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PATENTS FOR EVIDENCE-BASED DECISION-MAKING AND SMART SPECIALIZATION

The paper compares and contrasts the patent-based indicators, traditionally used to assess a country's technological capacities and specialization. It seeks to determine how a chosen metric might affect the results of such an analysis, sometimes being misleading. Empirically, the paper is based on the statistical information on patent activity of the top-10 patenting countries. It concludes with a clear demonstration of the need to employ a complex of patent-related indicators to make deliberate solutions on managing technological development of a country. Also the authors offer a taxonomy of technological capacities, which might further help understanding their current status and prospects for future progress. Above the methodological implications, the paper might be of an interest for policy-makers and practitioners as it analyzes the patent profiles and technological specialization of the global leaders.

Keywords technological development, technological specialization, patent statistics.

JEL classification: O31, O32, O33, O34, O38, O57.

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1. INTRODUCTION

An issue of utmost relevance within the current context in which innovation policy takes place concerns the increasing levels of complexity involved in its governance, coordination and formulation dynamics (Meissner et al., 2017). In this regard, a thorough understanding of countries' technological profiles becomes key in defining appropriate directions for future developments. Pure market dynamics is insufficient in providing reliable evidence for decision-making (Rodrik, 2004; Hausmann & Rodrik, 2003). Rather, Rodrik (2004) and Aghion et al. (2011) stress the need for embedding firms' initiatives in a context of public policy aiming at fostering technological dynamism beyond the sole prowess of market developments.

A fundamental challenge here concerns the build-up of internationally competitive productive structures. For this purpose, countries search for stronger knowledge bases in order to achieve or sustain global competitiveness (Foray, 2006). This proposition is intertwined with the concept of economic complexity, understood as a representation of the diversity in productive capabilities – knowingly a major driver of development conditions (Hidalgo & Hausmann, 2009). Diverse technological capabilities provide reasonable chances for countries to leverage new technological opportunities, spurring economic performance. Accordingly, resulting knowledge flows and technology spillovers are perceived as beneficial to all actors and firms especially within national boundaries (Griliches, 1990).

Thus, from an innovation policy point of view, comprehending what an economy is good at producing is a fundamental cornerstone in driving technological evolution (Hausmann & Rodrik, 2003). Nonetheless, knowing that innovation policy stands for a strategic feature in shaping countries' technological capabilities is far from instructive. One-size-fits-all propositions cannot efficiently tackle the challenges that lay ahead heterogeneous socioeconomic systems. Instead, evidence has shown that macroeconomic competitiveness can be achieved through different approaches to innovation and types of knowledge (Jensen et al., 2007). Hence, there is a need for policy strategies that are sensitive to countries' idiosyncratic technological profiles (Capello & Kroll, 2016).

A current trend in this respect is that of smart specialisation approaches. According to this particular view of technological profiling, regions and countries need to develop a clear specialisation outline in order to remain competitive in global markets. This has been discussed by many scholars (e.g. Piirainen et al., 2017; Tiits et al., 2015; Paliokaite et al., 2015; McCann & Ortega-Argilés, 2014; 2015; Foray, 2014), and resulted in numerous strategies dealing with innovation policymaking at the national and regional levels. Although smart specialisation is mainly known from the innovation policy perspective - thus much broader than looking at the technology dimension - it still emphasizes the relative technological position and competences of a regions and countries. The underlying motivation for this framework rests in the interpretation that innovation and technological capabilities are closely connected, and that economic development depends on building strengths in these areas.

This situation brings to the fore the need for attention concerning analytical exercises and methods to deal with the assessment of countries' technological profiles, i.e., the extent to which they should invest in diversification or apply its resources in specific areas (Archibugi & Pianta, 1992). This calls for a knowledgeable interpretation of indicators and metrics to formulate targets and benchmarks (Meissner et al., 2017). The purpose of this article is to dig deeper into these issues. We depart from the hypothesis that unidimensional approaches can be misleading for technology policy as they can neglect systemic strengths that do not comply with dominant assessment techniques.

Therefore, our empirical exercise dedicates attention to addressing

(i) whether the most traditional metrics used for countries' technological capabilities covers all the high-potential technological domains for each of the countries 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 indicators comparison for theoretical and practical needs.

To do so we have collected data on a set of patenting indicators which characterize technological capacities of the top 10 patenting countries and compared the evidences each of the selected metrics demonstrate. Hence, we look at different analytical scopes aiming at finding their levels of complementarity and discrepancy for smart specialisation recommendations. Results highlight the risk of resorting to unidimensional instruments. Although attractive from the political standpoint (Edquist & Zabala-Iturriagagoitia, 2015), such procedure can potentially harm industrial/technological (existing and prospective) capabilities.

After this introduction, the article is structured as follows. Section 2 discusses some key issues in technological profiles, specialisation and diversification of countries. Particular focus is given to the smart specialisation approach and to patent statistics as sources of information for innovation policymaking processes. Section 3 contains a detailed description of the approach and empirical data used for the study. Section 4 discusses results of the analysis and technological domains classification and concludes with recommendations for policy-makers to objectively assess countries' technological capacities for decision-making and investment strategies.

2. TECHNOLOGICAL PROFILING AND SPECIALISATION

The foundation of countries' technological profiles is a function of the aggregate picture of innovation capabilities perceived in firms, i.e., their capacity to accumulate and develop new technologies (Petralia et al., 2017). At the company-level, patented technologies translate into a broad scope of products, defining current and future market prospects (Dosi et al., 2017). For these reasons, technological diversification stands for a key area of innovation management approaches (Breschi et al., 2003; Granstrand, 1998).

Management literature argues that well-structured technology portfolios have the potential to create synergies between different R&D activities (Garcia-Vega, 2006). One dominant feature of technology portfolios are multi-field competences and technological diversification (Palmberg & Martikainen, 2006). Arguably, technology diversification results from the increasing products' complexity (Breschi et al., 2003). In its turn, this empowers the tendency of organizations' technological competencies to be dispersed over a wider range of R&D activities (Suzuki & Kodama, 2004). These conditions are derived from the breadth of a body of knowledge, and from how far and in what direction links in knowledge networks are pursued (Miller, 2006). Specialisation however does not stop at the borders of individual technology fields. Instead, it highlights the complementarities between technology fields and the resulting overlaps and interfaces. Thus, organizations are aiming at diversifying their technology profiles for several reasons. Among these is the assumption that technological diversification shows positive effects on entities' performance measured as financial returns from innovation and R&D intensity (Gambardella & Torrisi, 1998; Garcia-Vega, 2006). Ultimately, these processes are associated with enhanced microeconomic competitiveness (Miller, 2006).

However, these corporate dynamics happen within a systemic environment that offers the grounds for technologies to evolve (Freeman, 1987; Nelson & Rosenberg, 1993). Correspondingly, overall conditions and incentives for technological diversification/specialisation are highly heterogeneous across countries (Petralia et al., 2017), shaping the conditions for firm-level profiles. Following this perspective – and due to strong 'pure market' imperfections (Rodrik, 2004; Hausmann & Rodrik, 2003; Aghion et al., 2011) – innovation policy plays an important role as catalyser of firms' technological activity. Thus, national and regional authorities view technology-based competitiveness as a major factor for companies' investment decisions, and these are expected to contribute to aggregate economic development. The underlying rationale is that such investments lead to companies producing goods and services that are competitive at global markets, generating revenues for the advantage of regions and countries.

Incidentally, the technological profile (occasionally referred to as technological specialisation or technological diversification) of countries, regions and organizations has a significant influence on the capacity for combining and recombining the existing knowledge stock with new components that result in new breakthroughs (Quintana-García & Benavides-Velasco, 2008). These conditions go beyond codified knowledge and incorporated technology to include tacit knowledge, including experiences in handling and developing technology. Yet, these capabilities are often a source of competitive advantage for regions/countries for a limited period only. Once a region develops such skills, other regions establish efforts to catch up, sometimes overcoming the original levels of competence of the pioneering system. These dynamic features of localized innovation systems - at any geographic level of analysis - warrant the need for continuous evolution of aggregate capabilities in order to achieve sustainable levels of growth and development.

2.1 The Smart Specialisation Approach

A very influential approach to the field of technological profiling, specialisation and diversification – and which has consistently gained ground among academics and policymakers alike – concerns Smart Specialisation. It stands for a change in the elaboration of traditional innovation policies. Based on entrepreneurial discovery[5], its rationale is neither strictly related to high-technology activities nor to picking winners (Capello & Kroll, 2016). Instead, 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).

In this regard, smart specialisation occurs as an endogenous process, involving local potentials and needs (Capello & Kroll, 2016). However, the central focus is not based on a simple bottom-up approach. Since market failures ought to hamper spontaneous processes of smart specialisation, there is a call for coordination mechanisms through adequate policymaking (Foray, 2014). To achieve this, the key question that guides the process can be stated as "*where, in or between which sectors are structural changes most desirable?*" (Foray, 2014; p. 498).

In order to provide an answer to this inquiry, a first step deals with comprehending countries' (or regions') current strengths and future potential, helping to channel investment decisions (Paliokaite et al., 2015). The primary goal of smart specialisation is one of promoting new options that allow diversifying the economic structure (Foray, 2014). This can be achieved through policy initiatives aiming at nurturing the most promising activities, considering potentialities in technological change and systemic spillovers (Foray, 2014; Aghion et al., 2011), allowing the emergence of critical mass effects (Foray & Goenaga, 2013). An expected conse-

[5] Entrepreneurial discovery involves not only firms and individuals, but also universities, research institutions, governmental bodies and other economic agents (Grillitsch, 2016).

quence is the development of capabilities in specific technologies as a mean to achieve systemic competitiveness (Foray, 2014).

However, countries' technological profiles unravel over time according to path dependent, evolutionary patterns (Petralia et al, 2017; Mancusi, 2012; Neffke et al., 2011; Fai & Von Tunzelmann, 2001; Archibugi & Pianta, 1992; Dosi, 1988). Similarly, smart specialisation strategies do not take place in a vacuum and they should reflect previously existing institutions, policies and influential agents (Grillitsch, 2016; Kroll, 2015; McCann & Ortega-Argilés, 2014; Valdaliso et al., 2014). Even 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 & Pianta, 1992). Consequently, smart specialisation strategies should respect the variegated, evolutionary character of economic systems, taking into account their structures and existing dynamics (McCann & Ortega-Argilés, 2015), as well as areas of comparative advantage (Heimeriks & Balland, 2016; Correa & Güçeri, 2016). Such dynamics put emphasis on understanding current patterns and overall conditions of the innovative environment if the goal is one of enhancing systemic efficiency.

Furthermore, the appraisal of the socioeconomic and innovation conditions is built upon analytical frameworks that weigh not only understanding ongoing conditions, but also the future prospects of productive systems. Hereof, prioritization of selected activities is a core process of smart specialisation strategies (Correa & Güçeri, 2016; Capello & Lenzi, 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).

Important features of this process include its vertical and non-neutral character (Foray & Goenaga, 2013). That is, certain areas of interest are favoured and they should be pervasive across different sectors, supporting enabling technologies with broad applications (Foray, 2014; Tiits et al., 2015), not particular sectors or single firms (Correa & Güçeri, 2016). One crucial aspect in this discussion involves the weight on the economic structure of priority technologies (Foray & Goenaga, 2013). Moreover, this should be addressed without causing distortions to the 'natural' functioning of market forces (Meissner, 2016), facilitating existing systemic strengths in research and innovation (Foray et al., 2009).

The most difficult task here is to identify where resources should be allocated (Grillitsch, 2016), since the anticipation of adequate technological trajectories based on strengths and weaknesses of innovation systems is rather challenging (Piirainen et al., 2017). Indeed, the environment in which priority setting takes place is ever changing and complex

(Meissner et al., 2017), requiring target fields to be redefined in a continuous manner (Foray & Goenaga, 2013). In this case, stakes are high: inadequate policies can lead to undesirable lock-in effects (McCann & Ortega-Argilés, 2015), which may hamper technological upgrading and catching-up to leading systems (Capello & Lenzi, 2016).

Also, historical trajectories are not linear across distinct levels of development. More advanced countries are in a better position to take diversification 'leaps' based on leading technological capabilities (Petralia et al., 2017). This has implications on how smart specialisation policies should tackle technology upgrading along countries' levels of development. As a matter of fact, structural shifts from the existing knowledge base are hardly an option for innovation systems that are lagging behind. Additionally, different technological fields present distinct characteristics in terms of knowledge accumulation over time, thus requiring specific smart specialisation strategies (Heimeriks & Balland, 2016).

These assertions warrant the importance devoted to assess innovation systems' capabilities and future goals in a thorough manner. Next, we move to these issues by analysing a key vector of information for such approaches: patent data.

2.2 Addressing Technological Profiles through Patent Statistics

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 & Pianta, 1992). Presumably, patent portfolios at all different levels permit estimating potential synergies between the underlying technologies and their contribution to value creation. At the firm-level, Parchomovsky and Wagner (2005) show how patent portfolios can provide the firm a strong market position in a particular field, and further enhance the ability to consolidate related technological developments. Ahuja and Katila (2001) and Wu and Shanley (2009) use this methodology to analyse companies' capabilities. In a broader understanding, these approaches are also applicable at regional and country level, helping shaping the STI policymaking process (Carayannis et al., 2016).

Accordingly, patents supply data related to technological development and its inherent levels of commercial interest (Frietsch et al., 2014; Trappey et al., 2012; Harhoff et al., 1999; Trajtenberg, 1990), along with providing the capacity of establishing the location of inventive activity (Trappey et al., 2012; Fleming & Sorenson, 2001; Podolny & Stuart, 1995). Patent statistics can also provide insights on the dynamics of the level of agents' absorptive capacity (Cohen & Levinthal, 1989) and knowledge generation and flows across technological fields (Gambardella et al., 2008; Duguet & MacGarvie, 2005; Jaffe et al., 1993).

3. DATA AND APPROACH

In order to test and contrast the potential of available metrics for understanding countries' capabilities, patent profiles of the top 10 patenting countries (in 2016) were analysed: China, US, Japan, Republic of Korea, Germany, France, UK, Switzerland, Netherlands, Russia. Patent applications filed by their residents, both domestically and abroad, were assessed with a set of indicators calculated individually for each of the 35 technological domains identified in Technology Concordance Table and now broadly accepted by international expert community (Schmoch, 2008). The task was to understand which technologies – digital, computer, medical, bio, microstructural and nano, or any other – appear as a country's technological capacity and competitiveness potential when being measured by different indicators.

All the calculations were made as average for the 5-year period (2012-2016) to avoid biases caused by sharp jumps and falls of countries' patent activity in specific years. Empirically, the study is fully based on the World Intellectual Property Organization (WIPO) data (IP Statistics Data Center) as the most reliable source of patent information, aggregated from national and regional and patent offices.

Firstly, *Revealed Technological Advantage index (RTA)*, well-known and broadly used indicator, was calculated and analyzed. It quantifies the degree of technological specialization of country in a given technological domain and signals with powerful accuracy where it stands on technological domain 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 identification of a country's 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 2003). The lowest possible value of RTA is zero, which characterizes technological domains outside country's specialization. The highest value is not limited, though in most cases it is below 10. The higher RTA is, the more country is specialized on a corresponding technology. Domains with RTA index = 1.0 are those where country' efforts equal to the average world level. For the purposes of the study, technological domains were attributed to country's specialization and thus treated as its technological capabilities, if RTA exceeds 1.1 – which means that a country is more specialized on corresponding technologies than other countries on average.

The next indicator used for the analysis is *Country Share (CS)* in the total number of worldwide patent applications attributed to a specific technological domain. We consider technologies with CS higher than average position of a country as having better chances for development and global competitiveness, even if currently they are not a part of this country's specialization profile if measured by RTA.

Technology Share (TS) is another indicator which might be employed for identification of countries' technological capacities. It is a share of patent applications attributed to a certain technological domain in the total number of patent applications filed by a country's residents, both domestically and abroad. Similar to CS, for each country under consideration we grouped technologies around average value – and regard as an actual or potential technological capacities those, whose TSs exceed it. The rationale behind is that large domains 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.

Additionally, to identify the most dynamic and thus potentially promising technological domains, *Growth Rate (GR)* of patent activity (2016 to 2012) in each of them was assessed and, again, compared to an average growth rate calculated for the countries being analyzed.

In order to better understand the technological capacities of the countries and classify them, four sets of technologies – which were identified with a use of each of the four indicators – were elaborated and then compared for the country cases. This analytical exercise helped to answer the major questions raised in the study – if selected patent-related metrics show similar results and, if no, how they can be combined for better understanding of countries' technological capacities.

4. FINDINGS

The study revealed that the lists of the technological capabilities of the countries differ a lot if each of the four indicators is used separately. To give an example, for China RTA analysis returns with 15 domains which refer to the technological specialization of the country. They miss pharmaceuticals – the area which ranks high according to CS and TS, and thus should also be considered as the country's technological potential. For other countries, the results are similar – for most of them technological profile includes a wider spectrum of domains than those identified with technological specialization metrics. This observation demonstrates that reductionist, single metrics based approach might be misleading when the technological capacities of country are being assessed.

Currently *China* takes a strong position in food chemistry, basic materials chemistry, chemical engineering, handling, machine tools, other special machines and civil engineering.

These domains are complementing another well and point to a strong concentrated long time horizon orchestrated activity in China. Indeed China is features a strict long term industrial policy manifest in respective government degrees and activities as priority activity but also complemented by a strong roadmap based science and technology base development complementing the industrial development policy.

The overview of Chinas' specialization discloses differences depending on the indicator used. The values for share in the world, structure and RTA in the digital communication technology field provide indication of that China is strong in these fields but lacks momentum for future growth. This observation allows different interpretations, e.g. it might be either due to previous heavy investments and resulting achievements which are considered sufficient for Chinese industry and research but it might also be due to saturation of the technology field by means. Another possible interpretation is that the technology field itself has been downgraded in the priorities if Chinese strategy S&T and industrial development. A similar picture is evident for the electrical machinery, apparatus, energy field, computer technology, ICT methods for management, measurement, analysis of biological materials, control, medical technology, pharmaceuticals, macromolecular chemistry and polymers, materials and metallurgy, microstructural and nanotechnology, environmental technology, textile and paper machines, thermal processes and apparatus and other consumer goods.

The *US* technology profile shows an equally diversified picture at first sight. Digital communication, computer technology, IT methods for management, medical technology and basic materials chemistry are technology fields in which the United States show above average indicators whereas another 18 fields indicate partial world leadership of the US, e.g. above world average value in at least one indicator. Transport technologies is the most dynamic technology field in the US with clear above the average growth rate even outperforming digital communication but measured by the other indicators it shows that the US is lacking behind the average values. Therefore it might be assumed that transport technologies haven't received much attention over the last decades which might explain the weak US performance in global comparison but recently strong investments were done. Thus it's expected that the US will catch up in transportation technologies mid-term. This is especially likely to happen when considering transportation technologies in pair with digital communication, computer technology and IT enabled management. All these fields are interrelated for the often predicted next generation of transport, namely autonomous vehicles and related devices.

Japan has strong positions in all indicators in electrical machinery, apparatus and energy, engines, pumps and turbines, mechanical elements, transport and furniture and games. In addition Japan achieves above the average indicators in 21 technology fields, e.g. occupying leading technology position almost all technology fields. A special features appears in audio-visual technology, telecommunications and basic communications processes in which has a leading position globally but which are on significant decline over the last decade. When analysing selected indicators separately it appears that Japan holds a strong position in these technology domains. But the significant negative growth rates clearly indicate that these fields are potentially mature with a certain likelihood of replacement of selected technologies.

The Republic of Korea impresses with a much future oriented technology portfolio by means of the indicators used. With the exception of micro-structural and nano-technology as well as telecommunications all technology fields enjoy considerable growth rates, namely 18 out of 35 fields with growth above global averages. With the exception of mechanical elements, food chemistry and basic communication processes technologies Korea performs above global average in at least one indicator. Taking the technology fields together it clear one finds that the Korean industrial structure is well mirrored, including transport, semiconductors, communication and transport among others (which also include pharma and chemicals). From a technology perspective Korea seems to be well equipped with promising technologies.

Germany also possesses a diversified technology portfolio but features a considerable number of technology fields with negative growth (18 in total). In these fields Germany remains at holding strong positions in global comparison still but it appears that these positions are the result of previous activities which were not consequently continued thus are on the decrease. In other fields like digital communication, basic communication processes, computer technology and IT methods for management Germany aims at catching up with world average which is evidenced by the significant growth rates.

The *French* technology portfolio comes in a much diversified balanced shape with comparable few technology fields on the decline, namely basic communication processes, semiconductors, organic fine chemistry and macromolecular chemistry, polymers. The majority of technology fields where France achieves above the global average indicator values shows modest growth rates however with the exception of mechanical elements and transport. These fields also demonstrate a strong presence in the overall patenting activities by France. Presumably the French technology portfolio is currently robust but the rather modest values in growth and shares in the world allow to conclude that there will be a significant decline of France's presence among the leading countries globally.

The *Swiss* technology portfolio shows strengths in measurement, biotechnology, food chemistry and other consumer goods but only the latter provides a significantly above global average growth whereas the other three fields remain at or close to global growth level. Surprisingly Switzerland is in a clear leading position in pharmaceuticals but is far behind the global average growth rate in this field which might indicate that other countries are catching up with much higher pace. Digital communication and IT methods for management provide a contrary picture where Switzerland remains behind global averages in all indicators except the growth rate. Here it appears that Switzerland is aiming at catching up accordingly.

The *UK*'s patent portfolio shows a surprisingly overall decreasing tendency in growth rates especially in technology domains in which the UK holds leading positions in the remaining indicators. Because the indicators including growth rates were calculate until 2016 inclusive this development can't be assigned to the BREXIT as one reason. On the contrary this indicates the turn of the UK towards a significantly growing share of the service industry in the overall economy performance over the last decade which also affects the overall technology portfolio. Accordingly IT methods for management are exceeding the growth rate benchmark. A promising technology field is in the biotechnology area in which the UK holds leading positions in all indicators including a promising significant growth rate.

Medical technologies, biotechnology, pharmaceuticals, engines, pumps and turbines, mechanical elements, transport and other consumer goods are featuring the Dutch technology portfolio. These are technology domains in which the Netherlands are above global average in all indicator values. However with the exception of medical technologies and other consumer goods the Netherlands shows a close to benchmark growth rate only which allows to conclude that other countries have the potential to bypass the Netherlands in these fields.

The *Russian* technology portfolio shows strong above benchmark growth in telecommunications, digital communication, computer technology and IT methods for management but these are the only fields with considerable growth. Other fields are decreasing or close to the benchmark. A strong position is found for Russia in measurement, other special machines, mechanical elements and civil engineering. In food chemistry and materials, metallurgy Russia is performing above global benchmarks but these fields show a negative growth against the benchmark value.

Above the understanding of the current technological capacities of the countries under study, the patent analysis resulted in their taxonomy. We divided all the technological domains into four categories according to their current status in country (measured by the static patent indicators) and dynamics (Table 2):

- *Technological leadership*: the domains with RTA, CS and TS above the average values calculated for each of the countries. They are the domains large in patenting scope, what might guarantee a country safe and strong position on the global market and can be considered as a basis of their technological development in future.

- *Strong capability:* the domains with high CS and TS, but low (below average) RTA. Include well-established technologies, currently outside the technological specialization.
- *Potential capability:* high TS and GR, but low CS and RTA. Massive in patenting scope and fast growing technological domains, but currently less developed if compared to other countries.
- *'Jockers':* low CS, TS and RTA, but high GR. Small, sometimes starting technological domains, in which a country does not occupy a competing position on the global market, but fast growing, what gives them a chance for further progress.

Table 2: Taxonomy of the technological capabilities of the countries

№	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)
1	China	Digital communication Measurement Food chemistry Basic materials chemistry Materials, metallurgy Chemical engineering Machine tools Other special machines Civil engineering	Handling Pharmaceuticals	Computer technology	IT methods for management Analysis of biological materials Transport Furniture, games Other consumer goods
2	USA	Digital communication Computer technology IT methods for management Medical technology Organic fine chemistry Biotechnology Pharmaceuticals	Basic materials chemistry	Measurement Transport Civil engineering	Measurement Control Food chemistry Materials, metallurgy Engines, pumps, turbines Other special machines Transport Other consuming goods
3	Japan	Electrical machinery, apparatus, energy Audio-visual technology Semiconductors Optics Engines, pumps, turbines Transport Furniture, games	Mechanical instruments	Digital communication Medical technology	IT methods for management Control Basic materials chemistry Materials, metallurgy Machine tools Other special machines Civil engineering
4	Republic of Korea	Electrical machinery, apparatus, energy Audio-visual technology Telecommunication Digital communication Computer technology IT methods for management Semiconductors Optics Transport Other consumer goods Civil engineering	-	Medical technology	Analysis of biological materials Control Organic fine chemistry Biotechnology Pharmaceuticals Macromolecular chemistry, poly-mers Basic materials chemistry Materials, metallurgy Handling Mechanical elements

№	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)
5	Germany	Electrical machinery, apparatus, energy Measurement Medical technology Organic fine chemistry Basic materials chemistry Handling Machine tools Engines, pumps, turbines Mechanical elements Transport	Other special machines	Computer technology	Digital communication Basic communication processes Optics Control Materials, metallurgy Micro-structural and nano-technology
6	France	Digital communication Measurement Organic fine chemistry Biotechnology Pharmaceuticals Engines, pumps, turbines Mechanical elements Transport	Other special machines Civil engineering	Electrical machinery, apparatus, energy Computer technology Medical technology	IT methods for management Optics Control Basic materials chemistry Chemical engineering Thermal processes and apparatus
7	Switzerland	Measurement Medical technology Organic fine chemistry Biotechnology Pharmaceuticals Food chemistry Basic materials chemistry Handling Furniture, games Other consumer goods	-	-	Digital communication Computer technology IT methods for management Control Macromolecular chemistry, polymers Materials, metallurgy Micro-structural and nano-technology Engines, pumps, turbines Mechanical elements Transport
8	United Kingdom	Medical technology Organic fine chemistry Biotechnology Pharmaceuticals Basic materials chemistry Chemical engineering Mechanical elements Transport Furniture, games Other consumer goods Civil engineering	Measurement	Electrical machinery, apparatus, energy Digital communication	IT methods for management Food chemistry Materials, metallurgy Micro-structural and nano-technology Environmental technology

№	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)
9	Netherlands	Medical technology Organic fine chemistry Biotechnology Pharmaceuticals Basic materials chemistry Chemical engineering Engines, pumps, turbines Mechanical elements Transport Furniture, games Other consumer goods Civil engineering	Measurement	Electrical machinery, apparatus, energy Digital communication	IT methods for management Food chemistry Materials, metallurgy Micro-structural and nano-technology Environmental technology
10	Russia	Food chemistry Materials, metallurgy Chemical engineering Engines, pump, turbines Other special machines Mechanical elements Civil engineering	Measurement	-	Telecommunications Computer technology IT methods for management Biotechnology Furniture, games

5. CONCLUSIONS

Countries analysed show a remarkable growth in patenting activities even starting from different levels in the period of analysis (table 2).

Table 2: Dynamics of total number of patent publications for all technological domains in 2000 – 2016 for top-20 patenting countries in 2016 (thousands units).

Country	2000	2005	2010	2011	2012	2013	2014	2015	2016
1. China	14.7	75.9	233.2	277.6	432.3	527.8	663.3	841.6	**939.5**
2. USA	254.0	383.5	362.8	366.6	392.5	421.6	483.4	483.5	**491.7**
3. Japan	429.9	518.3	463.8	438.1	463.3	467.9	447.1	449.5	**435.1**
4. Republic of Korea	89.1	145.0	160.3	168.7	171.8	187.6	199.8	203.5	**209.5**
5. Germany	131.5	169.7	174.1	175.5	183.9	183.0	182.1	182.2	**179.3**
6. France	47.3	57.5	65.7	66.1	67.3	69.7	71.5	75.0	**73.7**
7. Switzerland	20.2	31.2	35.6	35.6	37.2	38.5	40.7	42.1	**42.0**
8. United Kingdom	39.5	41.9	41.0	39.5	40.7	40.3	42.0	42.4	**39.0**
9. Netherlands	20.4	36.9	30.9	30.5	29.4	28.4	30.6	33.3	**34.8**
10. Russian Federation	15.6	33.0	28.8	29.1	30.2	31.7	32.8	29.4	**27.2**
11. Sweden	21.3	17.9	22.7	21.8	21.8	22.4	23.9	26.2	24.8
12. Italy	22.6	24.0	22.0	22.6	22.2	20.8	21.1	22.2	23.0
13. Canada	13.8	19.7	20.8	22.6	23.5	23.4	22.5	21.3	20.4
14. Austria	5.4	7.4	10.0	10.6	11.4	11.8	12.5	13.0	13.2
15. Finland	10.1	13.3	12.6	11.7	11.4	12.8	13.1	13.7	12.4
16. Israel	4.3	8.6	10.1	10.4	10.1	10.5	11.3	12.6	12.0
17. Belgium	6.4	8.8	10.0	10.8	10.4	10.9	10.5	10.4	10.8
18. Australia	8.3	12.0	10.5	10.7	10.7	10.6	10.4	10.4	10.3
19. Denmark	5.3	7.4	9.7	9.7	9.3	10.0	10.5	10.5	10.2
20. Spain	4.3	7.0	9.7	10.5	11.1	11.2	10.4	10.5	9.8

Notes. 1. Cells are colored as follows – in each year the cells for countries with the highest number of patent publications are 100% filled grey. 2. Countries are sorted by total number of patent publications in 2016. 3. In bold we highlight top-10 patenting countries in 2016 for which we run the analysis of their technological profiles.

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 were done in January 2018.

The comparison of the total number of patents where the patent owner originates from needs to be interpreted with caution. Firstly the statistics don't provide insight in the place of origin of the patent underlying technology but counts patents according to patent owner place of residence. Inventors' place of residence and owner place of residence aren't necessarily identical especially in case of multinational companies with several technology labs in different countries. Also in this respect namely large multinational companies have established dedicated service companies acting as patent owners to the company for tax reasons. Again inventors and owners place of residence aren't identical. Therefore validity of aggregate patent numbers is limited at least partially. Furthermore emerging countries like China and Korea but also Russia have an industrial structure which is strongly oriented to manufacturing and raw materials but less towards the service economy which influences the patent numbers somewhat as well. Also countries are starting from different levels during the period of analysis which makes growth rates difficult to compare.

The analysis provides an indicative overview about the means of using patent related indicators to assessing the technological strength and competitive positions at country level. It also shows that using indicators separately inherits the risk of misinterpretation. Taking all analysis together we find that a comprehensive assessment of countries technology portfolio requires application of all indicators. Countries analyzed achieve leading positions in only half of the technology fields by means of applying all indicators for assessment but leading positions in 34 out of 35 technology fields when using selected indicators only (table 3).

Country analysis results also confirms that countries technology portfolios appear much stronger if not all indicators are used. This is obvious from the total number of technologies fields in which a country holds a leading position when assessed by a selection of indicators only (table 3).

Table 3: technology positions according to indicators

	China	US	Japan	Korea	Germany	France	Switzerland	UK	Netherlands	Russia
At least on indicator	16	18	21	19	17	16	18	13	15	19
All indicators	6	5	5	6	6	7	4	8	7	4

China would hold strong positions in 16 technology domains, the US 18, Japan 21, Korea 19, Germany 17, France 16, Switzerland 18, UK 13, The Netherlands 15 and Russia 19. Taking all indicators together this number clearly shrinks by half at least. This is a critical fact to consider when it comes to the use of such indicators in course of national STI priority setting or smart specialization activities by means of assessing technology fields for investment and comparing countries. The figures show clearly that countries technology performance is much different according to the respective indicator used for assessment. However given the importance of national or regional STI strategies and related resource allocations it becomes ever more important to assure that the indicators underlying priority setting exercises are meaningful and not misleading. Therefore the full bundle of indicators should be used but not selected indicators.

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Appendix. Technological Profile of 10 studied countries

Table A.1. Technological profile of China in 2012-2016.

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

Note. "Growth rate" is growth of the number of country's patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). "Share in the world" is share of country's patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. "Structure" is the share of patent publications in a technological domain in the total number of country's patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.2. Technological profile of the USA in 2012-2016.

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

Note. "Growth rate" is growth of the number of country's patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). "Share in the world" is share of country's patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. "Structure" is the share of patent publications in a technological domain in the total number of country's patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.3. Technological profile of Japan in 2012-2016.

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

Note. “Growth rate” is growth of the number of country’s patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). “Share in the world” is share of country’s patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. “Structure” is the share of patent publications in a technological domain in the total number of country’s patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.4. Technological profile of the Republic of Korea in 2012-2016.

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

Note. "Growth rate" is growth of the number of country's patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). "Share in the world" is share of country's patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. "Structure" is the share of patent publications in a technological domain in the total number of country's patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.5. Technological profile of Germany in 2012-2016.

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

Note. “Growth rate” is growth of the number of country’s patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). “Share in the world” is share of country’s patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. “Structure” is the share of patent publications in a technological domain in the total number of country’s patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.6. Technological profile of France in 2012-2016.

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

Note. “Growth rate” is growth of the number of country’s patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). “Share in the world” is share of country’s patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. “Structure” is the share of patent publications in a technological domain in the total number of country’s patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.7. Technological profile of Switzerland in 2012-2016.

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

Note. "Growth rate" is growth of the number of country's patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). "Share in the world" is share of country's patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. "Structure" is the share of patent publications in a technological domain in the total number of country's patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability 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 were done in January 2018.

Table A.8. Technological profile of United Kingdom in 2012-2016.

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

Note. “Growth rate” is growth of the number of country’s patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). “Share in the world” is share of country’s patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. “Structure” is the share of patent publications in a technological domain in the total number of country’s patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability by all the four indicators.

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Table A.9. Technological profile of Netherlands in 2012-2016.

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

Note. “Growth rate” is growth of the number of country’s patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). “Share in the world” is share of country’s patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. “Structure” is the share of patent publications in a technological domain in the total number of country’s patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability by all the four indicators.

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Table A.10. Technological profile of the Russian Federation in 2012-2016.

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

Note. “Growth rate” is growth of the number of country’s patent publications in a technological domain for 2012 – 2016 (2016 to 2011 level). “Share in the world” is share of country’s patent publications in a technological domain in the total number of patent publications in this technological domain, filed worldwide for 2012 -2016. “Structure” is the share of patent publications in a technological domain in the total number of country’s patent publications. RTA is Revealed Technological Advantage Index. In pink colour we highlight tech domains that are considered as country tech capability by at least one of the four indicators. In green we colour tech domains that appear as country tech capability by all the four indicators.

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