G06F17/20-17/28
7. Large-capacity information analysis	Database	G06F17/30
7. Large-capacity information analysis	Database	G06F17/40
7. Large-capacity information analysis	Data analysis, simulation, management	G06F17/50
7. Large-capacity information analysis	Data analysis,	G06F19

	simulation, management	
3. Security	Cyphering, authentication	G06F21
13. Others	Computer input-output	G06F3/00
9. Human-interface		G06F3/01-3/0489
13. Others	Computer input-output	G06F3/05
6. Large-capacity and high speed storage		G06F3/06–3/08
13. Others	Computer input-output	G06F3/09
13. Others	Computer input-output	G06F3/12
13. Others	Computer input-output	G06F3/13
9. Human-interface		G06F3/14-3/153
9. Human-interface		G06F3/16
13. Others	Computer input-output	G06F3/18
5. High speed computing		G06F5
5. High speed computing		G06F7
5. High speed computing		G06F9
13. Others	Other related technique	G06G7
13. Others	Other related technique	G06J
9. Human-interface		G06K11
6. Large-capacity and high speed storage		G06K13
6. Large-capacity and high speed storage		G06K13
13. Others	Other related technique	G06K15
13. Others	Other related technique	G06K17
6. Large-capacity and high speed storage		G06K1-7
3. Security	Cyphering, authentication	G06K19
8. Cognition and meaning understanding		G06K9
13. Others	Other related technique	G06N
7. Large-capacity information analysis	Data analysis, simulation, management	G06Q10
3. Security	Electronic	G06Q20

	payment	
7. Large-capacity information analysis	Data analysis, simulation, management	G06Q30
7. Large-capacity information analysis	Data analysis, simulation, management	G06Q40
7. Large-capacity information analysis	Data analysis, simulation, management	G06Q50
7. Large-capacity information analysis	Data analysis, simulation, management	G06Q90
7. Large-capacity information analysis	Data analysis, simulation, management	G06Q99
10. Imaging and sound technology	Imaging technique	G06T11 (exclude G06T11/80)
9. Human-interface		G06T11/80
10. Imaging and sound technology	Imaging technique	G06T13
10. Imaging and sound technology	Imaging technique	G06T15 3D
10. Imaging and sound technology	Imaging technique	G06T17-19
10. Imaging and sound technology	Imaging technique	G06T1-9 (exclude G06T7)
8. Cognition and meaning understanding		G06T7
3. Security	Electronic payment	G07F7/08-12
3. Security	Electronic payment	G07G1/12-1/14
4. Sensor and device network	Sensor network	G08B1/08
4. Sensor and device network	Sensor network	G08B13/18-13/196
4. Sensor and device network	Sensor network	G08B13/22-26
4. Sensor and device network	Sensor network	G08B25
4. Sensor and device network	Sensor network	G08B26
4. Sensor and device network	Sensor network	G08B27
4. Sensor and device network	Sensor network	G08B3/10
4. Sensor and device network	Sensor network	G08B5/22-38
4. Sensor and device network	Sensor network	G08B7/06
4. Sensor and device network	Sensor network	G08C
7. Large-capacity information analysis	Data analysis, simulation, management	G08G (exclude G08G1/01-065,G08G1/0962-0969)
4. Sensor and device network	Sensor network	G08G1/01-065

9. Human-interface		G08G1/0962-0969
9. Human-interface		G09B5
9. Human-interface		G09B7
9. Human-interface		G09B9
3. Security	Cyphering, authentication	G09C
10. Imaging and sound technology	Imaging technique	G09G
10. Imaging and sound technology	Sound technique	G10L (exclude G10L13/027, G10L15, G10L17, G10L25/63,66)
8. Cognition and meaning understanding		G10L13/027
8. Cognition and meaning understanding		G10L15
8. Cognition and meaning understanding		G10L17
8. Cognition and meaning understanding		G10L25/63,66
6. Large-capacity and high speed storage		G11C (exclude G11C8/20)
3. Security	Cyphering, authentication	G11C8/20
11. Information communication device	Cable and conductor	H01B11
11. Information communication device	Semiconductor	H01L21, 25, 27, 43-51
11. Information communication device	Semiconductor	H01L29-33
11. Information communication device	Others	H01P
11. Information communication device	Others	H01Q
11. Information communication device	Optic device	H01S5
11. Information communication device	Electronic circuit	H03B
11. Information communication device	Electronic circuit	H03C
11. Information communication device	Electronic circuit	H03D
11. Information communication device	Electronic circuit	H03F
11. Information communication device	Electronic circuit	H03G
11. Information communication device	Electronic circuit	H03H
11. Information communication device	Electronic circuit	H03J

1. High speed network	Digital communication technique	H03K
1. High speed network	Digital communication technique	H03L
1. High speed network	Digital communication technique	H03M
1. High speed network	Others	H04B1/00-1/68, H04B1/72-1/76, H04B3-17 (exclude 1/59, H04B5, H04B7)
4. Sensor and device network	Electronic tag	H04B1/59
1. High speed network	Digital communication technique	H04B1/69-1/719
4. Sensor and device network	Electronic tag	H04B5
2. Mobile communication		H04B7
1. High speed network	Others	H04H
1. High speed network	Digital communication technique	H04J
3. Security	Cyphering, authentication	H04K
1. High speed network	Digital communication technique	H04L (exclude H04L9,H04L12/14)
3. Security	Electronic payment	H04L12/14
3. Security	Cyphering, authentication	H04L9
9. Human-interface		H04M1 (exclude H04M1/66-665, H04M1/667-675, H04M1/68-70, H04M1/727)
3. Security	Cyphering, authentication	H04M1/66-665
3. Security	Cyphering, authentication	H04M1/667-675
3. Security	Cyphering, authentication	H04M1/68-70
3. Security	Cyphering, authentication	H04M1/727
13. Others	Other related technique	H04M15
13. Others	Other related technique	H04M17
1. High speed network	Exchange,	H04M3-13,19,99

	selecting	
10. Imaging and sound technology	Imaging technique	H04N (exclude H04N5/78-5/907, H04N7/167-7/171)
6. Large-capacity and high speed storage		H04N5/78-5/907
3. Security	Cyphering, authentication	H04N7/167-7/171
1. High speed network	Exchange, selecting	H04Q
10. Imaging and sound technology	Sound technique	H04R
10. Imaging and sound technology	Sound technique	H04S
2. Mobile communication		H04W (exclude H04W4/24, W12)
3. Security	Cyphering, authentication	H04W12
3. Security	Electronic payment	H04W4/24

Legend: An asterisk precedes those IPC codes that are relevant, although of secondary importance, for the technology area

Technology area	Sub area	IPC
4. Sensor and device network	Electronic tag	*G01S13/74-84
4. Sensor and device network	Electronic tag	*G01V15
4. Sensor and device network	Electronic tag	*G01V3
6. Large-capacity and high speed storage		*G06F12/14
8. Cognition and meaning understanding		*G06F15/18
4. Sensor and device network	Sensor network	*G06F17/40
9. Human-interface		*G06F17/50
9. Human-interface		*G06K9
9. Human-interface		*G06T11
10. Imaging and sound technology	Imaging technique	*G06T11/80
9. Human-interface		*G06T13
9. Human-interface		*G06T15
9. Human-interface		*G06T17-19
10. Imaging and sound technology	Imaging technique	*G06T7
7. Large-capacity information analysis	Data analysis, simulation, management	*G08G1/01-065, G08G1/0962-0969
10. Imaging and sound technology	Sound technique	*G10L13/027, G10L15, G10L17, G10L25/63,66
6. Large-capacity and high speed		*G11C8/20,

storage		G11C16/22
1. High speed network	Others	*H04B1/59, H04B5, H04B7
1. High speed network	Digital communication technique	*H04L9, H04L12/14
9. Human-interface		*H04M1/66-665, H04M1/667-675, H04M1/68-70, H04M1/727
10. Imaging and sound technology	Imaging technique	*H04N5/78-5/907, H04N7/167
2. Mobile communication		*H04W4/24, H04W12
4. Sensor and device network	Others	*H04W84/10
4. Sensor and device network	Sensor network	*H04W84/18

A.4 OECD source 2

Technical field to be identified	code	detail	
IoT	IPC	10 codes (G05B019/418, G06F015/16, G08C017/02, H04B007/26, H04L012/28, H04L029/06, H04L029/08, H04W004/00, H04W072/04, H04W084/18,)	https://www.sciencedirect.com/science/article/pii/S0040162517305498
M2M/IoT	CPC	1 code (H04W4/005)	
Robotics and Autonomous Systems	IPC	CPC: B25J9/16* B25J9/0003 B25J11/0005 B25J11/0015 B60W30/00* Y10S901/00* G05D1/0088 G05D1/02* G05D2201/0207 G05D2201/0212 ICP: B25J9/16* B60W30/00* G05D1/02*	UK IP Office, 2014. Robotics and Autonomous Systems: A patent overview, UK Intellectual Property (IP) Office Available at. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/318236/Robotics_Autonomous.pdf
AI	IPC, UPC	38 codes for IPC (G06E1/00, G06E3/00, G06F15/00, G06F15/18, G06F17/00, G06F17/20, G06G7/00, G06N99/00, G05B13/02, G06E1/00, G06E3/00, G06F15/18, G06G7/00, G06N3/00, G06N3/08, G06N3/02, G06N3/12,	http://www.tandfonline.com/doi/pdf/10.5172/impp.2013.15.4.463?needAccess=true

		G06E1/00, G06E3/00, G06F15/00, G06F15/18, G06F17/00, G06J1/00, G06N3/00, G06N3/04, G06N3/10, G06F15/00, G06F15/18, G06F17/00, G06F9/44, G06N5/00, G06N5/02, G06N5/04, G06N7/00, G06N7/02, G06N7/04, G06N7/06, G06N7/08) 62 codes for UPC (706 1-62)	
AI	IPC	G06N	from my memo in meeting of last December(Not published)
AI	IPC	IPC codes: G06N 3/00 G06N 3/02 G06N 3/04 G06N 3/06 G06N 3/063 G06N 3/067 G06N 3/08 G06N 3/10 G06N 3/12 G06N 5/00 G06N 5/02 G06N 5/04 G06N 7/00 G06N 7/02 G06N 7/04 G06N 7/06 G06N 7/08 G06N 99/00	Fujii, H., & Managi, S. (2018). Trends and priority shifts in artificial intelligence technology invention: A global patent analysis. Economic Analysis and Policy https://www.sciencedirect.com/science/article/pii/S0313592617302539

Appendix B – Linking PATSTAT to the Web of Science

To link and match the PATSTAT database to the Web of Science (WoS) database, we use non-disclosed propriety software developed at CWTS10. We identify scientific literature cited in patents by parsing character strings in bibliographic records of those patents. The 'non patent literature' (NPL) patent-to-publication citations are stored as text strings containing bibliographic information. These reference strings have no fixed format or prescribed structure and therefore in general a parsing algorithm is needed to extract relevant information. The text strings describing a reference to a NPL document are parsed to find information that identifies a publication.

If a DOI string is found it is matched with the DOIs in the WoS database to find the bibliographic information. When no matching DOI can be found the NPL reference strings are parsed in order to find identifying information such as publication year, journal volume number, issue number, beginning page, ending page, author(s) and title. Combinations of the identifying information is used and matched with the information in the WoS. If enough identifying information elements can be matched to accurately identify a publication in the WoS the NPL-reference is considered to match the information in the WoS for a specific publication.

More specifically, the information in field NPL_PBIBLIO in PATSTAT's table TLS214 and also use the information provided by the EPO in the latest versions of PATSTAT - the EPO also parses the information. From the parsed information items provided by the EPO and the results of our own parsing software, we extract as much identifying information (DOI, Volume, Issue, Publication year, pages, author(s), title, journal) as possible. With the exception of the DOI's - as they should identify a document by definition - we match as many items as possible with our in-house version of the Web of Science database as possible to find matches. Having established 'citing-cited' matches between citing patents and cited research publications, this results in a table that contains pairs of PATSTAT's NPL_PUBLN_ID's and WOS UT. This table contains low-level information.

The data collection is done on the DOCDB_FAMILY level, by combining the information from our 'link table' with information from other tables in PATSTAT. The DOCDB_FAMILY level is used as the documents that make up such a patent family are equivalent in legal sense. Our computational analysis is based on patent families, rather than individual patents, where highly related patents filed in different patent systems, occur. The 2017 autumn version of PATSTAT is used. It is important to use the same version of PATSTAT as the IDs in TBL214 are in general unstable between different version of PATSTAT and for each version of everything needs to be recalculated.

[10] The search algorithms and subsequent automated data-cleaning and parsing routines, to extract unique cited scientific references, are obtained by a multi-stage procedure. Duplicate references are identified and standardized. Zhao et al. (2016) and Caron (2017) present examples of such a computerized approach. Our methodology differs in the sense that also includes pre-parsed information provided by the EPO.

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Understanding how progress in science is connected to technological development is crucial to get a better handle of the drivers and policy levers that can foster science-based innovation in a rapidly changing innovation ecosystems and knowledge-intensive economies.

One area of rising interest is understanding in more detail the role of basic and applied scientific research in driving new emerging technologies and related technological innovations. Science is an important source of novel ideas, tools, materials and prototypes in some areas of advanced technological development. The key question however is whether or not science has become increasingly important in recent technological developments. To address this question, in a broad systematic fashion, one needs to establish a stable frame of reference, appropriate empirical information, and a sufficiently long time-window.

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