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# Patents for evidence-based decision-making and smart specialisation

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## Abstract

The article compares and contrasts different sets of patent-based indicators, traditionally used to assess countries' technological capacities and specialisation. By doing that, we seek to determine how a chosen metric might affect the results of such an analysis, sometimes causing misleading conclusions on technological profiling. This goal is achieved with the statistical analysis of patent activity of the top-10 patenting economies. Findings indicate the need for policymakers to employ a complex of patent-related indicators when formulating technological specialisation strategies. Results also offer a taxonomy of technological capacities of the leading countries, which can further help understanding their current status and prospects for future progress. Thus, the paper might be of interest for researchers and analysts, which seek to offer methodological approaches and models to assess technological development of economies, as well as for policymakers governing the process.

**Keywords** Technological development · Technological specialization · Patent statistics

## 1 Introduction

Technologies and innovations play a crucial role in economic development and growth (Mokyr et al. 2015; WIPO 2015; Porter 1998; Mowery and Rosenberg 1995), which leads to accelerating expenditures to maintain and enhance the momentum (OECD 2018; Correa 2015). This in turn leads to the growing complexity of the governance and coordination of related policy (Meissner et al. 2017), requiring a comprehensive, evidence-based approach to define the directions for future developments at different levels. Furthermore, it compels countries and regions to develop unique technology and innovation profiles to remain competitive at the global level. The reason is found in the complexity of technology and thus innovation, demanding a concentration on core

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competence fields at national and regional levels. Such concentration and the resulting unique technology and innovation profile are important determinants for the respective locations place in global value chains, thus impacting the respective economic development.

A frequently used tool to define such profiles is the smart specialisation approach. Its rationale relies on a focus on existing resources (static view) and capabilities (dynamic view), ultimately helping to define priority areas of intervention and facilitation (Lopes et al. 2018). Although smart specialisation is mainly known from the innovation perspective—much broader than looking solely at the technology dimension—it still emphasizes the relative technological position and competences countries (or regions) (Meissner et al. 2019). The underlying motivation rests in the interpretation that innovation and technological capabilities are closely connected, and that economic growth depends on building strengths in both areas. The key aim of smart specialisation is to define national or regional science, technology and innovation (STI) strategies and related priorities in a manner to achieve complementarity between current and prospective capabilities that generate comparative advantages (Kopczynska and Ferreira 2018; Hausmann and Rodrik 2003). Moreover, it builds on the need to strengthen effective specialisation that is aligned with the local context rather than following fashionable industrial trends (Zacharakis et al. 2003).

The starting point of any smart specialisation strategy is a thorough understanding of countries' technological capabilities and potential, which further helps to develop policy strategies sensitive to countries' idiosyncratic technological profiles and competitive advantages (Capello and Kroll 2016) and to determine where resources should be allocated (Grillitsch 2016). This is a challenging task (Piirainen et al. 2017) since the ever changing and complex environment of STI requires target fields to be redefined in a continuous manner (Foray and Goenaga 2013). Again, stakes are high: inadequate policies can lead to undesirable lock-in effects (McCann and Ortega-Argilés 2015), which may hamper technological upgrading and catching-up (Capello and Lenzi 2016). To avoid this, decision-makers tend to employ a set of reliable approaches and tools, designed to analyse national technological profile and specialization, and to identify actual technological capabilities of a country—e.g. technological foresight (Meissner and Rudnik 2017; Miles et al. 2016; Havas et al. 2010), official statistics and composite indicators (Cerulli and Filippetti 2012; Freeman and Soete 2009; Grupp and Mogee 2004), etc.

The hard data considered for the identification of competitive advantages and priority setting in the field of technology and innovation might include various indicators of R&D funding, personnel and infrastructure, R&D outputs, innovation activity and production, technology export and import and others. The assessment of technological specialisation and capabilities normally includes an analysis of one or several indicators of patent activity of a country (Gokhberg 2003; Granstrand 1998; Griliches 1990). The reason behind the commitment is the dominance of patenting as a strategy to protect inventions in most technological domains, which makes patents a valuable and representative source of information on new technologies (Boschma et al. 2014). Patents include the indication of the technological fields they refer to, thus allowing the analysis of the thematic structure of a country's patents and identification of the most advanced and rapidly developing technologies. An important challenge here is to choose between the variety of patent-related indicators, available for these analytical and research purposes (Khramova et al. 2013), or to combine them in a comprehensive system or model. The issue seems to be insufficiently covered in academic literature and thus calls for an additional investigation in the complementarity of patent-related indicators for the analysis of the national technological capabilities and specialization. Therefore, our paper addresses the following research issues:

(i) whether the most traditional patent-related metrics used to analyse countries' technological capabilities covers all the high-potential technological domains for each country under study; or

(ii) if the selected indicators demonstrate different results when being used for technological capabilities analysis; and

(iii) how technological domains might be classified with a use of different patent-related indicators for theoretical and practical needs.

We derive our analysis from data on a set of patenting indicators which characterize technological capacities of the top 10 patenting countries and compare the evidence from each of the selected metrics. Hence, we look at different analytical scopes aiming at finding their levels of complementarity and discrepancy for smart specialisation recommendations. The analysis is limited to the top 10 countries to demonstrate the impact resulting from the issues stated above.

After this introduction, the article is structured as follows. Section 2 discusses the smart specialisation approach and patent statistics as a source of information for innovation policymaking. Section 3 contains a detailed description of the approach and empirical data used for the study. Section 4 presents the results of the analysis and technological domains classifications. Section 5 concludes with recommendations for policymakers on the assessment of countries' technological capacities for decision-making and investment strategies.

## 2 Theoretical and methodological foundations

### 2.1 Evidence-based decision-making and smart specialization: the need for objective measurement

Smart specialisation is an influential approach to technological profiling, specialisation and diversification, which has consistently gained ground among academics and policymakers alike (Fischer et al. 2018; Breschi et al. 2003). It has become an agenda for economic development in countries and regions (Lopes et al. 2019) and it stands for a change in the elaboration of traditional innovation policies (Carayannis et al. 2018). The mainstay of smart specialisation strategies lies on leveraging existing resources towards modernization of the productive structure and building the appropriate settings to reinforce the conditions for technological upgrading (Piirainen et al. 2017). Prioritization of selected activities is a core process of smart specialisation strategies (Capello and Lenzi 2016; Correa and Güçeri 2016; OECD 2013). The justification is rather simple: countries cannot achieve high levels of competitiveness in all fields, so priority setting becomes a strategic issue in innovation policy (Grillitsch 2016). In other words, smart specialisation strategies are sets of policy initiatives aiming at nurturing the most promising activities, considering current technological capabilities and potentialities (Foray 2014; Aghion et al. 2011).

Thus, the initial step of any smart specialisation strategy is a comprehending countries' (or regions') current strengths and potential, which guarantees a more efficient use of public resources (Iacobucci 2014) and enables aggregate competitiveness (Santini et al. 2016; Furman et al. 2002). This is a challenging task due to the diversity and dynamism of national technological profiles. First, countries' technological profiles unravel over time according to path dependent and evolutionary patterns (Petralia et al. 2017; Mancusi 2012; Neffke et al. 2011; Fai and Von Tunzelmann 2001; Archibugi and Pianta 1992; Dosi 1988).

Secondly, the size of countries or regions can affect how competitive advantages arise: larger countries are more prone to cover a wider array of technological fields, while smaller economies are usually specialised in a handful of selected niches (Mancusi 2012; Archibugi and Pianta 1992). More advanced countries tend to be in better positions to take diversification 'leaps' based on leading technological capabilities (Petralia et al. 2017). This requires smart specialisation policies to tackle technology upgrading considering countries' levels of development. Consequently, smart specialisation strategies should respect the variegated, evolutionary character of economic systems, considering their structures and existing dynamics (McCann and Ortega-Argilés 2015), as well as areas of comparative advantage (Heimeriks and Balland 2016; Correa and Güçeri 2016).

These conditions add considerable complexity to diagnostics for effective smart specialisation strategies. While policymakers need adequate tools for decision making in smart specialisation processes (Kotnik and Petrin 2017), the adequacy of methods for prioritization remain unclear (Komninos et al. 2014). Academic and expert literature offers a variety of approaches for this purpose.

The most traditional is a statistical approach—the use of models or systems of statistical indicators, characterizing scientific, technological and economic specialisation (OECD 2013). Such an analysis mostly involves longitudinal cross-country data thus allowing answering the question of 'where does a country (or region) stand in various science/technology/economic domains, compared to other countries (or regions)?' (OECD 2013, p. 36). Despite some limitations (e.g., focus on past and present instead of predicting emerging developments; a descriptive character and low explanatory potential, etc.), this approach offers a transparent and replicable methodology and allows cross-country comparisons.

Combining a set of indicators into a composite index is a more recent trend in evaluation of technological capabilities, which is called into being by the growing complexity of science, technology and innovation, and their interplay with national economies. Composite indices integrate various sub-indicators, each of them representing a specific component of national innovation system (Khayyat and Lee 2015; Filipetti and Peyrache 2011). The composite indices developed during last 20 years are difficult to enumerate. TC-index (Khayyat and Lee 2015), ArCo index (Archibugi and Coco 2004), UNDP Technology Achievement Index (TAI) (UNDP 2001), Science and Technology Capacity Index (Wagner et al. 2001)—are just a few examples of the enormous effort made by researchers in the field. These and other indicators tend to assess national or regional technological capacities as an aggregated concept, as 'a precondition for countries to generate and manage technical change' (Filipetti and Peyrache 2011, p. 1110). Hence, in most cases they do not allow a detailed analysis of capabilities of a given country in a specific technological domain, which is the major limitation of composite indices for policy-making and development of smart specialisation strategies.

Despite of the differences of the quantitative approaches designed for evaluation of national or regional technological capabilities and priority setting, they still share some common features. One of them is the use of patent statistics as a source of information (Urraca-Ruiz 2019; Piirainen et al. 2017; Becic and Švarc 2015).

## 2.2 Addressing Technological Capabilities through Patent Statistics

The assessment of technological capabilities and specialisation is traditionally based on the analysis of patent activity, its thematic structure and dynamics (Gokhberg 2003; Griliches

1990). In most technological areas, obtaining a patent is the dominant method of protecting R&D results, making patent documents an important source of information on new technologies (Boschma et al. 2014).

They contain detailed information about the inventor and assignee, the country of origin and patent office, the date of filing or granting, the technological domain the invention refers to, etc., allowing to solve numerous research problems (Fleming and Sorenson 2001). Although patent data carries well-known limitations in terms of innovation analysis (Griliches 1990), it still offers in-depth breakdowns for technologies allowing international comparisons in terms of technological profiles and areas of specialisation (Mancusi 2012; Archibugi and Pianta 1992). Accordingly, patents supply data related to technological development and—indirectly—its inherent levels of commercial interest (Jiang et al. 2019; Frietsch et al. 2014; Trappey et al. 2012; Harhoff et al. 1999; Trajtenberg 1990).

There is a variety of indicators designed and successfully used for these purposes—both at the aggregate and individual technological domain levels (Khramova et al. 2013; OECD 2009). The most traditional is a basic indicator of the number of patent applications or grants which refer to specific technological domains. For cross-country comparisons, the relative indicator—as per 1 million inhabitants or labour force is normally preferred, e.g. the TC-Index (Khayyat and Lee 2015). Some researchers—for composite indices of technological capabilities—tend to control patent applications for a specific patent office and consider those filed in the leading ones (for this purpose, patent applications/grants of USPTO or triadic patent families are the most popular indicators) (Filipetti and Peyrache 2011). To measure technological specialization, Revealed Technological Advantage Index (RTA) seems to be the first-choice indicator.

Despite the long history of using patent statistics for the evaluation of technological specialisation and capabilities, the issue of comparability and compatibility of the available patent-based indicators still seems to be relevant. The selection of metrics, made by researchers and experts, often looks subjective and pattern-driven. This article seeks to fill this gap and to determine how can the well-established patent-related indicators be employed to measure technological capabilities of countries—especially if used in a combination.

## 3 Data and approach

To test and contrast the potential of available metrics for understanding countries' capabilities, patent profiles of the top 10 patenting countries (in 2016) are analysed: China, US, Japan, Republic of Korea, Germany, France, UK, Switzerland, Netherlands, and Russia. Countries are the traditional units of analysis when technological capabilities are being assessed (Cerulli and Filippetti 2012) and national-level studies enjoys a more extensive empirical base as patent data is mostly aggregated on the national level.

For this study, patent applications filed by residents, both domestically and abroad, are assessed with a set of indicators calculated individually for each of the 35 technological domains defined in the classification of the World Intellectual Patent Organization (WIPO) (Schmoch 2008). The goal is to understand which technologies (e.g. digital, computer, medical, bio, microstructural, nano, etc.) can be classified as countries' technological capabilities according to multifaceted measures.

All calculations are made for a 5-year period (2012–2016, with 2016 data being last available) to avoid biases caused by sharp jumps and falls of countries' patent activity in specific years. Empirically, the study is fully based on WIPO data (IP Statistics Data Center), a reliable source of patent information that allows simple aggregation of data derived from national and regional patent offices worldwide.

As a first step, the *Revealed Technological Advantage index* (RTA), a well-known and broadly used indicator is assessed. This procedure allows us to quantify the degree of countries' technological specialisation in technological domains and it accurately signals where they stand in comparison to other nations (OECD 2013; Gokhberg 2003). For instance, Petralia et al. (2017) and Mancusi (2012) use RTA to address issues of relative specialisation patterns of technological upgrading. In this case, the evolutionary character of technological changes—and the way they unravel over time—are of fundamental interest for policymakers, as longitudinal studies clarify the dynamism of innovative activities.

For the identification of countries' technological specialization, RTA compares a structure of its patent activity (shares of technological domains in the total number of patent applications filed by residents) with the overall thematic structure of patent applications filed worldwide (Khramova et al. 2013). The lowest possible value of RTA is zero, which characterizes technological domains outside countries' specialization. The highest value is not limited, though in most cases it is below 10. The higher (lower) the RTA, the more (less) a country is specialized on the corresponding technology. Domains with RTA index = 1.0 are those where countries' efforts equal the world average. For the purposes of our empirical exercise, we have identified the domains where countries have an evident specialisation—where RTA indices differ significantly from the average values. For this, we only treat RTAs exceeding 1.1 as a representation of technological domains in which countries are specialized, i.e., which constitute their respective technological profiles.

The second step assesses the *Country Share* (CS) in the total number of worldwide patent applications attributed to specific technological domains. As a benchmark, averages are used—as calculated for all the technologies in a country—and domains with CS higher value as those where a country makes a more outstanding contribution is taken. It is assumed that these countries possess better chances for development and global competitiveness even if currently these technological domains are not a part of its specialisation profile as measured by RTA.

Third, the *Technology Share* (TS) measure is addressed. TS is another indicator which might be employed for identification of countries' technological capacities. It comprehends the share of patent applications attributed to a certain technological domain in the total number of patent applications filed by countries' residents, both domestically and abroad. Similarly to CS, for each country under consideration we grouped technologies around average values. The underlying rationale is that large domains, exceeding this benchmark already have basic conditions for further development: scientific and technological reserves, funding, a group of organizations which are able to transform these resources into new technologies.

As a last stage in the empirical approach, the *Growth Rate* (GR) of patent activity (2012–2016) is considered. This procedure allows identifying the most dynamic and thus potentially promising technological domains. Once again, rates for each country were calculated and compared to an average growth rate calculated for the countries being analyzed. Technological profiles of the studied countries, including the four abovementioned indicators, are provided in Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 in "Appendix".

To better understand the technological capabilities of the countries and to classify them, four categories of technologies—which were identified through each of the four analytical indicators presented above—were elaborated and then compared. This approach helps answering two of the research questions raised in the article, i.e., (i) if selected patent-related metrics show similar results and, if no, (ii) how they can be combined for better understanding of countries' technological capabilities.

## 4 Findings

The empirical analysis reveals that the technological profiles of countries differ substantially once each of the four indicators is addressed separately. To give an example, for the RTA analysis in China, 15 domains are associated to levels of technological specialization. However, this approach misses pharmaceuticals—an area with low RTA, but ranking high in terms of CS and TS, and thus which should also be considered as a relevant area of technological potential in this country. For other economies, results are similar: for most of them, the overall technological profile includes a wider spectrum of domains than those identified for individual technological specialisation metrics. This observation demonstrates that reductionist approaches, based on a single metric might be misleading when the technological profiles are under scrutiny. In turn, an inadequate appraisal of such conditions is likely to lead to failed attempts at establishing effective smart specialisation strategies. A more complex approach, utilizing all the patent-based indicators, considered for this study, allows better understanding of countries' technological capabilities and potential and thus enhances evidence-based decision-making.

For the countries assessed, a simple taxonomy based on a multidimensional assessment of patent data was developed. All the technological domains are divided into four categories according to their current status [measured by the static patent indicators: RTA, CS, TS and dynamics (GR)]:

1. *Technological leadership* the domains with RTA, CS and TS above the average values calculated for each country. These are the domains with steadily high patent activity, what might warrant countries a relatively safe and strong position on the global market and can be considered as a basis of further technological development.
2. *Strong capability* the domains with high CS and TS, but low (below 1) RTA. Include well-established technologies, currently outside the current technological specialization.
3. *Potential capability* high TS and GR, but low CS and RTA. Massive in a number of patent applications and fast-growing technological domains, but currently less developed if compared to other countries.
4. *'Jokers'* low CS, TS and RTA, but high GR. Small, sometimes incipient technological domains, in which a country does not occupy a competitive position on the global market, but fast growing, what gives them a chance for further progress.

Following the proposed taxonomy, the technological portfolios of the countries under study were analyzed to comprehend their current capabilities and potential (see Table 1). Each of them has a rather vast leadership area—not a surprise considering that the top-10 countries were selected. Nevertheless, they differ considerably according to the focus given to different categories of technologies and capabilities in the corresponding domains.

*China* takes a strong position in several 'traditional' domains, which might be considered as mostly low- to medium-tech: food chemistry; basic materials chemistry; materials, metallurgy; machine tools, etc. The only exception within the leadership area of the country is digital communication. Pharmaceuticals is another strong high-tech

**Table 1** Taxonomy of the technological capabilities of the countries. *Sources*: Authors' calculations based on the data from WIPO IP Statistics Data Center (the technological profiles of the countries are provided in "Appendix")

| Country | Leadership (high RTA, CS, TS) | Strong capability (high CS, TS—low RTA) | Potential capability (high TS, GR—low CS, RTA) | Jokers (high GR—low CS, TS, RTA) |
|---|---|---|---|---|
| China | ELEC: Digital communication<br>INSTR: Measurement<br>CHEM: Food chemistry; Basic materials chemistry; Materials, metallurgy; Chemical engineering<br>MECH: Machine tools; Other special machines<br>OTH: Civil engineering | CHEM: Pharmaceuticals<br>MECH: Handling | ELEC: Computer technology | ELEC: IT methods for management<br>CHEM: Analysis of biological materials; Medical technology<br>MECH: Transport<br>OTH: Furniture, games; Other consumer goods |
| USA | ELEC: Digital communication; Computer technology; IT methods for management<br>INSTR: Medical technology<br>CHEM: Organic fine chemistry; Biotechnology; Pharmaceuticals | CHEM: Basic materials chemistry | INSTR. Measurement<br>MECH: Transport<br>OTH: Civil engineering | INSTR: Control<br>CHEM: Food chemistry; Materials, metallurgy<br>MECH: Engines, pumps, turbines; Other special machines; Mechanical elements; Transport;<br>OTH: Other consumer goods |
| Japan | ELEC: Electrical machinery, apparatus, energy; Audio-visual technology; Semiconductors<br>INSTR: Optics<br>MECH: Engines, pumps, turbines; Transport<br>OTH: Furniture, games | MECH: Mechanical elements | INSTR: Medical technology | ELEC: Digital communication; IT methods for management<br>INSTR: Control<br>CHEM: Basic materials chemistry; Materials, metallurgy<br>MECH: Machine tools; Other special machines<br>OTH: Civil engineering |

**Table 1** (continued)

| Country | Leadership (high RTA, CS, TS) | Strong capability (high CS, TS—low RTA) | Potential capability (high TS, GR—low CS, RTA) | Jokers (high GR—low CS, TS, RTA) |
|---|---|---|---|---|
| Republic of Korea | ELEC: Electrical machinery, apparatus, energy; Audio-visual technology; Telecommunication; Digital communication; Computer technology; IT methods for management; Semiconductors<br>INSTR: Optics<br>MECH: Transport<br>OTH: Civil engineering | … | INSTR: Measurement; Medical technology | INSTR: Analysis of biological materials; Control; Medical technology<br>CHEM: Organic fine chemistry; Biotechnology; Pharmaceuticals; Macromolecular chemistry, polymers; Basic materials chemistry; Materials, metallurgy<br>MECH: Handling; Mechanical elements |
| Germany | ELEC: Electrical machinery, apparatus, energy<br>INSTR: Measurement; Medical technology<br>CHEM: Organic fine chemistry; Basic materials chemistry<br>MECH: Handling; Machine tools; Engines, pumps, turbines; Mechanical elements; Transport | MECH: Other special machines | ELEC: Computer technology | ELEC: Digital communication; Basic communication processes; IT methods for management<br>INSTR: Optics; Control<br>CHEM: Materials, metallurgy; Micro-structural and nano-technology |
| France | ELEC: Digital communication<br>INSTR: Measurement<br>CHEM: Organic fine chemistry; Biotechnology; Pharmaceuticals<br>MECH: Engines, pumps, turbines; Mechanical elements;<br>Transport | MECH: Other special machines<br>OTH: Civil engineering | ELEC: Electrical machinery, apparatus, energy<br>Computer technology<br>Medical technology | ELEC: IT methods for management<br>INSTR: Optics; Control<br>CHEM: Basic materials chemistry; Chemical engineering<br>MECH: Thermal processes and apparatus |

**Table 1** (continued)

| Country | Leadership (high RTA, CS, TS) | Strong capability (high CS, TS—low RTA) | Potential capability (high TS, GR—low CS, RTA) | Jokers (high GR—low CS, TS, RTA) |
|---|---|---|---|---|
| Switzerland | INSTR: Measurement; Medical technology<br>CHEM: Organic fine chemistry; Biotechnology; Pharmaceuticals; Food chemistry; Basic materials chemistry<br>MECH: Handling<br>OTH: Furniture, games; Other consumer goods | … | … | ELEC: Digital communication; Computer technology; IT methods for management<br>INSTR: Control<br>CHEM: Macromolecular chemistry, polymers; Materials, metallurgy; Micro-structural and nano-technology<br>MECH: Engines, pumps, turbines; Mechanical elements; Transport |
| United Kingdom | INSTR: Medical technology<br>CHEM: Organic fine chemistry; Biotechnology; Pharmaceuticals; Basic materials chemistry; Chemical engineering<br>MECH: Mechanical elements; Transport<br>OTH: Furniture, games; Other consumer goods; Civil engineering | INSTR: Measurement | ELEC: Electrical machinery, apparatus, energy; Digital communication | ELEC: IT methods for management<br>CHEM: Food chemistry; Materials, metallurgy; Micro-structural and nano-technology; Environmental technology |
| Netherlands | INSTR: Medical technology<br>CHEM: Organic fine chemistry; Biotechnology; Macromolecular chemistry, polymers; Food chemistry; Basic materials chemistry<br>MECH: Handling; Other special machines<br>OTH: Civil engineering | INSTR: Measurement | ELEC: Electrical machinery, apparatus, energy; Computer technology<br>CHEM: Pharmaceuticals | ELEC: IT methods for management<br>CHEN: Surface technology<br>MECH: Machine tools; Textile and paper machines; Transport<br>OTH: Furniture, games; Other consumer goods |

**Table 1** (continued)

| Country | Leadership (high RTA, CS, TS) | Strong capability (high CS, TS—low RTA) | Potential capability (high TS, GR—low CS, RTA) | Jokers (high GR—low CS, TS, RTA) |
|---|---|---|---|---|
| Russia | INSTR: Measurement; Medical technology<br>CHEM: Pharmaceuticals; Food chemistry; Materials, metallurgy; Chemical engineering<br>MECH: Engines, pump, turbines; Other special machines<br>OTH: Civil engineering | … | … | ELEC: Telecommunications; Computer technology; IT methods for management<br>CHEM: Biotechnology<br>MECH: Mechanical elements<br>OTH: Furniture, games |

Technological domains are grouped into categories according to Technology Concordance Table (Schmoch 2008): Electrical Engineering (ELEC); Instruments (INSTR); Chemistry (CHEM); Mechanical Engineering (MECH); Other fields (OTH) capability of China, though not within the sphere of its technological specialisation—most probably due to the rapid growth of this domain worldwide, with many countries giving a specific attention to its development and support.

*The United States* has a focus on ICT and healthcare-related technologies: biotechnology and pharmaceuticals. Currently, several domains not inherent to the US technological portfolio are growing fast (such as food chemistry, materials and metallurgy, engines, pumps ad turbines, etc.), with transport demonstrating the highest growth rate. Thus, it might be expected that the US will catch up in transport technologies over a mid-term perspective. This is especially likely to happen when considering this domain in pair with digital communication, computer technology and other technologies the country is strong in: all these domains are interrelated for the often-predicted next generation of transport, namely autonomous vehicles and related devices.

The strongest technological capabilities of *Japan* include those traditional for the country: electrical machinery, apparatus, energy; audio-visual technology; semiconductors; optics; and engines, pumps, turbines. It is worth mentioning the steady decrease in Japanese patent activity in audio-visual technology, optics, and semiconductors, which suggests that these domains have reached maturity, with a certain likelihood of replacement by new priorities. Some novel technologies for the portfolio are being developed rather intensively, thus giving Japan better chances to diversify in future. Among them, the largest area is medical technology: RTA and CS are rather low, while TS and GR are above average. A group of 'jokers' is also diverse with domains of all the five categories (electrical engineering, instruments, chemistry, mechanical engineering, and other domains).

*The Republic of Korea* impresses with an ICT-oriented technological portfolio: all the domains included into this category are in the sphere of the country's leadership. An evolving focus is chemistry with a wide range of technologies being today's 'jokers' and demonstrating a stable and rapid growth: organic fine chemistry, pharmaceuticals, macromolecular chemistry, polymers, etc.

*Germany* possesses a diversified portfolio, with quite an expected dominance in mechanical engineering. The technologies in which this country is traditionally strong in includes handling; machine tools; engines, pumps, turbines; mechanical elements; transport. Nevertheless, a new ICT-turn might appear as Germany currently demonstrates a catching-up activity in domains such as computer technology, digital communication, basic communication processes, and IT methods for management. Although these technologies are relatively weak in its present patent portfolio, above average growth rates suggest the inclusion of the country as an important player within these technologies in years to come—a perspective that could go unnoticed if only a static view of indicators were to be analysed.

The patent activity of *France* also demonstrates the diverse technological capabilities of the country. However, two of the domains which might be considered as the France' most traditional—organic fine chemistry and pharmaceuticals—demonstrate a stable negative GR. This might suggest that the country may face a significant decline among the leading nations if it does not tackle these trends properly.

*Switzerland* has a strong focus on the chemistry-related technological domains. Some of them (namely organic fine chemistry, biotechnology, pharmaceuticals, etc.) can be considered the guarantee of its leading position on the technological market, while others (macromolecular chemistry, polymers; materials, metallurgy; microstructural and nanotechnology) have recently started a rapid growth and thus give a chance for future development and diversification of the technological portfolio of the country. No technological domains are identified as strong or potential capabilities of Switzerland. That might be an indicator of a stability of its technological priorities: all the potentials have already been transformed into competitive advantages.

*United Kingdom* is somehow similar to Switzerland if the technological capacities of the two countries are measured with a use of patent statistics. Again, chemistry and a group of the technologies for healthcare are among the most significant in the British technological portfolio. However, this country seems more successful in promoting ICT-related sectors: recently, two technological domains (electrical machinery, apparatus, energy; digital communication) have grown considerably to become potential capabilities of the country. It is worth mentioning that none of the European states takes the leading position in ICT globally, but if all the patent-based metrics are considered, the catching-up activity of the countries becomes evident, and this tendency might change the current alignment of forces. This trend is also observable in the other two countries in the top-10 list.

*The Netherlands* and *Russia* have diverse technological portfolios with a wide spectrum of domains inside their respective areas of leadership, which guarantee their high positions in the global ranking. However, for most of these technologies, the Netherlands and Russia show GRs that are close to benchmark values. While this suggests a relatively stable patent activity in the domains, it provides hints that other, more dynamic countries have the potential to bypass the Netherlands and Russia.

## 5 Concluding remarks

The analysis undertaken in this article provides an indicative overview about the means of using patent-related indicators to assessing the technological strengths and competitive positions at country level. It also shows that using patent-related indicators separately inherits the risk of misinterpretation. Moreover, the study offers a taxonomy of technological capacities of the leading countries, which can further help understanding their current status and prospects for future progress. Such exercise represents a straightforward and useful tool for smart specialisation policies as combines distinct scopes of information concerning the dynamics of countries' technological development.

Taking all analyses together, it becomes clear that a comprehensive assessment of countries technology portfolio requires application of a complex of patent-related indicators. Otherwise, simplistic and misplaced conceptions about the strengths and potential of countries technological portfolios are likely to harm innovation policy and strategies that target at implementing smart specialisation approaches.

In this regard, countries' capabilities to achieve technological evolution towards high value-added activities involves a complex understanding of nations' knowledge portfolios (Lee 2013; Radosevic and Yoruk 2016), their productive structures (McCann and Ortega-Argilés 2015), and areas demonstrating comparative advantages (Heimeriks and Balland 2016; Correa and Güçeri 2016). This is fundamentally related to the complexity of economic structures (Hidalgo and Hausmann 2009; Krüger 2008), dynamic specialisation towards emerging technologies (Radosevic and Yoruk 2014), and sequential upgrading based on leading sectors (Ozawa 2009). Accordingly, the empirical exercise underscores that countries' own technological profiles can significantly diverge in terms of content when different indicators are taken individually, a clear representation of the multidimensional phenomenon under scrutiny. This is a critical aspect to consider when it comes to the use of such indicators as quantitative subsidies for STI priority-setting or smart specialisation activities. Given the importance of national or regional STI strategies—as well as related allocation of resources—it becomes key to assure that indicators used for decision making processes are meaningful.

In this regard, the article opens relevant avenues for future research in the context of smart specialisation strategies. First, we recognize that derivations from data representing leading countries in terms of patents may not hold for relatively laggard nations. The results might also be limited by the adopted timeframe—which falls short in defining long-term evolutionary processes of innovation systems. The study also faces the usual constraints related to patent data—additional information that can link technological profiles to other measures of aggregate economic competitiveness (e.g. trade statistics) can be a way forward in understanding technological development.

From a different perspective, the study offers directions from a purely quantitative viewpoint. Qualitative case studies that look into sectoral relevance for economic systems and potential to influence STI policies are also needed to understand the complexity of smart specialisation processes within contexts of technological inertia. Complementarily, further connections of the employed methodology with foresight exercises can represent a fruitful path for researchers in this field.

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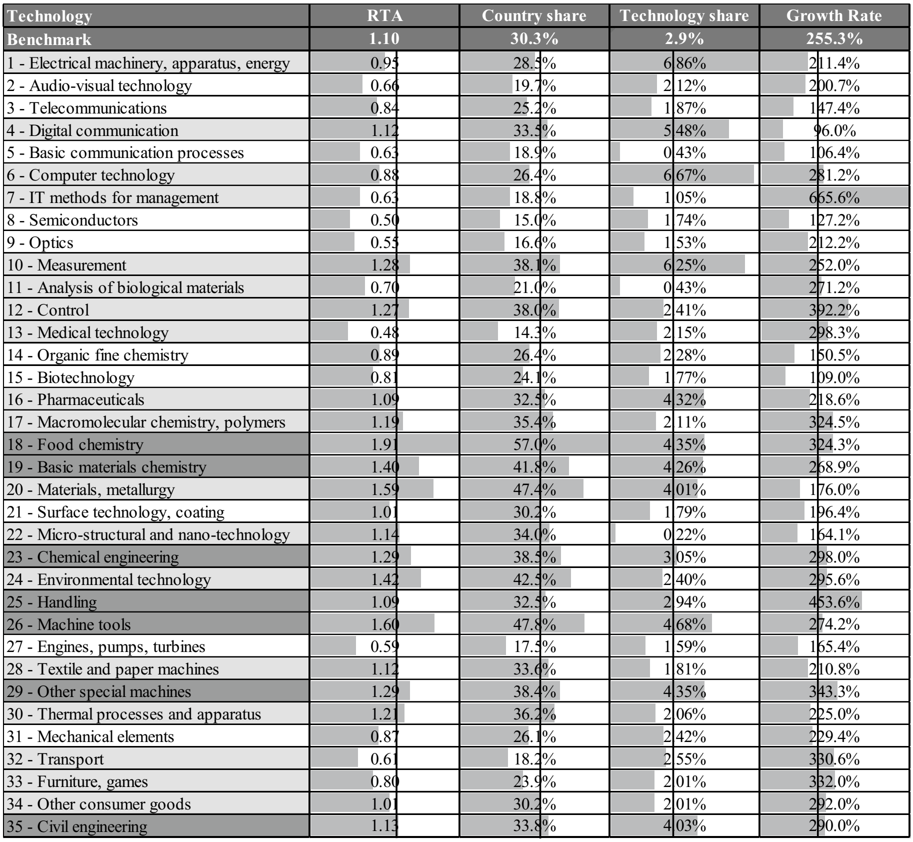
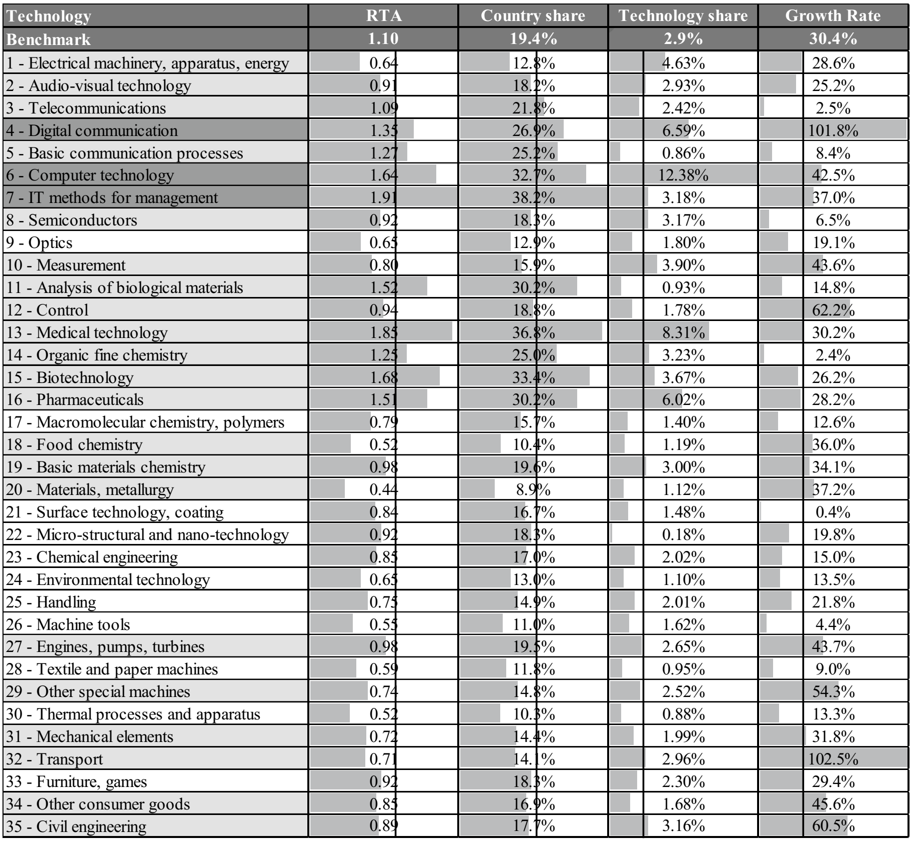
## Appendix: Technological profiles of the 10 studied countries

See Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10.



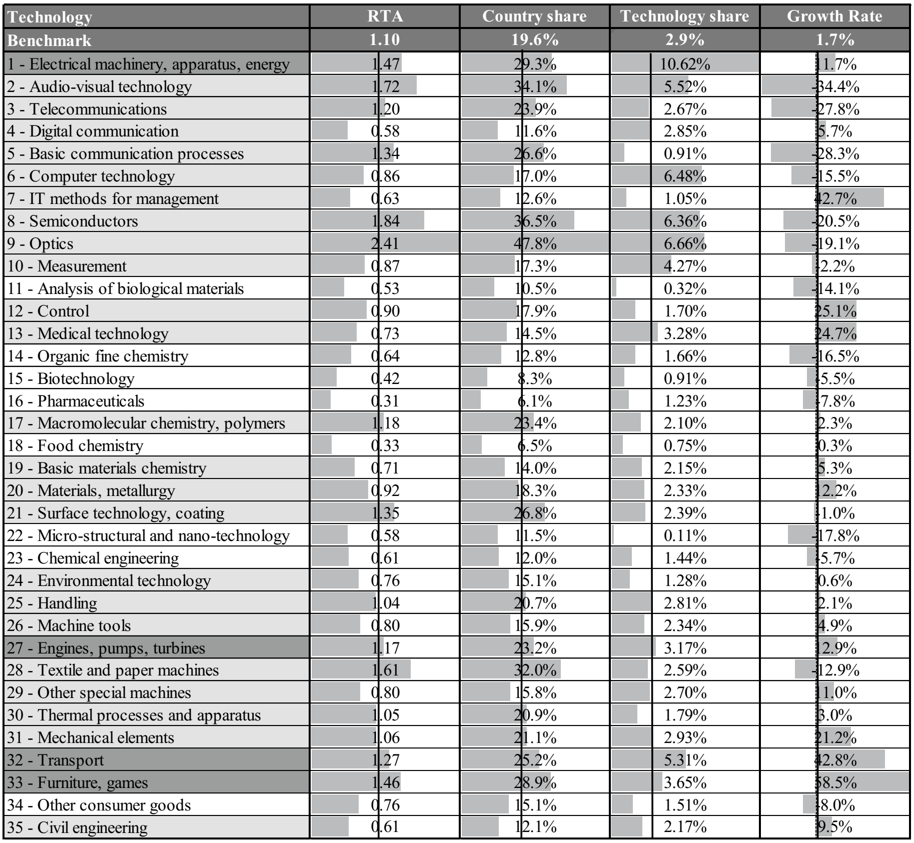
| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **30.3%** | **2.9%** | **255.3%** |
| 1 - Electrical machinery, apparatus, energy | 0.95 | 28.5% | 6.86% | 211.4% |
| 2 - Audio-visual technology | 0.66 | 19.7% | 2.12% | 200.7% |
| 3 - Telecommunications | 0.84 | 25.2% | 1.87% | 147.4% |
| 4 - Digital communication | 1.12 | 33.5% | 5.48% | 96.0% |
| 5 - Basic communication processes | 0.63 | 18.9% | 0.43% | 106.4% |
| 6 - Computer technology | 0.88 | 26.4% | 6.67% | 281.2% |
| 7 - IT methods for management | 0.63 | 18.8% | 1.05% | 665.6% |
| 8 - Semiconductors | 0.50 | 15.0% | 1.74% | 127.2% |
| 9 - Optics | 0.55 | 16.6% | 1.53% | 212.2% |
| 10 - Measurement | 1.28 | 38.1% | 6.25% | 252.0% |
| 11 - Analysis of biological materials | 0.70 | 21.0% | 0.43% | 271.2% |
| 12 - Control | 1.27 | 38.0% | 2.41% | 392.2% |
| 13 - Medical technology | 0.48 | 14.3% | 2.15% | 298.3% |
| 14 - Organic fine chemistry | 0.89 | 26.4% | 2.28% | 150.5% |
| 15 - Biotechnology | 0.81 | 24.1% | 1.77% | 109.0% |
| 16 - Pharmaceuticals | 1.09 | 32.5% | 4.32% | 218.6% |
| 17 - Macromolecular chemistry, polymers | 1.19 | 35.4% | 2.11% | 324.5% |
| 18 - Food chemistry | 1.91 | 57.0% | 4.35% | 324.3% |
| 19 - Basic materials chemistry | 1.40 | 41.8% | 4.26% | 268.9% |
| 20 - Materials, metallurgy | 1.59 | 47.4% | 4.01% | 176.0% |
| 21 - Surface technology, coating | 1.01 | 30.2% | 1.79% | 196.4% |
| 22 - Micro-structural and nano-technology | 1.14 | 34.0% | 0.22% | 164.1% |
| 23 - Chemical engineering | 1.29 | 38.5% | 3.05% | 298.0% |
| 24 - Environmental technology | 1.42 | 42.5% | 2.40% | 295.6% |
| 25 - Handling | 1.09 | 32.5% | 2.94% | 453.6% |
| 26 - Machine tools | 1.60 | 47.8% | 4.68% | 274.2% |
| 27 - Engines, pumps, turbines | 0.59 | 17.5% | 1.59% | 165.4% |
| 28 - Textile and paper machines | 1.12 | 33.6% | 1.81% | 210.8% |
| 29 - Other special machines | 1.29 | 38.4% | 4.35% | 343.3% |
| 30 - Thermal processes and apparatus | 1.21 | 36.2% | 2.06% | 225.0% |
| 31 - Mechanical elements | 0.87 | 26.1% | 2.42% | 229.4% |
| 32 - Transport | 0.61 | 18.2% | 2.55% | 330.6% |
| 33 - Furniture, games | 0.80 | 23.9% | 2.01% | 332.0% |
| 34 - Other consumer goods | 1.01 | 30.2% | 2.01% | 292.0% |
| 35 - Civil engineering | 1.13 | 33.8% | 4.03% | 290.0% |

**Fig. 1** Technological profile of China in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



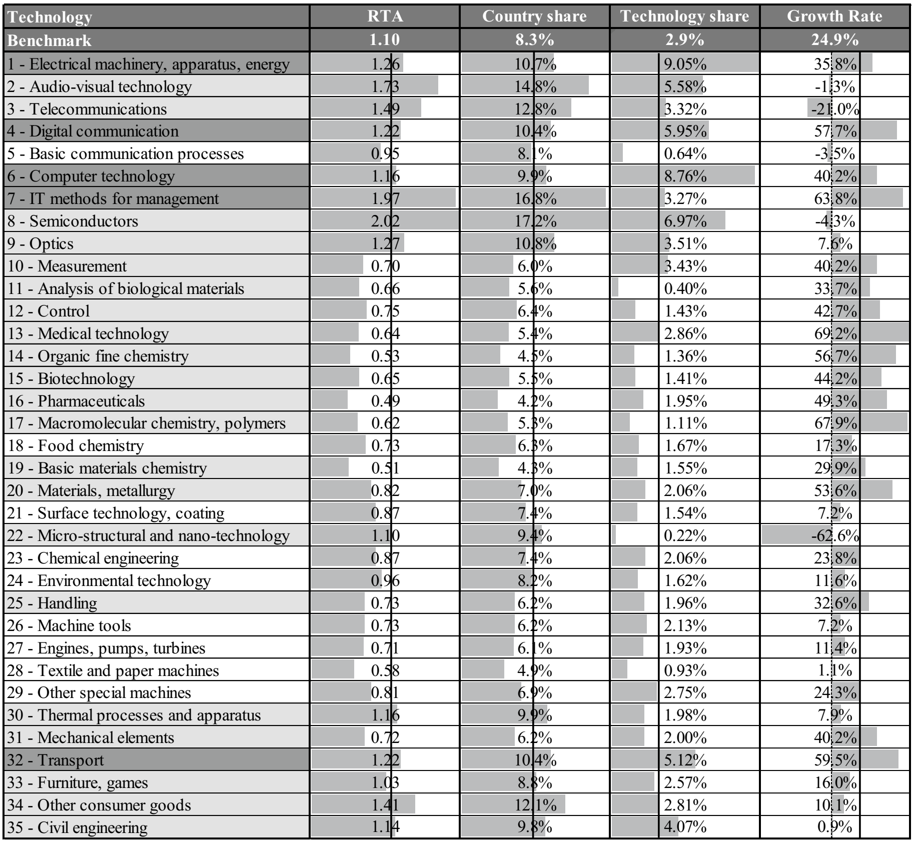
| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **19.4%** | **2.9%** | **30.4%** |
| 1 - Electrical machinery, apparatus, energy | 0.64 | 12.8% | 4.63% | 28.6% |
| 2 - Audio-visual technology | 0.91 | 18.2% | 2.93% | 25.2% |
| 3 - Telecommunications | 1.09 | 21.8% | 2.42% | 2.5% |
| 4 - Digital communication | 1.35 | 26.9% | 6.59% | 101.8% |
| 5 - Basic communication processes | 1.27 | 25.2% | 0.86% | 8.4% |
| 6 - Computer technology | 1.64 | 32.7% | 12.38% | 42.5% |
| 7 - IT methods for management | 1.91 | 38.2% | 3.18% | 37.0% |
| 8 - Semiconductors | 0.92 | 18.3% | 3.17% | 6.5% |
| 9 - Optics | 0.65 | 12.9% | 1.80% | 19.1% |
| 10 - Measurement | 0.80 | 15.9% | 3.90% | 43.6% |
| 11 - Analysis of biological materials | 1.52 | 30.2% | 0.93% | 14.8% |
| 12 - Control | 0.94 | 18.8% | 1.78% | 62.2% |
| 13 - Medical technology | 1.85 | 36.8% | 8.31% | 30.2% |
| 14 - Organic fine chemistry | 1.25 | 25.0% | 3.23% | 2.4% |
| 15 - Biotechnology | 1.68 | 33.4% | 3.67% | 26.2% |
| 16 - Pharmaceuticals | 1.51 | 30.2% | 6.02% | 28.2% |
| 17 - Macromolecular chemistry, polymers | 0.79 | 15.7% | 1.40% | 12.6% |
| 18 - Food chemistry | 0.52 | 10.4% | 1.19% | 36.0% |
| 19 - Basic materials chemistry | 0.98 | 19.6% | 3.00% | 34.1% |
| 20 - Materials, metallurgy | 0.44 | 8.9% | 1.12% | 37.2% |
| 21 - Surface technology, coating | 0.84 | 16.7% | 1.48% | 0.4% |
| 22 - Micro-structural and nano-technology | 0.92 | 18.3% | 0.18% | 19.8% |
| 23 - Chemical engineering | 0.85 | 17.0% | 2.02% | 15.0% |
| 24 - Environmental technology | 0.65 | 13.0% | 1.10% | 13.5% |
| 25 - Handling | 0.75 | 14.9% | 2.01% | 21.8% |
| 26 - Machine tools | 0.55 | 11.0% | 1.62% | 4.4% |
| 27 - Engines, pumps, turbines | 0.98 | 19.5% | 2.65% | 43.7% |
| 28 - Textile and paper machines | 0.59 | 11.8% | 0.95% | 9.0% |
| 29 - Other special machines | 0.74 | 14.8% | 2.52% | 54.3% |
| 30 - Thermal processes and apparatus | 0.52 | 10.3% | 0.88% | 13.3% |
| 31 - Mechanical elements | 0.72 | 14.4% | 1.99% | 31.8% |
| 32 - Transport | 0.71 | 14.1% | 2.96% | 102.5% |
| 33 - Furniture, games | 0.92 | 18.3% | 2.30% | 29.4% |
| 34 - Other consumer goods | 0.85 | 16.9% | 1.68% | 45.6% |
| 35 - Civil engineering | 0.89 | 17.7% | 3.16% | 60.5% |

**Fig. 2** Technological profile of the USA in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| Benchmark | 1.10 | 19.6% | 2.9% | 1.7% |
| 1 - Electrical machinery, apparatus, energy | 1.47 | 29.3% | 10.62% | 11.7% |
| 2 - Audio-visual technology | 1.72 | 34.1% | 5.52% | -34.4% |
| 3 - Telecommunications | 1.20 | 23.9% | 2.67% | -27.8% |
| 4 - Digital communication | 0.58 | 11.6% | 2.85% | 5.7% |
| 5 - Basic communication processes | 1.34 | 26.6% | 0.91% | -28.3% |
| 6 - Computer technology | 0.86 | 17.0% | 6.48% | -15.5% |
| 7 - IT methods for management | 0.63 | 12.6% | 1.05% | 42.7% |
| 8 - Semiconductors | 1.84 | 36.5% | 6.36% | -20.5% |
| 9 - Optics | 2.41 | 47.8% | 6.66% | -19.1% |
| 10 - Measurement | 0.87 | 17.3% | 4.27% | -2.2% |
| 11 - Analysis of biological materials | 0.53 | 10.5% | 0.32% | -14.1% |
| 12 - Control | 0.90 | 17.9% | 1.70% | 25.1% |
| 13 - Medical technology | 0.73 | 14.5% | 3.28% | 24.7% |
| 14 - Organic fine chemistry | 0.64 | 12.8% | 1.66% | -16.5% |
| 15 - Biotechnology | 0.42 | 8.3% | 0.91% | -5.5% |
| 16 - Pharmaceuticals | 0.31 | 6.1% | 1.23% | -7.8% |
| 17 - Macromolecular chemistry, polymers | 1.18 | 23.4% | 2.10% | 2.3% |
| 18 - Food chemistry | 0.33 | 6.5% | 0.75% | 0.3% |
| 19 - Basic materials chemistry | 0.71 | 14.0% | 2.15% | 5.3% |
| 20 - Materials, metallurgy | 0.92 | 18.3% | 2.33% | 12.2% |
| 21 - Surface technology, coating | 1.35 | 26.8% | 2.39% | -1.0% |
| 22 - Micro-structural and nano-technology | 0.58 | 11.5% | 0.11% | -17.8% |
| 23 - Chemical engineering | 0.61 | 12.0% | 1.44% | -5.7% |
| 24 - Environmental technology | 0.76 | 15.1% | 1.28% | 0.6% |
| 25 - Handling | 1.04 | 20.7% | 2.81% | 2.1% |
| 26 - Machine tools | 0.80 | 15.9% | 2.34% | 4.9% |
| 27 - Engines, pumps, turbines | 1.17 | 23.2% | 3.17% | 12.9% |
| 28 - Textile and paper machines | 1.61 | 32.0% | 2.59% | -12.9% |
| 29 - Other special machines | 0.80 | 15.8% | 2.70% | 11.0% |
| 30 - Thermal processes and apparatus | 1.05 | 20.9% | 1.79% | 3.0% |
| 31 - Mechanical elements | 1.06 | 21.1% | 2.93% | 21.2% |
| 32 - Transport | 1.27 | 25.2% | 5.31% | 42.8% |
| 33 - Furniture, games | 1.46 | 28.9% | 3.65% | 58.5% |
| 34 - Other consumer goods | 0.76 | 15.1% | 1.51% | -8.0% |
| 35 - Civil engineering | 0.61 | 12.1% | 2.17% | 9.5% |

**Fig. 3** Technological profile of Japan in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **8.3%** | **2.9%** | **24.9%** |
| 1 - Electrical machinery, apparatus, energy | 1.26 | 10.7% | 9.05% | 35.8% |
| 2 - Audio-visual technology | 1.73 | 14.8% | 5.58% | -1.3% |
| 3 - Telecommunications | 1.49 | 12.8% | 3.32% | -21.0% |
| 4 - Digital communication | 1.22 | 10.4% | 5.95% | 57.7% |
| 5 - Basic communication processes | 0.95 | 8.1% | 0.64% | -3.5% |
| 6 - Computer technology | 1.16 | 9.9% | 8.76% | 40.2% |
| 7 - IT methods for management | 1.97 | 16.8% | 3.27% | 63.8% |
| 8 - Semiconductors | 2.02 | 17.2% | 6.97% | -4.3% |
| 9 - Optics | 1.27 | 10.8% | 3.51% | 7.6% |
| 10 - Measurement | 0.70 | 6.0% | 3.43% | 40.2% |
| 11 - Analysis of biological materials | 0.66 | 5.6% | 0.40% | 33.7% |
| 12 - Control | 0.75 | 6.4% | 1.43% | 42.7% |
| 13 - Medical technology | 0.64 | 5.4% | 2.86% | 69.2% |
| 14 - Organic fine chemistry | 0.53 | 4.5% | 1.36% | 56.7% |
| 15 - Biotechnology | 0.65 | 5.5% | 1.41% | 44.2% |
| 16 - Pharmaceuticals | 0.49 | 4.2% | 1.95% | 49.3% |
| 17 - Macromolecular chemistry, polymers | 0.62 | 5.3% | 1.11% | 67.9% |
| 18 - Food chemistry | 0.73 | 6.3% | 1.67% | 17.3% |
| 19 - Basic materials chemistry | 0.51 | 4.3% | 1.55% | 29.9% |
| 20 - Materials, metallurgy | 0.82 | 7.0% | 2.06% | 53.6% |
| 21 - Surface technology, coating | 0.87 | 7.4% | 1.54% | 7.2% |
| 22 - Micro-structural and nano-technology | 1.10 | 9.4% | 0.22% | -62.6% |
| 23 - Chemical engineering | 0.87 | 7.4% | 2.06% | 23.8% |
| 24 - Environmental technology | 0.96 | 8.2% | 1.62% | 11.6% |
| 25 - Handling | 0.73 | 6.2% | 1.96% | 32.6% |
| 26 - Machine tools | 0.73 | 6.2% | 2.13% | 7.2% |
| 27 - Engines, pumps, turbines | 0.71 | 6.1% | 1.93% | 11.4% |
| 28 - Textile and paper machines | 0.58 | 4.9% | 0.93% | 1.1% |
| 29 - Other special machines | 0.81 | 6.9% | 2.75% | 24.3% |
| 30 - Thermal processes and apparatus | 1.16 | 9.9% | 1.98% | 7.9% |
| 31 - Mechanical elements | 0.72 | 6.2% | 2.00% | 40.2% |
| 32 - Transport | 1.22 | 10.4% | 5.12% | 59.5% |
| 33 - Furniture, games | 1.03 | 8.8% | 2.57% | 16.0% |
| 34 - Other consumer goods | 1.41 | 12.1% | 2.81% | 10.1% |
| 35 - Civil engineering | 1.14 | 9.8% | 4.07% | 0.9% |

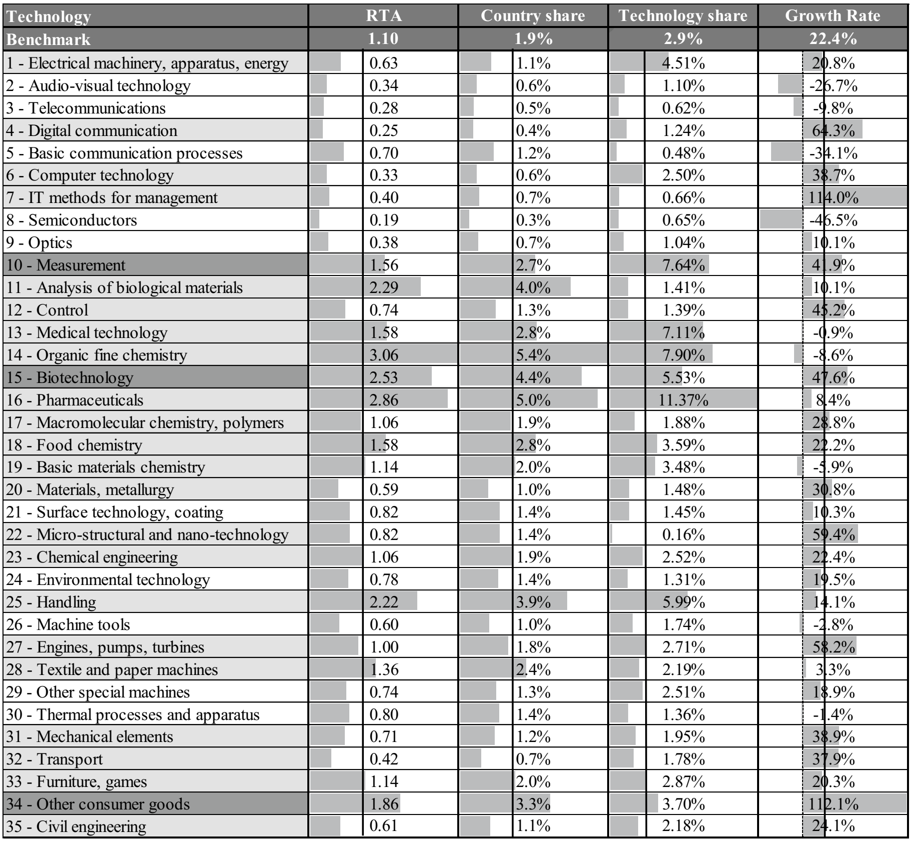
**Fig. 4** Technological profile of the Republic of Korea in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018

| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **8.0%** | **2.9%** | **0.3%** |
| 1 - Electrical machinery, apparatus, energy | 1.25 | 10.0% | 8.99% | 15.3% |
| 2 - Audio-visual technology | 0.46 | 3.7% | 1.47% | 1.0% |
| 3 - Telecommunications | 0.42 | 3.4% | 0.93% | -9.7% |
| 4 - Digital communication | 0.32 | 2.5% | 1.56% | 33.3% |
| 5 - Basic communication processes | 0.85 | 6.8% | 0.58% | 17.5% |
| 6 - Computer technology | 0.40 | 3.2% | 2.99% | 8.6% |
| 7 - IT methods for management | 0.27 | 2.1% | 0.44% | 21.4% |
| 8 - Semiconductors | 0.74 | 6.0% | 2.58% | -8.8% |
| 9 - Optics | 0.58 | 4.6% | 1.59% | 17.8% |
| 10 - Measurement | 1.12 | 8.9% | 5.47% | 12.9% |
| 11 - Analysis of biological materials | 1.01 | 8.1% | 0.62% | -19.5% |
| 12 - Control | 0.95 | 7.6% | 1.80% | 25.2% |
| 13 - Medical technology | 1.09 | 8.7% | 4.91% | 4.6% |
| 14 - Organic fine chemistry | 1.40 | 11.2% | 3.61% | -16.2% |
| 15 - Biotechnology | 0.84 | 6.7% | 1.85% | -6.5% |
| 16 - Pharmaceuticals | 0.71 | 5.7% | 2.83% | -22.1% |
| 17 - Macromolecular chemistry, polymers | 1.21 | 9.7% | 2.16% | -5.4% |
| 18 - Food chemistry | 0.22 | 1.7% | 0.49% | -22.4% |
| 19 - Basic materials chemistry | 1.14 | 9.1% | 3.48% | -14.4% |
| 20 - Materials, metallurgy | 0.77 | 6.1% | 1.94% | 5.7% |
| 21 - Surface technology, coating | 1.00 | 8.0% | 1.77% | -10.7% |
| 22 - Micro-structural and nano-technology | 1.03 | 8.2% | 0.20% | 3.5% |
| 23 - Chemical engineering | 1.19 | 9.5% | 2.81% | -6.6% |
| 24 - Environmental technology | 0.93 | 7.5% | 1.57% | -6.6% |
| 25 - Handling | 1.23 | 9.8% | 3.31% | 7.4% |
| 26 - Machine tools | 1.29 | 10.3% | 3.76% | -10.0% |
| 27 - Engines, pumps, turbines | 2.29 | 18.3% | 6.21% | 9.1% |
| 28 - Textile and paper machines | 0.95 | 7.6% | 1.53% | -10.4% |
| 29 - Other special machines | 1.07 | 8.5% | 3.61% | 8.8% |
| 30 - Thermal processes and apparatus | 1.14 | 9.1% | 1.93% | -20.3% |
| 31 - Mechanical elements | 2.41 | 19.3% | 6.66% | 14.6% |
| 32 - Transport | 2.21 | 17.6% | 9.25% | 17.9% |
| 33 - Furniture, games | 0.67 | 5.3% | 1.67% | -6.2% |
| 34 - Other consumer goods | 1.04 | 8.3% | 2.08% | -13.3% |
| 35 - Civil engineering | 0.94 | 7.5% | 3.35% | -5.5% |

**Fig. 5** Technological profile of Germany in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018

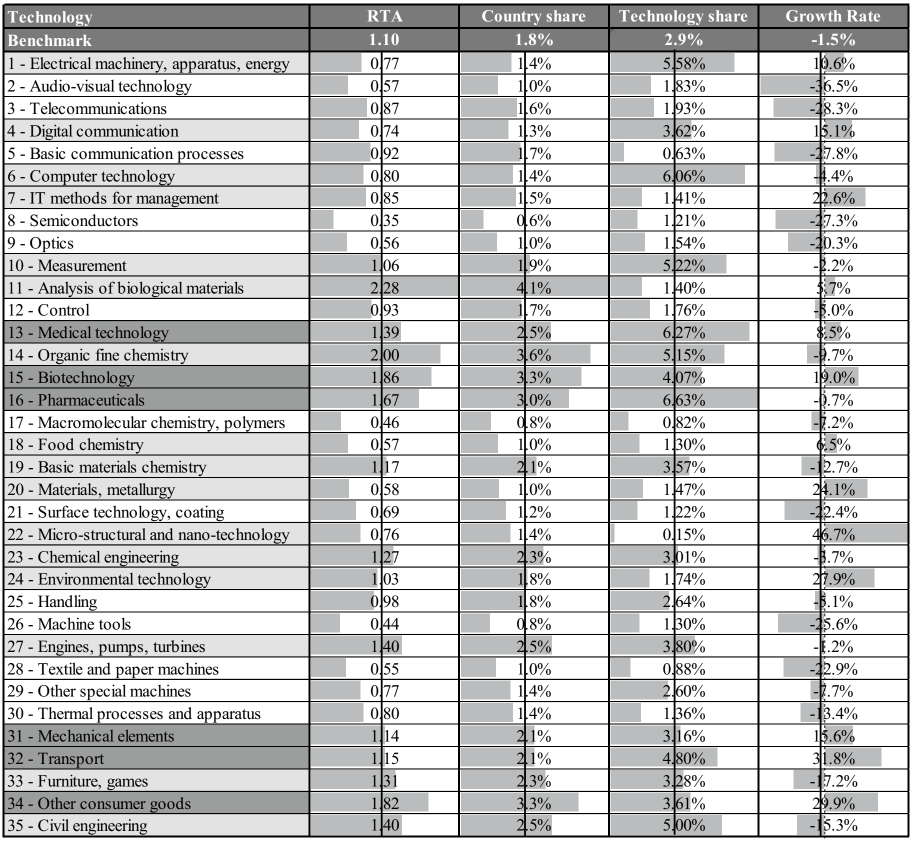
| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **3.1%** | **2.9%** | **10.6%** |
| 1 - Electrical machinery, apparatus, energy | 0.86 | 2.7% | 6.17% | 33.2% |
| 2 - Audio-visual technology | 0.78 | 2.4% | 2.50% | -11.8% |
| 3 - Telecommunications | 1.14 | 3.6% | 2.53% | -5.2% |
| 4 - Digital communication | 1.24 | 3.9% | 6.08% | 22.3% |
| 5 - Basic communication processes | 0.98 | 3.1% | 0.67% | -35.6% |
| 6 - Computer technology | 0.76 | 2.4% | 5.71% | 15.3% |
| 7 - IT methods for management | 0.55 | 1.7% | 0.91% | 63.8% |
| 8 - Semiconductors | 0.70 | 2.2% | 2.42% | -12.2% |
| 9 - Optics | 0.65 | 2.0% | 1.79% | 28.6% |
| 10 - Measurement | 1.06 | 3.3% | 5.19% | 23.9% |
| 11 - Analysis of biological materials | 1.62 | 5.1% | 1.00% | -6.0% |
| 12 - Control | 0.69 | 2.2% | 1.31% | 15.5% |
| 13 - Medical technology | 0.86 | 2.7% | 3.88% | 40.3% |
| 14 - Organic fine chemistry | 1.97 | 6.2% | 5.09% | -20.8% |
| 15 - Biotechnology | 1.39 | 4.4% | 3.04% | 14.8% |
| 16 - Pharmaceuticals | 1.18 | 3.7% | 4.70% | -24.8% |
| 17 - Macromolecular chemistry, polymers | 0.87 | 2.7% | 1.56% | 6.7% |
| 18 - Food chemistry | 0.36 | 1.1% | 0.83% | 5.3% |
| 19 - Basic materials chemistry | 0.71 | 2.2% | 2.15% | 20.1% |
| 20 - Materials, metallurgy | 0.90 | 2.8% | 2.27% | 5.4% |
| 21 - Surface technology, coating | 0.89 | 2.8% | 1.58% | 4.1% |
| 22 - Micro-structural and nano-technology | 1.30 | 4.1% | 0.26% | 20.0% |
| 23 - Chemical engineering | 1.01 | 3.2% | 2.39% | 14.0% |
| 24 - Environmental technology | 0.92 | 2.9% | 1.54% | -2.1% |
| 25 - Handling | 0.86 | 2.7% | 2.31% | 2.6% |
| 26 - Machine tools | 0.53 | 1.7% | 1.55% | -12.1% |
| 27 - Engines, pumps, turbines | 1.63 | 5.1% | 4.41% | 21.8% |
| 28 - Textile and paper machines | 0.45 | 1.4% | 0.72% | -0.2% |
| 29 - Other special machines | 1.04 | 3.3% | 3.51% | 25.9% |
| 30 - Thermal processes and apparatus | 0.96 | 3.0% | 1.63% | 13.5% |
| 31 - Mechanical elements | 1.28 | 4.0% | 3.54% | 50.5% |
| 32 - Transport | 2.29 | 7.2% | 9.57% | 32.3% |
| 33 - Furniture, games | 0.65 | 2.0% | 1.64% | -12.0% |
| 34 - Other consumer goods | 1.10 | 3.5% | 2.19% | 34.1% |
| 35 - Civil engineering | 0.94 | 3.0% | 3.36% | 1.4% |

**Fig. 6** Technological profile of France in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



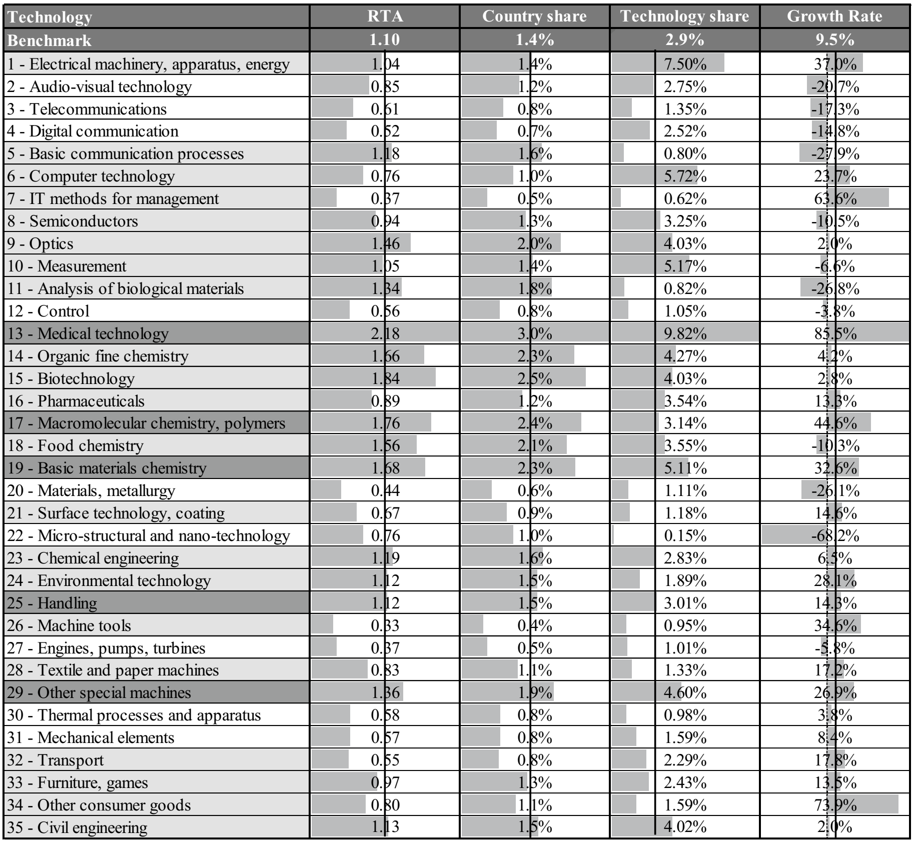
| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **1.9%** | **2.9%** | **22.4%** |
| 1 - Electrical machinery, apparatus, energy | 0.63 | 1.1% | 4.51% | 20.8% |
| 2 - Audio-visual technology | 0.34 | 0.6% | 1.10% | -26.7% |
| 3 - Telecommunications | 0.28 | 0.5% | 0.62% | -9.8% |
| 4 - Digital communication | 0.25 | 0.4% | 1.24% | 64.3% |
| 5 - Basic communication processes | 0.70 | 1.2% | 0.48% | -34.1% |
| 6 - Computer technology | 0.33 | 0.6% | 2.50% | 38.7% |
| 7 - IT methods for management | 0.40 | 0.7% | 0.66% | 114.0% |
| 8 - Semiconductors | 0.19 | 0.3% | 0.65% | -46.5% |
| 9 - Optics | 0.38 | 0.7% | 1.04% | 10.1% |
| 10 - Measurement | 1.56 | 2.7% | 7.64% | 41.9% |
| 11 - Analysis of biological materials | 2.29 | 4.0% | 1.41% | 10.1% |
| 12 - Control | 0.74 | 1.3% | 1.39% | 45.2% |
| 13 - Medical technology | 1.58 | 2.8% | 7.11% | -0.9% |
| 14 - Organic fine chemistry | 3.06 | 5.4% | 7.90% | -8.6% |
| 15 - Biotechnology | 2.53 | 4.4% | 5.53% | 47.6% |
| 16 - Pharmaceuticals | 2.86 | 5.0% | 11.37% | 8.4% |
| 17 - Macromolecular chemistry, polymers | 1.06 | 1.9% | 1.88% | 28.8% |
| 18 - Food chemistry | 1.58 | 2.8% | 3.59% | 22.2% |
| 19 - Basic materials chemistry | 1.14 | 2.0% | 3.48% | -5.9% |
| 20 - Materials, metallurgy | 0.59 | 1.0% | 1.48% | 30.8% |
| 21 - Surface technology, coating | 0.82 | 1.4% | 1.45% | 10.3% |
| 22 - Micro-structural and nano-technology | 0.82 | 1.4% | 0.16% | 59.4% |
| 23 - Chemical engineering | 1.06 | 1.9% | 2.52% | 22.4% |
| 24 - Environmental technology | 0.78 | 1.4% | 1.31% | 19.5% |
| 25 - Handling | 2.22 | 3.9% | 5.99% | 14.1% |
| 26 - Machine tools | 0.60 | 1.0% | 1.74% | -2.8% |
| 27 - Engines, pumps, turbines | 1.00 | 1.8% | 2.71% | 58.2% |
| 28 - Textile and paper machines | 1.36 | 2.4% | 2.19% | 3.3% |
| 29 - Other special machines | 0.74 | 1.3% | 2.51% | 18.9% |
| 30 - Thermal processes and apparatus | 0.80 | 1.4% | 1.36% | -1.4% |
| 31 - Mechanical elements | 0.71 | 1.2% | 1.95% | 38.9% |
| 32 - Transport | 0.42 | 0.7% | 1.78% | 37.9% |
| 33 - Furniture, games | 1.14 | 2.0% | 2.87% | 20.3% |
| 34 - Other consumer goods | 1.86 | 3.3% | 3.70% | 112.1% |
| 35 - Civil engineering | 0.61 | 1.1% | 2.18% | 24.1% |

**Fig. 7** Technological profile of Switzerland in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



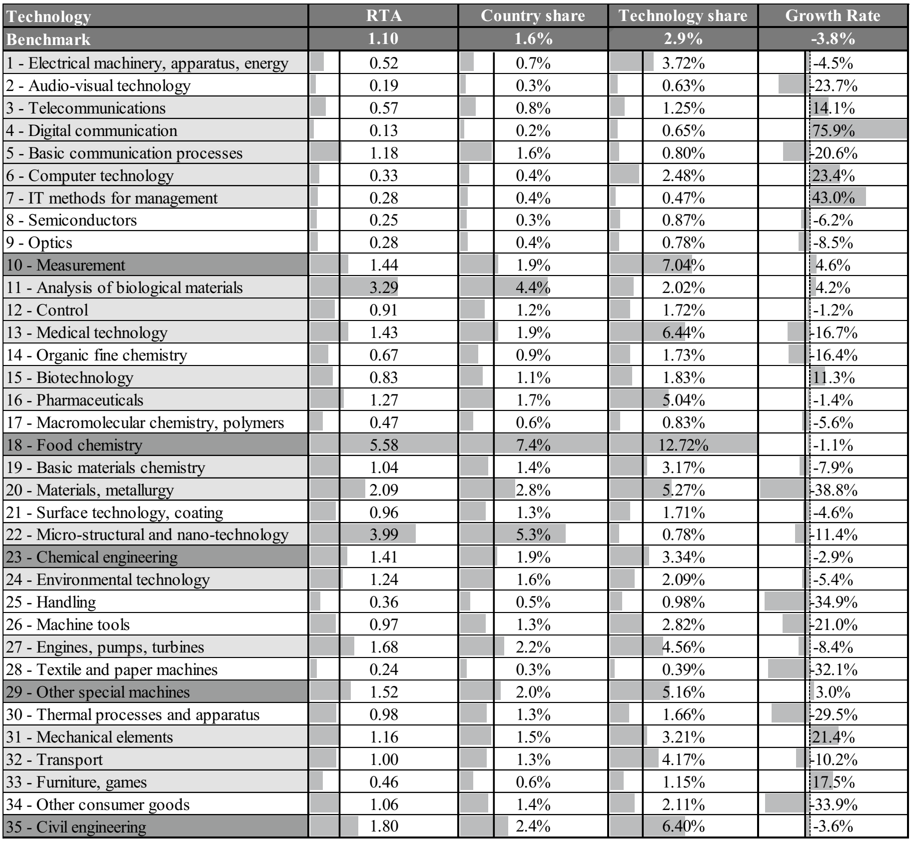
| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| **Benchmark** | **1.10** | **1.8%** | **2.9%** | **-1.5%** |
| 1 - Electrical machinery, apparatus, energy | 0.77 | 1.4% | 5.58% | 10.6% |
| 2 - Audio-visual technology | 0.57 | 1.0% | 1.83% | -36.5% |
| 3 - Telecommunications | 0.87 | 1.6% | 1.93% | -28.3% |
| 4 - Digital communication | 0.74 | 1.3% | 3.62% | 15.1% |
| 5 - Basic communication processes | 0.92 | 1.7% | 0.63% | -27.8% |
| 6 - Computer technology | 0.80 | 1.4% | 6.06% | -4.4% |
| 7 - IT methods for management | 0.85 | 1.5% | 1.41% | 22.6% |
| 8 - Semiconductors | 0.35 | 0.6% | 1.21% | -27.3% |
| 9 - Optics | 0.56 | 1.0% | 1.54% | -20.3% |
| 10 - Measurement | 1.06 | 1.9% | 5.22% | -2.2% |
| 11 - Analysis of biological materials | 2.28 | 4.1% | 1.40% | 5.7% |
| 12 - Control | 0.93 | 1.7% | 1.76% | -5.0% |
| 13 - Medical technology | 1.39 | 2.5% | 6.27% | 8.5% |
| 14 - Organic fine chemistry | 2.00 | 3.6% | 5.15% | -9.7% |
| 15 - Biotechnology | 1.86 | 3.3% | 4.07% | 19.0% |
| 16 - Pharmaceuticals | 1.67 | 3.0% | 6.63% | -0.7% |
| 17 - Macromolecular chemistry, polymers | 0.46 | 0.8% | 0.82% | -7.2% |
| 18 - Food chemistry | 0.57 | 1.0% | 1.30% | 6.5% |
| 19 - Basic materials chemistry | 1.17 | 2.1% | 3.57% | -12.7% |
| 20 - Materials, metallurgy | 0.58 | 1.0% | 1.47% | 24.1% |
| 21 - Surface technology, coating | 0.69 | 1.2% | 1.22% | -22.4% |
| 22 - Micro-structural and nano-technology | 0.76 | 1.4% | 0.15% | 46.7% |
| 23 - Chemical engineering | 1.27 | 2.3% | 3.01% | -3.7% |
| 24 - Environmental technology | 1.03 | 1.8% | 1.74% | 27.9% |
| 25 - Handling | 0.98 | 1.8% | 2.64% | -5.1% |
| 26 - Machine tools | 0.44 | 0.8% | 1.30% | -25.6% |
| 27 - Engines, pumps, turbines | 1.40 | 2.5% | 3.80% | -1.2% |
| 28 - Textile and paper machines | 0.55 | 1.0% | 0.88% | -22.9% |
| 29 - Other special machines | 0.77 | 1.4% | 2.60% | -7.7% |
| 30 - Thermal processes and apparatus | 0.80 | 1.4% | 1.36% | -13.4% |
| 31 - Mechanical elements | 1.14 | 2.1% | 3.16% | 15.6% |
| 32 - Transport | 1.15 | 2.1% | 4.80% | 31.8% |
| 33 - Furniture, games | 1.31 | 2.3% | 3.28% | -17.2% |
| 34 - Other consumer goods | 1.82 | 3.3% | 3.61% | 29.9% |
| 35 - Civil engineering | 1.40 | 2.5% | 5.00% | -15.3% |

**Fig. 8** Technological profile of United Kingdom in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| Benchmark | 1.10 | 1.4% | 2.9% | 9.5% |
| 1 - Electrical machinery, apparatus, energy | 1.04 | 1.4% | 7.50% | 37.0% |
| 2 - Audio-visual technology | 0.85 | 1.2% | 2.75% | -20.7% |
| 3 - Telecommunications | 0.61 | 0.8% | 1.35% | -17.3% |
| 4 - Digital communication | 0.52 | 0.7% | 2.52% | -14.8% |
| 5 - Basic communication processes | 1.18 | 1.6% | 0.80% | -27.9% |
| 6 - Computer technology | 0.76 | 1.0% | 5.72% | 23.7% |
| 7 - IT methods for management | 0.37 | 0.5% | 0.62% | 63.6% |
| 8 - Semiconductors | 0.94 | 1.3% | 3.25% | -10.5% |
| 9 - Optics | 1.46 | 2.0% | 4.03% | 2.0% |
| 10 - Measurement | 1.05 | 1.4% | 5.17% | -6.6% |
| 11 - Analysis of biological materials | 1.34 | 1.8% | 0.82% | -26.8% |
| 12 - Control | 0.56 | 0.8% | 1.05% | -3.8% |
| 13 - Medical technology | 2.18 | 3.0% | 9.82% | 85.5% |
| 14 - Organic fine chemistry | 1.66 | 2.3% | 4.27% | 4.2% |
| 15 - Biotechnology | 1.84 | 2.5% | 4.03% | 2.8% |
| 16 - Pharmaceuticals | 0.89 | 1.2% | 3.54% | 13.3% |
| 17 - Macromolecular chemistry, polymers | 1.76 | 2.4% | 3.14% | 44.6% |
| 18 - Food chemistry | 1.56 | 2.1% | 3.55% | -10.3% |
| 19 - Basic materials chemistry | 1.68 | 2.3% | 5.11% | 32.6% |
| 20 - Materials, metallurgy | 0.44 | 0.6% | 1.11% | -26.1% |
| 21 - Surface technology, coating | 0.67 | 0.9% | 1.18% | 14.6% |
| 22 - Micro-structural and nano-technology | 0.76 | 1.0% | 0.15% | -68.2% |
| 23 - Chemical engineering | 1.19 | 1.6% | 2.83% | 6.5% |
| 24 - Environmental technology | 1.12 | 1.5% | 1.89% | 28.1% |
| 25 - Handling | 1.12 | 1.5% | 3.01% | 14.3% |
| 26 - Machine tools | 0.33 | 0.4% | 0.95% | 34.6% |
| 27 - Engines, pumps, turbines | 0.37 | 0.5% | 1.01% | -5.8% |
| 28 - Textile and paper machines | 0.83 | 1.1% | 1.33% | 17.2% |
| 29 - Other special machines | 1.36 | 1.9% | 4.60% | 26.9% |
| 30 - Thermal processes and apparatus | 0.58 | 0.8% | 0.98% | 3.8% |
| 31 - Mechanical elements | 0.57 | 0.8% | 1.59% | 8.4% |
| 32 - Transport | 0.55 | 0.8% | 2.29% | 17.8% |
| 33 - Furniture, games | 0.97 | 1.3% | 2.43% | 13.5% |
| 34 - Other consumer goods | 0.80 | 1.1% | 1.59% | 73.9% |
| 35 - Civil engineering | 1.13 | 1.5% | 4.02% | 2.0% |

**Fig. 9** Technological profile of Netherlands in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018



| Technology | RTA | Country share | Technology share | Growth Rate |
|---|---|---|---|---|
| Benchmark | 1.10 | 1.6% | 2.9% | -3.8% |
| 1 - Electrical machinery, apparatus, energy | 0.52 | 0.7% | 3.72% | -4.5% |
| 2 - Audio-visual technology | 0.19 | 0.3% | 0.63% | -23.7% |
| 3 - Telecommunications | 0.57 | 0.8% | 1.25% | 14.1% |
| 4 - Digital communication | 0.13 | 0.2% | 0.65% | 75.9% |
| 5 - Basic communication processes | 1.18 | 1.6% | 0.80% | -20.6% |
| 6 - Computer technology | 0.33 | 0.4% | 2.48% | 23.4% |
| 7 - IT methods for management | 0.28 | 0.4% | 0.47% | 43.0% |
| 8 - Semiconductors | 0.25 | 0.3% | 0.87% | -6.2% |
| 9 - Optics | 0.28 | 0.4% | 0.78% | -8.5% |
| 10 - Measurement | 1.44 | 1.9% | 7.04% | 4.6% |
| 11 - Analysis of biological materials | 3.29 | 4.4% | 2.02% | 4.2% |
| 12 - Control | 0.91 | 1.2% | 1.72% | -1.2% |
| 13 - Medical technology | 1.43 | 1.9% | 6.44% | -16.7% |
| 14 - Organic fine chemistry | 0.67 | 0.9% | 1.73% | -16.4% |
| 15 - Biotechnology | 0.83 | 1.1% | 1.83% | 11.3% |
| 16 - Pharmaceuticals | 1.27 | 1.7% | 5.04% | -1.4% |
| 17 - Macromolecular chemistry, polymers | 0.47 | 0.6% | 0.83% | -5.6% |
| 18 - Food chemistry | 5.58 | 7.4% | 12.72% | -1.1% |
| 19 - Basic materials chemistry | 1.04 | 1.4% | 3.17% | -7.9% |
| 20 - Materials, metallurgy | 2.09 | 2.8% | 5.27% | -38.8% |
| 21 - Surface technology, coating | 0.96 | 1.3% | 1.71% | -4.6% |
| 22 - Micro-structural and nano-technology | 3.99 | 5.3% | 0.78% | -11.4% |
| 23 - Chemical engineering | 1.41 | 1.9% | 3.34% | -2.9% |
| 24 - Environmental technology | 1.24 | 1.6% | 2.09% | -5.4% |
| 25 - Handling | 0.36 | 0.5% | 0.98% | -34.9% |
| 26 - Machine tools | 0.97 | 1.3% | 2.82% | -21.0% |
| 27 - Engines, pumps, turbines | 1.68 | 2.2% | 4.56% | -8.4% |
| 28 - Textile and paper machines | 0.24 | 0.3% | 0.39% | -32.1% |
| 29 - Other special machines | 1.52 | 2.0% | 5.16% | 3.0% |
| 30 - Thermal processes and apparatus | 0.98 | 1.3% | 1.66% | -29.5% |
| 31 - Mechanical elements | 1.16 | 1.5% | 3.21% | 21.4% |
| 32 - Transport | 1.00 | 1.3% | 4.17% | -10.2% |
| 33 - Furniture, games | 0.46 | 0.6% | 1.15% | 17.5% |
| 34 - Other consumer goods | 1.06 | 1.4% | 2.11% | -33.9% |
| 35 - Civil engineering | 1.80 | 2.4% | 6.40% | -3.6% |

**Fig. 10** Technological profile of the Russian Federation in 2012–2016. Note. In pale grey colour, we highlight technological domains that are considered as technological capabilities of a country by at least one of the four indicators. In dark grey, we colour technological domains that appear as a country technological capabilities by all the four indicators. *Sources*: Authors' calculations based on data from WIPO IP Statistics Data Center https://www3.wipo.int/ipstats/index.htm. We take here "total count by applicant's origin (equivalent count)" indicator as the measure of number of patent publications for each country. All calculations are done in June 2018

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