Belgium's innovative capacity seen through the lens of patent data

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Introduction

Largely documented, the slowdown of productivity growth observed over the last decades has been more pronounced in Europe than in the United States. Belgium, in particular, has precariously exhibited some of the lowest gains[1]. This happened despite the emergence of new technological waves, like digitalisation. These new technologies came along with their share of promise to revive the lethargic trend in productivity, feeding into what is commonly referred to as the productivity "puzzle" or "paradox". Amongst the various tracks investigated, a lack of technological diffusion, along with increasingly complex processes faced by firms to master new cross-cutting technologies and business models, might have contributed to explaining the widening productivity gap between firms operating at the efficiency frontier and the technological laggards. Some empirical studies[2] also suggest that the emergence of breakthrough innovations has been accompanied by the rise of global champions and greater industry concentration, perpetuating the growing productivity divide.

Empirical work on innovation performance frequently relies on patent data: patents are a mean of protecting inventions – either new products or new processes – and they are typically used to proxy the innovative capacity of a country. Although the relationship is not straightforward, a positive correlation between patent counts and other indicators related to innovative and economic performance has been put forward in the literature. Yet, a broader generalisation of such effects of patenting is difficult to make, as the effectiveness of patents seems to vary considerably by industry sector and technological field[3]. Patents essentially play a dual role of providing incentives to innovate, thanks to the protection they confer on inventions, and of facilitating the diffusion of technology, since they are legal titles that can be traded, in turn improving the allocation of technology resources in the economy[4]. But before an invention even becomes an innovation, in addition to the initial efforts made at the upstream level of research and development (R&D), entrepreneurial efforts are further required to develop, manufacture and market the new product or process invented. On that account, patents provide information on the output or downstream side of innovation.

The documents filed for each patent application provide a large amount of information, from its technological description and sketch of the invention to the geographical location of the researchers or entities involved. The latter makes it possible to identify and distinguish the owners of the patent – called 'applicants' – from its inventors.

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1 See NBB (2020) and National Productivity Board (2019).

2 See IMF (2019).

3 See OECD (2004) and OECD (2009).

4 See OECD (2009).

This rich and complex information on patents is a major gateway to analysing the ability of research entities – private firms, universities, laboratories, etc. – involved in yielding inventions and new technologies, whether they originally produce them, or rather collaborate with them.

That said, patenting is not compulsory and therefore not all inventions are patented. Companies may prefer secrecy agreements or rely on other types of mechanisms to gain market dominance. Others may choose to go through contractual agreements to be able to buy the right to use a specific technology, without necessarily contributing to its production : licensing and other similar types of arrangements between firms offers this extra dimension of technology cross-fertilisation between firms or other entities involved in research and innovation.

This article aims at providing some descriptive insight into the following questions : how does the innovative capacity of Belgium compare with its European peers ? Does the fact that it is a small open economy come with its perks, namely the benefits from the technology flows induced by joining the international research collaboration networks ? Or rather, does this strategy mean that the innovative capacity of the country is more vulnerable ? New emerging technologies – green tech, artificial intelligence (AI), digitalisation – offer tremendous opportunities, not least in view of the productivity gains they could bring. Gauging whether Belgium is well-positioned in those fields is of great importance for potential (future) growth.

1. The patent filing landscape

Before analysing the patterns of patenting that characterise Belgium, this first section takes a look at the main trends observed in similar geographical markets. Further described in Annex 1, patent data are a rich source of information. At the same time, they are complex, not least because of the large range of possible patent protections and routes (national, regional, international), but also since they can be largely influenced by the laws and procedures of the national patenting offices. Irrespective of innovative strategies engaged by companies or other research entities, the different standards imposed by patent offices may merely result in varying propensities to fill an application for a patent. In addition, the timeliness of data availability may also diverge depending on the patent office considered. Ultimately this will be reflected into the patent counts. Therefore, it is necessary to handle such data cautiously and their interpretation must take into account these constraints and specificities.

For this reason, and to start with, setting the stage for Belgium requires a careful comparison of patent-based indicators. A common statistical approach to analyse cross-country indicators of patents is to gather information on filings (or eventually grants) from a particular patent office [1]. In this section, we focus on patent applications filed at the European Patent Office (EPO). This section seeks to address the following issues : which countries are most active in patenting ? How does Belgium compare with other major economies ? Which technologies are most patented and developed the most quickly ?

1.1 Setting the stage in the European market

According to the OECD definition [2], patents are a legal instrument endowing their owner with a set of exclusive rights over an invention, a product or process that is new, and/or involves an inventive step, susceptible of

1 As explained in the caveat on patents’ measurement issues further, a single office of reference is also usually preferred because differences in patent regulations and changes in patent laws over the years make it difficult to compare counts across countries and to analyze trends over time. Patent counts across different offices are usually not directly comparable to allow for a correct assessment of countries’ performances.

2 OECD (2009).

industrial application. Such protection gives the owner the right to exclude others from making, using, selling, or importing the patented invention during the term of the patent, valid for a maximum of 20 years after the date of application. To do that, national, regional and international procedures are possible avenues for applicants to register their patents. Those administrative procedures are very diverse and will be chosen by the applicant depending on the specific needs and commercial strategy sought[1].

The EPO offers legal protection of inventions in the 28 EU countries[2] and in 10 other associated countries. We consider direct applications to the EPO as well as the international patent applications that entered the European phase during the reference period (Euro-PCT[3] applications) from all countries, as a proxy of the overall patenting activity in the European market: this broadly reflects the interest and appeal of research entities worldwide to protect their innovations on the European market.

Over the three most recent years for which data are available (2017-2019)[4], the aggregate number of patents applied for with the EPO increased steadily, by around 4.5 % a year on average. This pace is slightly above the growth recorded during the recovery phase of the last euro area sovereign debt crisis. Since this crisis, Europe has therefore reaffirmed itself as being an attractive and strategic place for innovation.

Looking at the country of origin of the patent applicants, nearly half of them come from European countries. This naturally reflects a so-called 'home bias' (see our caveat on measurement issues below) where European entities are more inclined to protect the new product developed in Europe than non-Europeans entities. But besides this strong European foothold, an international presence also remains firmly grounded in the European market, especially applications from the United States which accounts for one-quarter of all patent applications to the EPO, followed by Japan (14 %). That said, some of these main players have gradually lost market power at the expense of other international – especially Asian – countries. The latter have penetrated the European market to strategically protect their innovations there. Korea, and especially China, have posted well-above-average growth of patents applications to the EPO, with the steepest acceleration in the years after 2000. As a result, while China only ranked the 22nd biggest applicant in 2000, it jumped to the 5th leading position in 2019, as evidence of the country's technology catch-up.

As far as European applicants are concerned, Germany leads the pack, accounting for nearly 40 % on average of all EU28 applicants, well ahead of the second runner France (around 7 % of all EPO applications), followed by the United Kingdom, the Netherlands and Italy (around 3 % each). In Germany's case, it is worth noting that a legal provision increases the propensity to patent for German firms[5]: but even despite this, the country is the real power house among European countries in terms of patenting. The breakdown of European applications by type of entity in 2019 shows that nearly two-thirds were initiated by large enterprises (72 %) while only 18 % were filed by SMEs and individual inventors, and the remaining 10 % by public research entities[6].

1 See Annex 1 for a detailed description of the patenting process.

2 In this article, we considered the aggregate of the EU28 when the years considered preceded the Brexit (2017).

3 PCT stands for Patent Cooperation Treaty (see Annex 1).

4 In what follows, the most recent data presented come from the official publications of the EPO. The reason for it is that one major drawback from pour internal research work based on extractions from the PATSTAT database is their timeliness issue: due to the 18 months publication delay, official EPO data estimations for the most recent years (2017-2019) cannot be fully replicated with the information that is made publicly available in the PATSTAT database. The EPO official figures published for those most recent years are calculated internally (through extrapolations) at the EPO and cannot be replicated for external users.

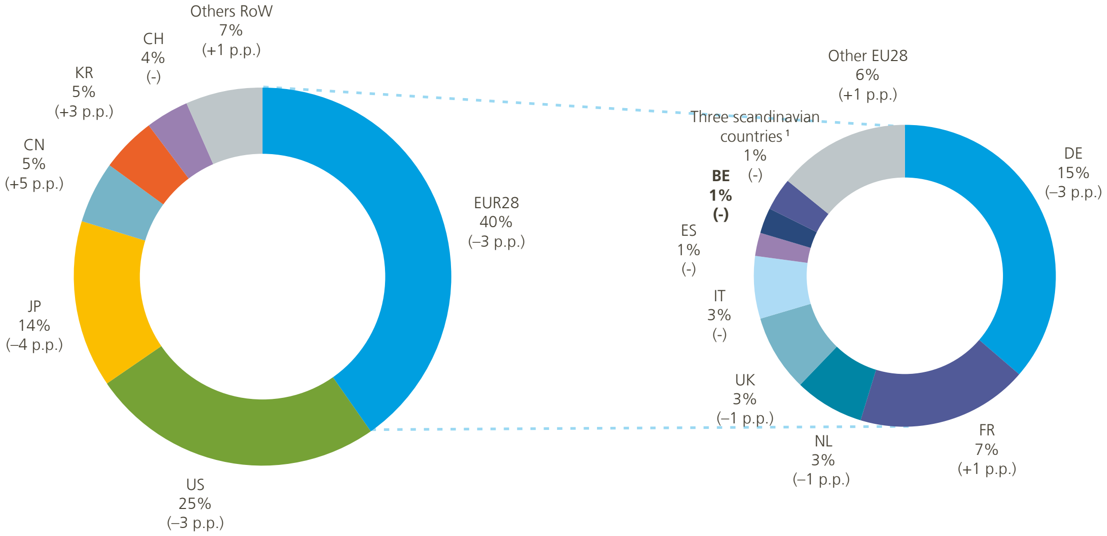
5 According to the German Employee Inventions Act, any invention made by an employee must be immediately reported to his/her employer and the right over the invention is thus transferred to the employer who has to apply for a corresponding patent. Changes introduced to the regulation stipulates that if employers do not explicitly waive their claim to the invention within four months of receiving the report, the invention and all the rights and obligations associated with it belong to the employer.

6 The definition used by the EPO includes different sub-entities including universities. Their specific role will be further addressed in a subsequent section.

Chart 1

Country of origin of patent application at the EPO from all world economies and the EU28

(in % of direct and Euro-PCT applications, average for 2015-2016, figures in brackets are in p.p. and compared to the average in 2000-2004)



Source: EPO (PATSTAT).
1 Denmark, Finland, Sweden.

1.2 How is Belgium ranked?

Over the last ten years, Belgium has produced around 2 000 patents a year: according to the EPO, 2 423 patents were filed with its office in 2019[1], an increase of 18.5 % since 2010. This figure falls short of Belgium's three neighbouring countries and most Scandinavian nations that perform better.

Belgium makes up barely 1 % of all patent applications filed with the EPO and nearly 3 % of those originating from EU28 countries. While this seems relatively modest, Belgium still ranks in the top 15 countries internationally and its share is comparable to Spain's. Thanks to sustained growth in applications, it seems quite remarkable to have consistently kept such a solid position over nearly two decades (2000-2019). This contrasts with some of the leading economies at EU or international level that have remained predominant but have lost some ground over time (e.g. the United Kingdom, Australia).

Moreover, when normalising the number of patent applications by the size of the country (e.g. its population[2]), Belgium's position slightly improves in the overall rankings[3]. But – and still considering normalised figures – some of Belgium's neighbours (Germany, the Netherlands) and the Scandinavian countries (Finland, Denmark, Sweden) continue to fare much better. Switzerland, too, holds a strong position in the relative count of patenting. But this needs to be put into context and does not necessarily reflect the underlying performance of the country's innovative fabric. Switzerland has an attractive and competitive tax regime, which explains why many innovative multinationals have set up operations in the country. In the same vein, Luxembourg also tends to show a strong position in terms of patents per capita; however, this fact is influenced by a policy

1 See the previous comment on relying on the EPO official publication data to be able to present data over the most recent years.
2 Considering other metrics such as GDP and R&D expenditure could also be used.
3 For a single patent, many applicants (or owners), as well as multiple inventors located in different countries, may be involved (a further section is dedicated to the international cooperation amongst reserachers). So an alternative counting approach to the simple count of patents should be used ('fractional counts)' which is adopted in what follows (see Annex 1 for further details).

of exempting patent and software income through an intellectual property (IP) box regime[1]. Other countries, such as the United States, naturally fall substantially in the ranking of patents per capita. China produces a negligible number of patents per capita but managed to increase that very small number by a factor of 5 over the years 2010-2016.

1 The latter was revised in 2018 but the new IP regime provides for a transition period with the old regime until 2021.

Table 1

Top 20 countries ranked according to their patent applications with the EPO[1]

(in absolute number and divided by the population in millions of inhabitants, unless otherwise stated, direct and Euro-PCT applications)

Country[2]	Applicants at EPO – Fractional count					Country[2]	Applicants at EPO – Fractional count per capita				
	2000	Rank 2000	2016	Rank 2016	Rank change 2000-2016		2000	Rank 2000	2016	Rank 2016	Rank change 2000-2016
US	32 566	1	37 054	1	0	LU	416	2	800	1	1
DE	21 187	2	21 824	2	0	CH	497	1	669	2	–1
JP	19 364	3	20 926	3	0	SE	289	4	343	3	1
FR	7 248	4	9 334	4	0	FI	316	3	277	4	–1
CN	206	22	8 145	5	17	DE	258	5	265	5	0
KR	1 125	12	6 952	6	6	NL	223	6	263	6	0
CH	3 574	6	5 599	7	–1	DK	157	7	240	7	0
UK	4 649	5	4 870	8	–3	AT	114	11	222	8	3
NL	3 557	7	4 487	9	–2	MT	31	27	186	9	18
IT	3 407	8	4 073	10	–2	JP	153	8	165	10	–2
SE	2 566	9	3 407	11	–2	IL	103	12	151	11	1
AT	916	15	1 942	12	3	**BE**	**101**	**13**	**143**	**12**	**1**
BE	**1 037**	**13**	**1 617**	**13**	**0**	FR	119	9	140	13	–4
FI	1 637	11	1 520	14	–3	KR	24	28	136	14	14
TW	255	21	1 416	15	6	IS	75	16	131	15	1
ES	613	18	1 392	16	2	US	115	10	115	16	–6
DK	841	16	1 377	17	–1	IE	71	17	112	17	0
CA	1 643	10	1 364	18	–8	NO	83	14	88	18	–4
IL	648	17	1 293	19	–2	SG	33	25	79	19	6
AU	929	14	787	20	–6	UK	79	15	74	20	–5
Others											
IE	271	20	535	22	–2	IT	60	20	67	22	–2
LU	182	23	465	24	–1	TW	12	33	60	23	10
NO	372	19	459	25	–6	CA	54	21	38	30	–9
SG	133	25	445	26	–1	AU	48	23	33	33	–10
MT	12	47	85	38	9	ES	15	31	30	34	–3
IS	21	42	44	46	–4	CN	0.2	76	6	52	24

Source: EPO (PATSTAT).

1 The country of residence is determined by the first applicant listed (first-named applicant principle). The ranking sample is composed of 182 countries. The list excludes Liechtenstein, the British Virgin Islands, Barbados, Monaco, the Cayman Islands, Bermuda, San Marino, Gibraltar and Turks and Caicos Islands.

2 The countries are ordered by numbers of patents in 2016.

1.3 Technological fields and the digitalisation break through

Looking at the type of technologies patented at the EPO, the leading sectors have tended to be modified over the last decade. This mirrors the profound changes in innovation dynamics triggered by the rise of digital technology and innovations. While medical technology was the top sector in 2010, digital communication has seen the strongest growth of patent applications since then, finally taking the top spot in 2019[1]: this reflects developments surrounding 5G technologies[2], notably under the impulse of patenting in digital information transmissions and wireless communication networks (as important enablers for 5G). The other fastest developing field over 2010-2019 was computer technology, with a very recent and steep increase fuelled by the rise of AI and in particular with machine learning and pattern recognition, image data processing and generation and data retrieval contributing to the growing number of patent applications in this field. More recently, growth in this area has been driven by various industries, not specifically from IT firms: companies active in logistics, automotive industry suppliers and medical firms have also been active, with innovation in security, medical imaging, and traffic control contributing to the increase in computer technology patent applications[3]. Besides digital, patents in new medical technologies are quickly developing with promising fields in new medical devices (implants and bionics made through 3D printing, medical imaging and diagnostics through biosensors, high-definition and virtual screening models, and personalised medicine with computer-assisted and robot-assisted surgery). Patents in the energy (e.g. batteries and electricity storage spearheaded by lithium-ion batteries for electric vehicles) and transport (e.g. energy-efficient cars) sectors are also expanding through innovation in clean and sustainable transitions. Other fast-growing patenting sectors are other special machines[4]; and others in the top ten fields are measurement and pharmaceuticals. While the former maintained robust growth over the last decade, the latter has exhibited more subdued growth since 2010 but has picked up again recently (2017-2019). Finally, patents in biotechnology and organic fine chemicals also feature in the top sectors, but applications in these areas have tended to diminish over the whole period from 2010 to 2019.

How do countries position themselves in those top patenting fields? The anchoring of international applicants at the EPO appears relatively stronger in some sectors than in others. Digital technology, which encompasses here both digital communications (e.g. transmission of digital information and wireless communication networks) and computer technologies, is one of them and such grounding of global countries is not a new phenomenon. China became the EPO's most active applicant in 2019 (with Huawei behind the recently boosted figures). The Asian footprint is more marked in digital communications, while that of US digital tech giants – Alphabet (Google) and Microsoft – relate more to computer technologies. Together these two countries account for half of all patents in the field of digital technologies in the European market. Among the other global economies, South Korea and Japan are also prolific applicants in this field. Regarding applications originating from Europe, Sweden (Ericsson) ranks first, followed by Germany and France. Computer technology has a somewhat stronger share of patents from European countries (a third of all patents in that field in 2019) than for digital communications. Germany leads the other European countries, followed from afar by France and the United Kingdom.

Turning to the other sectors, a relatively predominant global presence is also found in areas such as medical technologies, pharmaceuticals and biotechnology. The United States is the most prolific EPO applicant in those fields, way ahead of all other countries, suggesting a sustained patenting activity of American global groups in the European market. By contrast, patents in mechanical engineering – which covers mechanical elements, machines and tools, and transport – as well as other fields such as civil engineering, continue to originate mostly from European countries, and more precisely from Germany. Interestingly, too, patents in environmental technologies are also showing a European footprint.

1 See previous comment on relying on the EPO official publication data to be able to analyse estimated patent counts for recent years.

2 See European Patent Office (2020).

3 *Ibid*.

4 "Other special machines" are part of the aggregate field "Mechanical engineering". They entail e.g. tools and machinery in agriculture, horticulture, forestry, machines for harvested food, shaping clays and other ceramic composition, working cement or stone, working of plastics and other plastic substances, manufacture of glass or minerals, preparation of chemicals.

Table 2

Top ten technology fields of all patent applications to the EPO from all world economies

(in absolute numbers, unless otherwise stated, direct and Euro-PCT applications)

Technology fields	2010	2019	Growth 2010-2019 (in %)	Ranking	
				2010	2019
Digital communication	8 410	14 175	68.5	4	1
Medical technology	11 136	13 833	24.2	1	2
Computer technology	8 649	12 774	47.7	2	3
Electrical machinery, apparatus, energy	8 530	11 255	31.9	3	4
Transport	6 364	9 635	51.4	9	5
Measurement	6 717	9 045	34.7	8	6
Pharmaceuticals	6 910	7 697	11.4	7	7
Biotechnology	7 723	6 801	–11.9	5	8
Other special machines	4 329	6 436	48.7	10	9
Organic fine chemistry	7 670	6 167	–19.6	6	10

Source: EPO.

2. Stylised facts on patent filings in Belgium

2.1 Sectoral specificities

When considering patent counts in absolute numbers and looking at the breakdown by field of technology, other special machines[1], biotechnology, pharmaceuticals, materials, transport and medical devices are the most prominent fields in Belgium's patenting activity. The composition of this portfolio varies somewhat from the other countries applying for patents at the EPO. Moreover, Belgium does not tend to be specialised in those fields that have proved to be the most dynamic in recent years (e.g. digital technologies). Rather, it is trending away from what is generally observed on the European market.

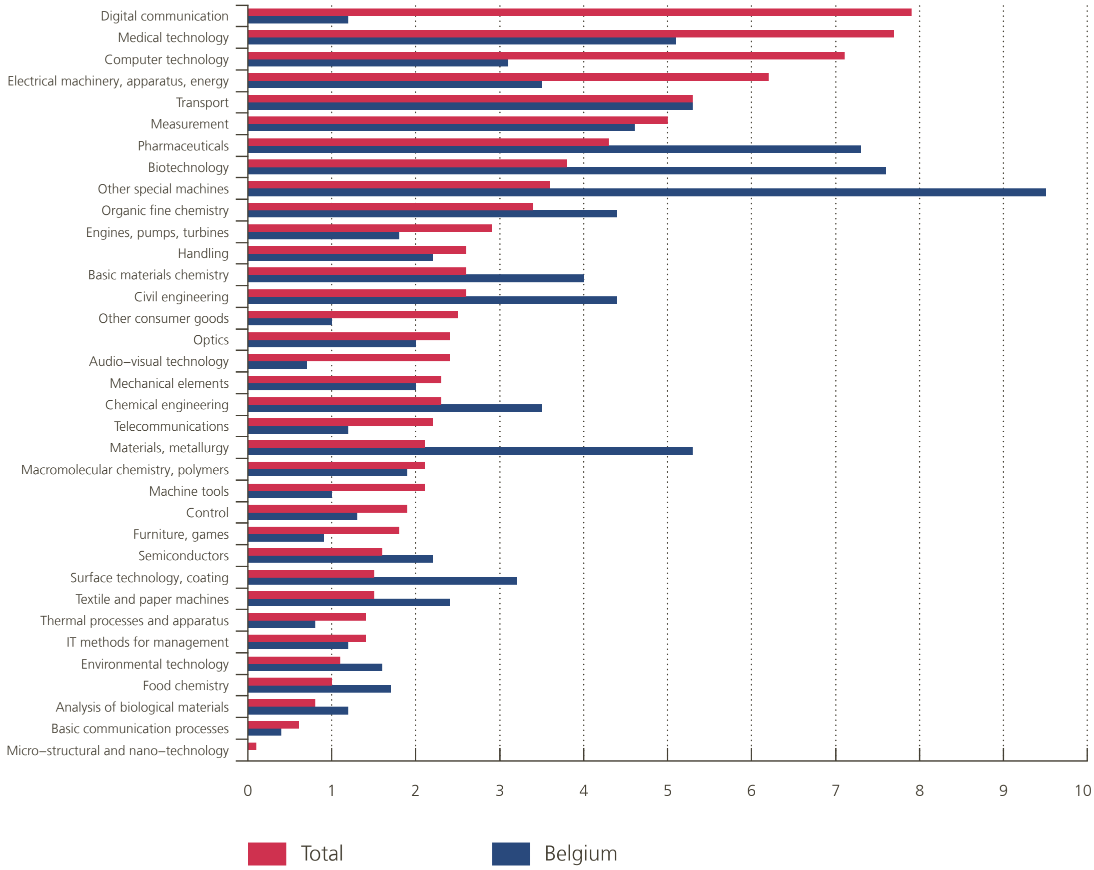
Although some of the top sectors of patenting activity in Belgium are found amongst the most important ones in the overall European market, they do not belong to the fastest-growing segments; some even declining. This does not necessarily mean that no development towards some of the fastest-growing sectors could be observed in Belgium. In the field of digital technology, patents in Belgium grew at a similar pace over 2010-2019 (57 %) to that observed at the EPO (58 %). However, since this technology accounts for a very small part of the Belgian patent portfolio, digital tech patents remain relatively limited compared to other countries. Such sectoral distribution of patents rather resembles that of Germany for instance, where transport, electrical machinery and measurement come as its top three sectors. Broadly speaking, these domains involve research efforts aimed at industrial applications and use and relate to relatively more mature technologies. Yet, unlike Belgium, Germany holds a leading position in a broad range of technologies and represents the real European patent engine.

1 *Ibid*.

Chart 2

Top technology fields in 2019 of patent application at the EPO from all world economies and Belgium

(in % of all patents and Belgian patents at the EPO, direct and Euro‑PCT applications)



Source : EPO.

The above ranking of the top technologies in which Belgium engages its innovative efforts hints at the fact that they contrast quite evidently with those breaking through and the most promising in the European market. The Belgian patenting specialisation is further analysed through the Revealed Technological Advantage (RTA) of patent applications. This indicator identifies the relative specialisation and dynamics over time of Belgium compared to other EU countries taken as a group of reference. The RTA is defined as the share of a technology in a country's overall patents, divided by the global share of this technology in all patents at the EPO[1]. Comparing the years 2010 to 2019 (hence broadly covering the last decade) makes it possible to discern whether specialisation of patents has persisted over time or whether there have been any major changes in the dynamics.

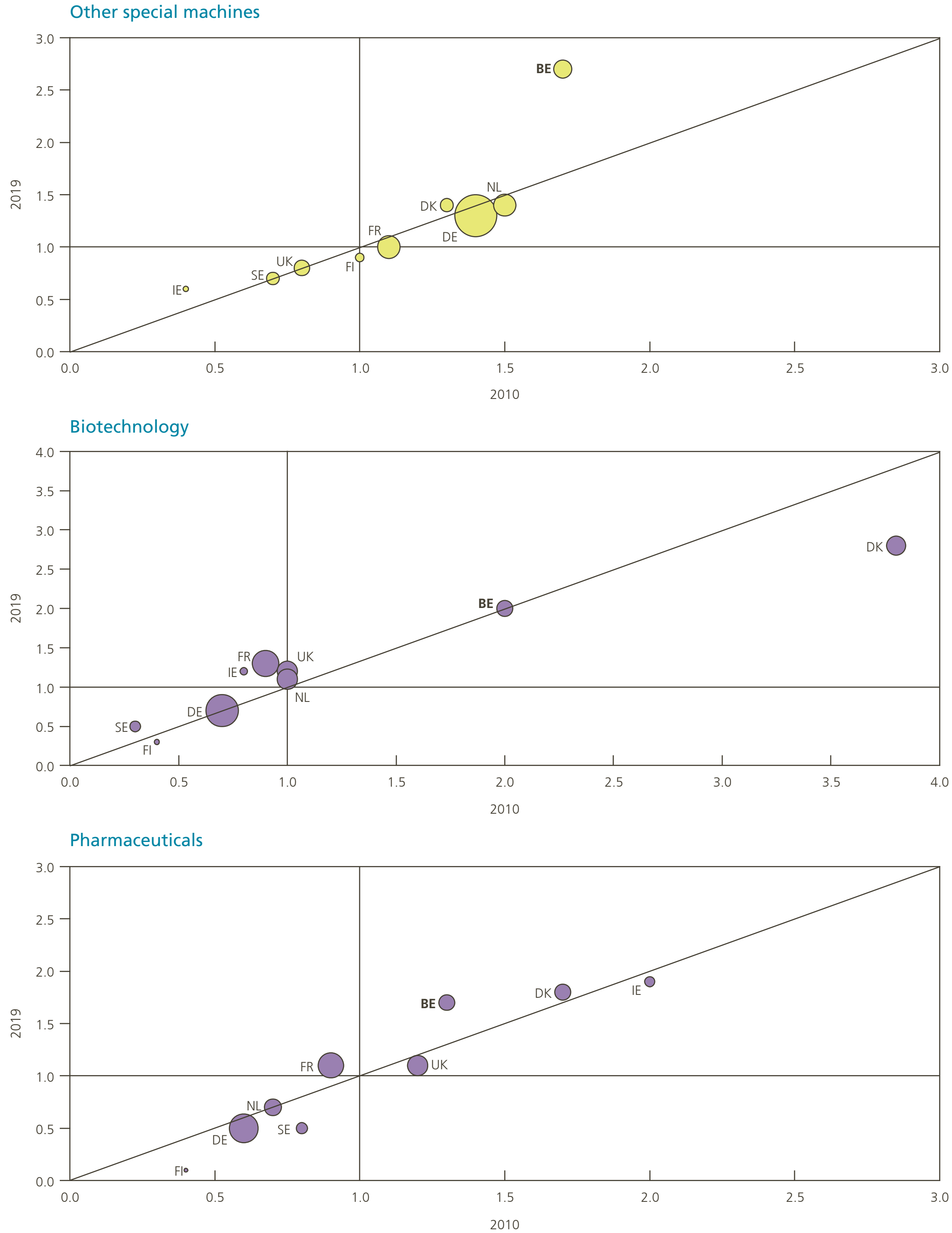
First, considering the top three fields yielding the largest patenting volumes in Belgium – i.e. other special machines, biotechnology, pharmaceuticals – Belgium's RTAs are compared to those of its European peers. Over the last decade, the country has tended to reinforce its specialised profile into other special machines. These include various types of inventions, such as new production methods in cement, plastics, polymer materials applied in petroleum product processing ; but also new methods and apparatus for lasers, 3‑D printing and

1 The definition resembles that of the Revealed Comparative Advantage traditionally used to analyse countries' trade specialisation.

Chart 3

Revealed Technology Advantage of the top 3 technology patenting fields of Belgium at the EPO[1]

(2010 on the x-axis, 2019 on the y-axis, direct and Euro-PCT applications)



Source: EPO.

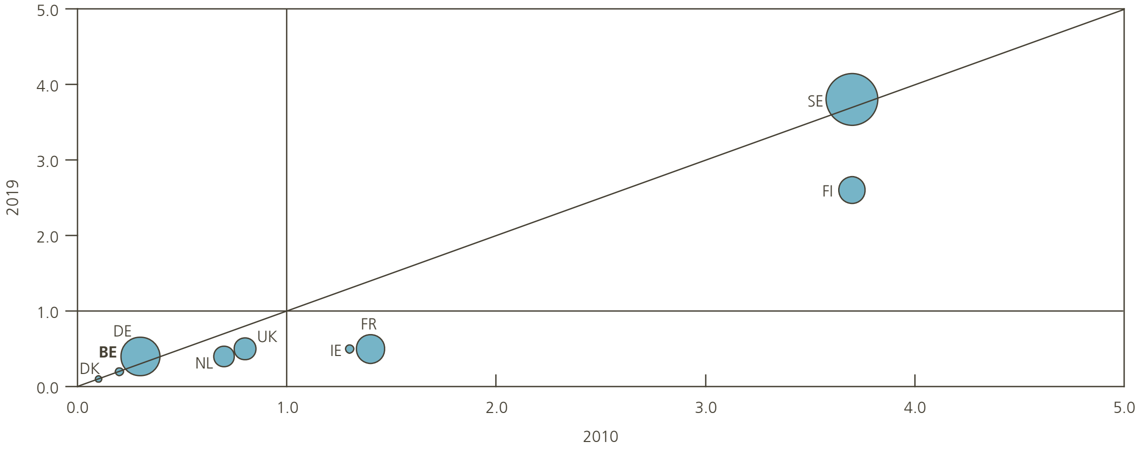
1 The size of the bubbles is proportional to the absolute number of patents from the country in the field of technology considered. An index above 1 signals a specialisation of patents in the sector considered (the higher, the more specialisation is reported). Countries above (below) the 45-degree line have reinforced (reduced) their specialisation in the technology field between 2010 and 2019.

Chart 4

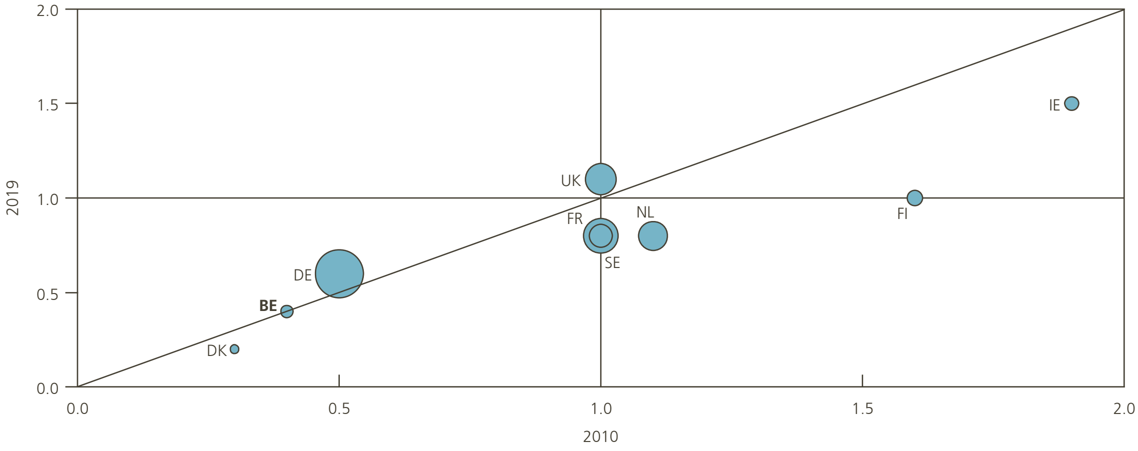
Revealed Technology Advantage of the top three technology patenting fields of all countries at the EPO[1]

(2010 on the x-axis, 2019 on the y-axis, direct and Euro-PCT applications)

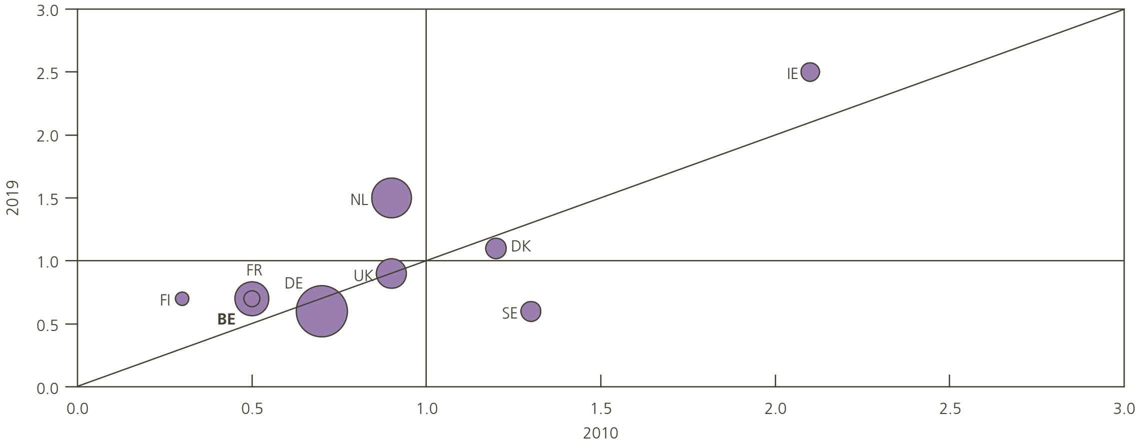
Digital communication



Computer technology



Medical technology



Source: EPO.

1 The size of the bubbles is proportional to the absolute number of patents of the country in the field of technology considered. An index above 1 signals a specialisation of patents in the sector considered (the higher, the more specialisation is reported). Countries above (below) the 45-degree line reinforced (reduced) their specialisation in the technology field between 2010 and 2019.

combine harvesters. In the other EU countries considered, the Netherlands, Germany and Denmark also exhibit some specialisation in this field, but to a much lesser extent compared to Belgium, and in a stable way over time. Belgium's specialisation in biotech patents remained strong and constant over time. The portfolio of Danish patents is relatively more orientated towards this field than Belgium, but their advantage has weakened slightly over time. Belgium also specialises in pharmaceuticals – along with Denmark and Ireland – and has bolstered this advantage relatively well over the last decade. This sector is likely to record massive changes stemming from the COVID-19 crisis. A worldwide race to find the most effective vaccines and cure available on a large scale is underway and some Belgian firms are highly involved in several projects, conveying the recognition of the high-level expertise of Belgian researchers in the field. As its favourable positioning in the pharmaceuticals RTA shows, Belgium – besides the other counties that are part of this same quadrant – can expect to be an important player in those fields in future.

Secondly, when considering, more broadly, the top three patenting sectors recorded in Europe, RTAs signal two interesting cross-country dynamics over time. First, Belgium seems chronically lacking in the patenting specialisation of digital technologies; more so for digital communications than for computer technologies. That said, the other EU countries are also not very involved in this patch of innovation, apart from Sweden (with firms like Ericsson in the lead), Ireland (Accenture Global Services and Skype) and Finland (Nokia). Still, our European peers fare far better than Belgium in computer technologies (United Kingdom, France or the Netherlands). This highlights the backlog of Belgium as an innovative place for digital technologies. That said, such a disadvantage is not irremediable: the integration of digital applications (made possible by AI advances, for instance) into the physical sectors that make up Belgium's patent specialisation can widen the opportunities for cross-fertilisation, especially since the boundaries between the use of technologies are becoming increasingly blurred (e.g. medical devices, implants and bionics made through 3D printing, autonomous vehicles integrating AI technologies). This opens the way for new opportunities offered to Belgian applicants to better position themselves by tweaking their relative advantage with the developing disruptive technologies. Second, Belgium also lags behind the reference group of countries in the field of medical technologies, even if, over time though, its specialisation in this field has grown slightly. Ireland is among the leading nations in this area. Generally speaking for the latter country, the strong position found in several sectors follows from its attractive foreign direct investment strategy as a key engine driving Irish economic development, resulting in a number of leading companies establishing their operations in its jurisdiction in sectors such as ICT, software, life sciences, engineering and business services amongst others.

2.2 The structure of patent ownership

Beyond attractive fiscal provisions driving local R&D expenditure (such as patent box systems in Belgium, which constitute interesting avenues for further research[1]), innovation dynamics in Belgium are influenced by several structural characteristics. Amongst those is the high degree of openness of the economy, which has strong implications on the constellation of patenting activities in Belgium. Other strong Belgian assets relate to its regional strategic development of major university research poles, closely collaborating with private sector entities and resulting in a few prolific technological hubs and clusters.

This section seeks to identify the types of relationships that lead Belgium into patenting activities. Broadly, it highlights that most patenting falls under the impetus of multinationals, with many foreign corporations established in Belgium. But there is also a high involvement of Belgium's own innovative fabric in research conducted abroad. Universities are also found to be an important platform for patenting work, suggesting that domestic SMEs are relatively less involved.

1 See for instance Dumont M. (2019) and Schoonackers R. (2020). Future research should also look at which part of the patenting activity in Belgium stems from intra-group transfers, some of such transactions are being partly motivated by pure optimisation strategies.

2.2.1 Who are the key Belgian owners?

Looking at the ten biggest Belgian applicants for patents at the EPO in 2019 reveals that inventions are the fruit of the research efforts of a few Belgian entities and multinationals, active in a handful of key sectors (e.g. chemicals, pharmaceuticals and biotech industries). Broadly speaking, almost 40 % of patents filed at the EPO are in the hands of the top ten Belgian players, which testifies to the concentrated nature of patenting. This finding overlaps with that already established on the upstream side of Belgian innovation and R&D expenditure more broadly[1].

Even if at this stage we intentionally disregard the foreign presence in the top ten presented – in order to focus solely on the main Belgian patenters – it already appears that some of the principal patenters are co‑owned by foreign companies (e.g. Agfa, AB InBev) and continued to operate from Belgium, a reflection of their mergers and acquisitions history. A common denominator for most of them is that they have established foreign facilities or are involved in collaboration projects with inventors located in other countries[2].

The presence of universities, their spin-offs or consortia with private entities, is also apparent. Some of them may also be interconnected (e.g. the VIB (*Vlaams instituut voor biotechnologie*) is the outcome of collaboration between five universities in Flanders – Ghent University, KU Leuven, University of Antwerp, Vrije Universiteit Brussel and Hasselt University – in life sciences research). The consolidation of all records of their inventive activities – inter-universities themselves, or with some of the top private patenting companies – naturally translates into higher volumes in patent application counts. The next sections of this article further reflect on the main features detected through the top ten Belgian patent applicants.

1 See Vennix S. (2019).

2 In fact, among Belgian applicants, one can distinguish between (i) Belgian-based firms with affiliates abroad – which are listed in the table here – and (ii) affiliates of foreign firms located in Belgium; see Cincera M. *et al.* (2005).

Table 3

Top ten Belgian applicants of patents filed at the EPO in 2019[1]

(in absolute number and in % of total patents)

Rank	Company	Number of patents in 2019	In % of total patents in 2019	Technological field of companies or other type of entity
1	SOLVAY SA	306	12.6	Chemicals and plastics
2	IMEC VZW	174	7.2	Micro- and nano-electronics, digital technologies
3	UMICORE NV	89	3.7	Metals and mining
4	K.U. LEUVEN	70	2.9	University
5	UNIVERSITEIT GENT	67	2.8	University
6	AGFA NV	56	2.3	Imaging and IT systems
7	MELEXIS NV	48	2.0	Micro-electronic semiconductors
8	VIB VZW	44	1.8	Biotechnology
9	VITO NV	40	1.7	Energy, chemistry, materials, health and land use
10	ANHEUSER-BUSCH INBEV NV	34	1.4	Instruments in beverages
Total		2 423	38.3	

Source: EPO.

1 This is the ranking of the main consolidated applicants at the EPO in 2019 (first-named applicant principle).
It is based on direct and Euro-PCT applications filed with the EPO during the reporting period.
IMEC: *Interuniversity Microelectronics Centre*, VIB: *Vlaams Instituut voor Biotechnologie*,
VITO: *Vlaamse Instelling voor Technologisch Onderzoek*.

2.2.2 Cross-border ownership and international collaboration

Without being a strict prerogative of Belgium, innovative activities are becoming increasingly globalised as more and more research initiatives are organised in multiple countries. Researchers with specialised knowledge in complementary fields may collaborate in a scientific consortium project based on their respective comparative advantages, creating synergies. Such projects are usually of higher value and bear larger costs. Purely relying on domestic resources can act as a constraint. Besides, many other considerations contribute to the attraction of a country and come into play to determine the constellation of countries and research units involved, such as favourable IP and tax regimes, the availability of a highly-educated workforce, and local innovative hubs or specific know-how in the sectors of interest.

Apart from research alliances, the ownership of innovation may involve distinct entities established in several countries, and such cross-border ownerships actually encompass a large spectrum of possible cases. Inventions made by a domestic resident can be owned by a foreign firm: as in the case of a Belgian inventor employed by an American company because that company will ultimately come to own the patent produced by the Belgian employee. Likewise, a domestic company, e.g. a Belgium firm with a branch or with a laboratory established abroad, may employ inventors residing in another country – for example, an Italian inventor working for a Belgian pharmaceuticals company, in which case the patent produced is the intellectual property of the Belgian firm. Differences observed between the owner and the inventor of a patent can thus be a sign of multinationals' activities and/or of intensive international cooperation.

Such international relationships may be considered as a form of technology diffusion[1]. Innovative firms may wish to establish itself in a country to penetrate the local market and adapt its products to it; this strategy of proximity may be accompanied by the provision of technological support to the local subsidiaries that adopt the new processes of the foreign firm. Ultimately, this results in technological transfers that could benefit the recipient country. An alternative strategy is that firms eager to closely monitor a specific technology could tap into and target the foreign local know-how. In this case, the flow of technology is reversed and leads to a knowledge transfer in favour of the investing country.

In this section, cross-border ownership strategies and research collaborations are analysed. We compare Belgium to other European countries, enabling us to sketch out some of the typical Belgian features. What comes across clearly is that international ownership structures primes somewhat over that of Belgian-owned inventions (whether conceived domestically or abroad). Besides this, Belgium is highly involved in international research collaboration.

■ Cross-border ownership of patents

Recourse to a patent database is particularly helpful to capture cross-border ownership as it involves detailed information included in patent documents, namely: the applicant that owns the patent, the inventor that created it and their respective geographical locations. When the applicants' and inventors' country of residence differ, this signals the existence of a cross-border ownership. There are two different aspects to it: international ownership over locally produced patents and, conversely, domestic ownership over international inventions performed abroad.

First, **foreign ownership of domestic inventions** reflects the extent to which international firms have a substantial influence over domestic inventions. Without being a new phenomenon, it may result from a wide range of strategies and business choices[2]. For instance, multinationals, mergers and joint ventures between firms of different nationalities may choose to establish their research facilities in one country of the parties involved for different reasons. The decision processes take into consideration the benefits from drawing on adequate local

1 See Guellec D. and B. van Pottelsberghe (2001).
2 *Ibid*.

Table 4

Foreign ownership of domestic inventions

(in % of domestically invented patents filed at the EPO, average over periods)

Country	2000-2004	2005-2009	2010-2014	2015-2016
DE	16.2	17.9	18.1	18.1
DK	24.9	24.7	26.1	20.8
FI	13.1	18.1	18.0	20.9
NL	23.2	27.8	25.2	21.2
FR	25.9	24.8	22.6	21.5
IT	19.4	21.8	23.9	22.1
CH	26.0	27.9	24.6	22.9
SE	22.5	24.5	24.7	24.9
AT	40.2	37.2	30.2	32.5
ES	33.0	30.2	31.7	35.0
BE [1]	**46.4**	**46.4**	**44.9**	**39.7**
UK	41.9	42.0	43.9	40.1
LU	60.7	47.7	53.0	49.8
IE	43.0	40.9	47.2	52.3

Source: OECD.

1 Over the whole period the top five companies are: Electrolux Home Products Corporation, Janssen Pharmaceutica (Belgian subsidiary of Johnson & Johnson), Case New Holland, Agfa-Gevaert, GlaxoSmithKline Biologicals.

human capital, the opportunity to penetrate a network of researchers backing up the firms' core technology or to strategically develop a new one. The presence of infrastructure and proximity to hubs, as well as national R&D systems make the host country more attractive.

The OECD [1] provides comparable percentages across countries of patents owned by foreign residents. The concept of foreign ownership over domestic patents can be measured by the SHIA indicator, defined as the share of patents held by foreign residents in the total fractional number of patents invented by residents [2]. The larger countries such as Germany, France and Italy display lower ratios, suggesting a smaller propensity for their patents to be held by non-residents and that they tend to master their own inventions and collaborate more locally. Interestingly, the Netherlands and some Scandinavian countries (to a lesser extent in Sweden's case) also tend to be characterised by less foreign ownership of their domestic patents.

Conversely, Belgium belongs to the group of countries where the ratio is amongst the highest. This signals that foreign companies tend to hold quite a lot of domestic innovations there: nearly four out of ten Belgian patents are in international hands [3]. In this same group of countries though, others display an even stronger international ownership, such as Ireland, Luxembourg and the United Kingdom. It is worth mentioning too that, since 2010, the ratio in Belgium has tended to decline slightly – but has remained quite high –, potentially signalling a resumed taking back of patents' property from domestic firms in Belgium. However,

1 OECD database on Science Technology and Patents.
2 Defined in Guellec D. and B. van Pottelsberghe (2001).
3 Cincera M. *et al.* (2005) further find that a large part of patents with Belgian inventors are in fact assigned to Belgian affiliates of foreign firms.

Table 5

Domestic ownership of patents made abroad

(in % of domestically owned patents filed at the EPO, average over periods)

Country	2000-2004	2005-2009	2010-2014	2015-2016
IT	6.4	6.2	7.2	7.8
ES	7.7	9.5	10.1	10.6
DE	14.0	16.5	17.6	17.0
FR	21.1	22.1	22.6	18.9
UK	21.5	21.0	21.5	20.9
DK	23.0	23.9	28.0	24.5
AT	29.1	24.1	24.6	25.1
FI	27.9	34.2	30.0	28.5
NL	38.8	38.9	34.8	33.4
BE	**35.7**	**41.7**	**40.6**	**34.0**
SE	**32.5**	**35.8**	**38.7**	**35.4**
CH	53.5	58.8	58.0	56.3
IE	60.9	64.9	65.4	65.2
LU	87.3	90.0	93.5	87.9

Source: OECD.

this could also relate to companies having established themselves on Belgian territory, creating a Belgian entity from a joint ownership within their multinational structures, or to foreign firms establishing their European operating base in Belgium (e.g. Toyota Motor Europe).

Secondly, **domestic ownership of patents invented abroad** reflects the extent to which domestic firms hold inventions produced by residents abroad, which is the flip side of the above concept. Based on the SHAI indicator[1] – defined as the share of patents owned by country residents, with at least one foreign inventor in the total patents owned by the resident country – the OECD data highlights a contrasting picture between European countries. In a way, this indicator also signals the extent to which countries have been successful in appropriating the returns of knowledge produced elsewhere – a form of technology flow to the benefit of domestic resident entities.

Belgium continues to exhibit relatively higher ratios, indicating that more than a third of patents held by Belgian entities were co-invented with a foreign researcher. This is in fact not surprising, given the high involvement of Belgian inventors in international research collaboration (which will be further addressed below), the indicators are not independent from one another. The two measures of cross-border ownership are quite high and similar in the case of Belgium, which hints at a mixed strategy from the firms involved.

When plotting domestic against non-domestic patent ownership over the most recent period available in the data (2015-2016), the predominant pattern between countries is immediately perceptible: countries above (below) the diagonal – in the north-west (south-east) quadrant – tend to exhibit a wider domestic (international) ownership base for their patents. This frame reveals that, in Belgium, the foreign dimension

1 Defined in Guellec D. and B. van Pottelsberghe (2001).

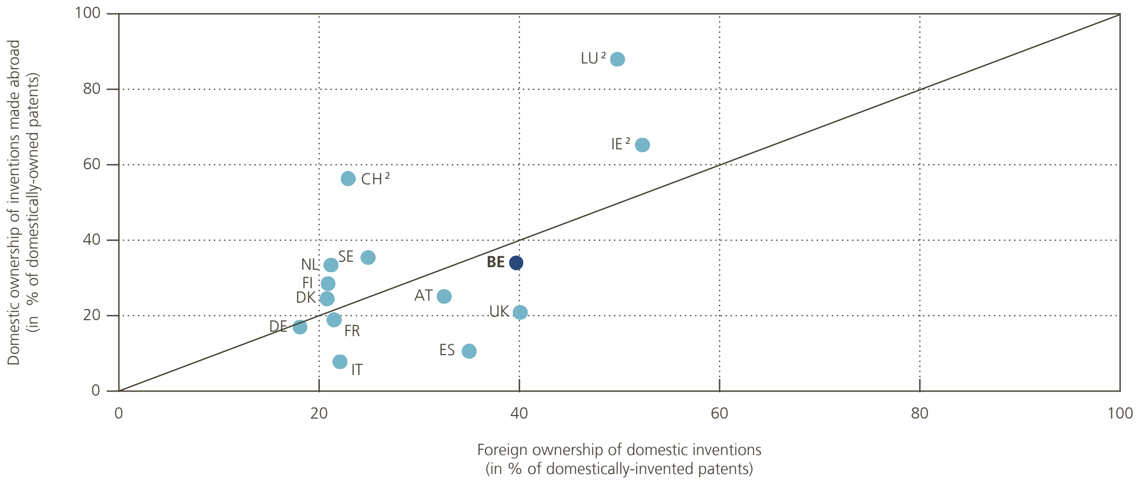
tended to overtake that of domestic ownership in those last two years considered. In the other EU countries, the scatter plot further shows that large economies such as Germany and France display low ratios of domestic ownership, more or less in line with international ratios. By contrast, patents from Spain and Italy tend to be relatively more prone to external rather than domestic ownership. Even if some variations amongst them are visible, the Scandinavian countries are all situated in a quadrant where patents remain to a larger extent within the domestic sphere. Finally, and in contrast to Belgium, Switzerland, Ireland and Luxembourg are small open economies where multinationals have established as national residents. They benefit from a significant number of inventions made abroad under their supervision; yet, these are strongly influenced by some of their national provisions making them highly attractive for global companies that have established business operations in their jurisdiction thanks to the FDI-led strategy in Ireland, competitive general tax regimes in Switzerland and Luxembourg and an even more attractive IP box regime in Ireland and Luxembourg.

Broadly considering the countries above the diagonal of the scatter plot, these correspond to a group with the largest R&D expenditure and suggests that innovative countries are also the ones that tend to have a stronger hold over both domestic and foreign inventions. In other words, the more a country is engaged in research and innovation efforts, the more it tends to exert a form of control over its patents. As well as being R&D-intensive, the education system is likely to play an important role and make a substantial contribution to these results too, through the fact that it is able to provide sufficient capacity to absorb and use new knowledge thanks to the available and adequate qualified workforce. In the chart, Belgium does not belong to this group, highlighting a missed opportunity from its internationalisation of innovation: knowledge created by Belgian inventors, wherever they operate, to some extent flows out towards foreign owners, reflecting that the country is not fully mastering the associated returns from its own patent efforts.

Chart 5

Domestic vs foreign ownership of patents

(in % of patent applications filed at the EPO, average in 2015-2016)[1]



Source: OECD.

1 Countries above (below) the 45-degree line tend to exhibit a larger domestic (foreign) ownership base of their patents.

2 The high domestic ownership performance of Luxembourg, Switzerland and Ireland is strongly influenced by some of their national provisions making them highly attractive for global companies to establish their business operations there.

International collaborations in patents

As mentioned above, scientific research and projects are increasingly shifting from single or individual concerns to groups of laboratories or research units established in several countries and where mutual expertise can complement one another through interdisciplinarity. International collaboration resulting in transnational research can be measured by the SHII indicator[1], defined as the share of patents co-invented by a domestic researcher and another that is resident in another country in the total number of patents invented domestically.

Belgium's ratios stand out from those of its neighbours and the Scandinavian countries. This highlights one of the key features of innovation in Belgium, namely the high degree of openness and international collaboration: more than a third of Belgian inventions stem from international teamwork with other inventors abroad. Switzerland, Ireland and even more so Luxembourg also have similar attributes. This comes as no surprise, since smaller open economies tend to benefit from larger economies of scale from joining a network of researchers rather than purely relying on domestic resources. Larger European countries (Italy, Germany, France) tend to benefit from a wider pool of domestic researchers and have smaller ratios.

The close international cooperation that Belgium is known for is not only a matter of inter-firm collaboration, it also stems from intra-group global strategies. Whatever form it takes, being highly integrated into global research networks that produce patents is likely to encourage technology diffusion benefiting such a small open country. Without necessarily being the original producer of patents, Belgium still contributes to the advanced technologies developed and gains from the foreign spillovers of such collaboration. This also reflects the recognition of the skills and value of Belgian inventors and researchers and their attractiveness to foreign

1 Defined in Guellec D. and B. Van Pottelsberghe (2001).

Table 6

Share of international co-inventions of patents

(in % of domestically invented patents filed at the EPO, average over periods)

Country	2000-2004	2005-2009	2010-2014	2015-2016
IT	10.5	11.0	12.4	12.8
DE	13.1	14.7	15.0	14.7
FR	17.4	19.1	18.1	17.2
NL	17.5	19.3	18.4	17.8
FI	14.7	19.5	18.4	19.2
DK	21.3	20.0	21.4	19.8
SE	17.5	20.4	22.3	21.7
ES	22.4	21.5	20.1	22.8
UK	24.1	25.8	25.7	23.4
AT	27.2	26.5	27.3	29.0
BE	**36.4**	**38.4**	**37.1**	**34.4**
CH	33.7	37.5	37.2	36.1
IE	34.2	34.7	35.9	36.3
LU	53.6	56.4	69.2	58.1

Source: OECD.

multinationals seeking to work with them. What will be crucial is to be closely involved in those high-value technological innovations and to be able to move up the ladder as new technologies and important scientific advances emerge (green tech, digital, health treatments and vaccines against COVID-19, etc.).

But on the flipside, and unlike other small economies, Belgium does not seem to have been able to fully appropriate the returns from the knowledge created domestically and abroad. This is a source of vulnerability and dependence upon external entities at a time of huge uncertainty, not least because of deglobalisation fears and reshuffling of supply chains in a wide range of industries, but also because of the changing underlying dynamics of innovation, tilting towards digital and health innovative treatment therapy in the context of the coronavirus pandemic.

2.2.3 The role of universities

The reporting of applicants' institutional sector in patent documents enables universities to be identified amongst the reported categories of applicants[1]. In what follows, we only consider *university-owned* patents. Over the period 2000-2016, the number of patent applications at the EPO involving universities as their applicant has more than doubled, highlighting the sharp increase in academic patenting over the last few decades, first in the United States, then in Europe[2]. Below, we reflect on the relative importance of universities in patenting activity in several European countries and in Belgium.

Before commenting on the findings, one should be aware that such statistics are largely influenced by the heterogeneous IP regimes in place nationally, and that not all academic inventions are patented under the name of the university, but rather under the individual researchers themselves: as a result, comparing the data of university-owned patents across European countries can be misleading for some countries. The principal illustration of it is that Finland, and even more so Sweden, exhibit strikingly low ratios. Of course, this should not be interpreted as Finnish and Swedish universities having a weaker innovative capacity than elsewhere. The relatively low figures are largely attributable to the bias relating to their IP regime governing university inventions and related ownership rules in those countries. National regimes were in fact still very diverse in

1 A patent may be assigned to a combination of one or more of the following entities: individual, company, government, non-profit, university, hospital. We considered universities at large, i.e. including any grouping of the sectors where they are reported as the only owner or as the co-owner of a patent (e.g. company-university).

2 See van Zeebroeck N. *et al.* (2008).

Table 7

Universities' ownership of patent applications at the EPO

(direct and Euro-PCT applications, average over 2006-2016)

Country	All patents of the country (in %)	Inhabitants (in millions)	Country	All patents of the country (in %)	Inhabitants (in millions)
CH	2.6	18.3	AT	2.9	5.8
BE	**11.6**	**17.2**	UK	7.5	5.6
IE	11.4	13.2	FI[1]	0.8	2.7
DK	4.8	12.0	LU	0.3	2.7
FR	4.6	7.1	ES	7.9	2.4
NL	2.6	7.0	IT	2.3	1.6
DE	2.1	6.3	SE[1]	0.1	0.4

Source: EPO (PATSTAT).
1 Finland was one of the last European countries to abolish the "professor's privilege" (in 2007); it is still currently effective in Sweden.

Europe at the end of the 1990s and only began to converge – even imperfectly – in the early 2000s. It was precisely institutional differences of academic patents that were highlighted by the "European paradox" to explain Europe's lag behind the United States[1]. Several countries (Denmark, Germany, Austria, and much later Finland) introduced some legislative changes in the 2000s by repealing the so-called "professor's privilege", which allows university researchers to retain ownership of their inventions, while others like Sweden retained it[2].This explains the weak figures for some countries and their corresponding large pool of patents filed by academics as individuals (but not listed as universities)[3]. In fact, when one considers the other definition of academic patents[4], according to which any inventions where a research university scientist has contributed to some degree amongst the inventors of a patent, the result is very different: Sweden has a much higher share of academic patents than the figures for university-owned patents suggest[5]. Data for university-owned patents presented here therefore only show a lower bound estimate of the patenting performance of universities[6].

Once this caveat is borne in mind, the figures can give us some information for countries where IP regimes allow university-owned patents. Overall, on average over the ten years from 2006 to 2016, the weight of universities in all patents was highest in Belgium and Ireland. Once such patents are considered in per capita terms, Switzerland and Denmark join those two countries in a group with a solid university performance (and as reported through their national IP regimes).

Considering Belgium more specifically, both high figures signal an active role of universities in patenting activity. The most important technology areas in which Belgian universities are active are electronics (e.g. semiconductor devices), medicinal and pharmaceutical preparations (e.g. specific therapeutic treatments), organic and biochemistry (e.g. genetics) and physics (e.g. instruments, measuring or testing processes, optical devices). In line with the findings in the previous sections, this does not come as any surprise since some of the technology fields in which Belgium is relatively more specialised (biotech, pharmaceuticals, some domains in chemicals and instruments of measurement) require more fundamental research. Especially since legal dispositions around the "professor's privilege" ended throughout Europe, and more specifically in Belgium since the introduction of stronger enforcement of the institutional ownership system already in place[7], this finding actually echoes the emergence of research laboratories and universities amongst the key stakeholders on which a society's innovative potential can count. The rising entrepreneurial orientation among academia puts the country in an advantageous position in emerging knowledge-intensive fields of economic activity, through more intense marketing of research results, patenting and licensing activities, or managerial and attitudinal changes among academics towards collaborative projects with industry[8].

When looking at a sample of the most cited patents in which Belgian universities were involved, they tend to come from partnerships rather than a unique entity. Domestic inter-university research is quite wide (e.g. IMEC or VIB are themselves involved in cooperation with other Belgian universities) which produces an overall high volume of patents recorded by this sector. That said, there is also cooperation with foreign entities, further evidence of the strong international research collaboration of Belgium as a core characteristic of its innovative fabric (see above). Besides this, universities also tend to be part of a strong nexus through partnerships with private companies. On the flipside of such a strong role for Belgian universities, Belgian companies, especially SMEs, appear to make relatively less effort. This echoes the observation of a lack of entrepreneurship in the Belgian economic fabric more generally[9].

1 According to the European paradox, despite a strong science base in European countries, scientific advances were less successfully translating into commercially viable new technologies. The Bayh-Dole Act in the US in 1980, along with other incentives introduced at the time, allowed universities to have the right to own the patents on inventions financed by federal public funds and to become the exclusive providers of licences to third parties. In its aftermath, there was a surge of US patents filed by universities and their research marketing, which brought support in some European countries to replicate such a system (see Lissoni F. *et al.* (2008) and Martinez C. and V. Sterzi (2020)).

2 See Martinez C. and V. Sterzi (2020).

3 These are not presented in this article.

4 Following the definition of Lissoni F. and F. Montobbio (2015).

5 See Lissoni F. *et al.* (2008). In principle, *academic* patents should be considered in order to properly assess the role of academic research in the innovative activity of the different European countries. However, this exercise requires further step-by-step work of matching the inventors' names to a national list of listed academic professors, which falls outside the scope of this article.

6 See van Zeebroeck N. *et al.* (2008).

7 See Martinez C. and V. Sterzi (2020).

8 See Van Looy B. *et al.* (2011).

9 See previous editions of NBB Annual Reports and De Mulder J. and H. Godefroid (2016).

2.3 Measurement issues and introducing the notion of patent value

Patents filed at a given patent office provide a rich source of data, but they also bear many statistical limitations and should be interpreted with caution. The main ones are chiefly reviewed below.

First, the so-called "*home bias*", which refers to the fact that domestic applicants tend to file more patents in their home country (than non-resident ones), rather than applying for an initial patent request in another country or market. For instance, innovative firms from the United States are more likely to seek protection of their innovation by filling a patent application at their own national office. That said, the geographical and cultural proximity, as well as the home market size, also influence the decision to patent in the most prominent offices, e.g. some Canadian or Mexican firms may be more likely to first file an application in the United States before extending it to their own national office[1]. In addition, the overall fees required throughout the whole patenting procedure at the offices may involve a large spectrum of varying costs, from validation, renewal and translation fees, which are likely to further affect the behaviour and choice of the patent office by applicants. This is particularly true for the still fragmented system prevailing in Europe[2]. Second, some sectors and technologies are more prone to be patented than others, resulting in *variable propensities to patent across industries*. This is the case, for instance, for technologies where basic research and R&D are central, naturally resulting in a higher volume of patents. On top of this, filing strategies may also influence the extent to which firms in a given sector are more likely to file a very high number of patents for any given invention[3]. Third, the same holds true for *the size of the company* considered: the larger ones will encounter less difficulty in covering the various costs associated with patenting procedures than SMEs or new arrivals to the market. Fourth, because of legal rules governing the application process, information on patents is generally only disclosed publicly after 18 months (as a "priority" filing): patent indicators are typically and intrinsically associated with a *timeliness issue* which can extend to more than five years depending on the route taken and the offices chosen (see Annex 1 for further definitions). Finally, *varying regulations governing patent offices and procedures* may complicate the comparability of patent counts across countries and influence the propensities to patent. The international heterogeneity of operational designs may ultimately lead to different degrees of rigour and transparency in patent selection processes (which can be referred to as the "quality" of a patent examination process); and evidence shows that the propensity to patent is lower in those systems with a higher quality index[4]. Changes in patent laws over time further add to such difficulties. So, patent counts across different offices are usually not directly comparable for correctly assessing countries' performance. For this reason (amongst others) and to get round this limitation, our analysis throughout this article has been based on a single office of reference (EPO).

In addition to the above, patents typically display a *skewed distribution value*, i.e. only a few inventions have high technical and economic values, while many are never used and some simply turn out to have no industrial application, so are of little value to society. Many inventions are also not patented simply because they are not patentable or because inventors chose to protect the inventions through other instruments such as secrecy agreements (see box for a review of other types of practices). It follows that a simple count using the same weight for all patents regardless of their value can therefore give a truncated view of their underlying reality. It may be that less intensive production of patents in a country – for instance Belgium compared to its neighbouring countries – may be compensated by inventions of higher quality.

1 See OECD (2009).

2 Once a patent is granted by the EPO, the assignee must validate and eventually translate it, and additionally in the future pay the renewal fees to keep it in force in each country in which protection is sought. See Annex 1 and Harhoff D. *et al.* (2009).

3 As Danguy J. *et al.* (2014) describe, this extra dimension of filing strategies contributes to explain part of sectoral differences in propensities to patents, even when two technologies are already characterised by a high appropriability strategy (e.g. in the telecommunications industry, firms typically have numerous patents per innovation; by contrast, drugs in the pharmaceuticals industry are generally protected by a small number of key patents).

4 See de Saint-Georges M. and B. van Pottelsberghe de la Potterie (2013).

The value of patents is nevertheless a complex notion that can be defined in several ways or concepts [1]. A whole range of patent indicators was found to be associated with the largest economic impact and to capture different dimensions of patent value [2], including:

- the *renewal fees* over the lifetime of a patent, indicating that the expected revenues from extending the protection are higher than the costs incurred [3],
- the *number of inventors* associated with the patent, as a proxy for the overall cost of the research involved,
- the *forward citations* of a patent, which is the number of citations a patent receives in other subsequent patent applications, indicating the technological impact that the initial patent had on all downstream research further developed in a field,
- the *geographic coverage* of a patent, which is the number of applications recorded across the different offices of international jurisdictions, commonly referred to as the *family size*. Applying for a patent abroad with a view to seeking protection in numerous geographical markets is usually a sign of higher economic value and greater potential for marketing and profit despite the multiple costs incurred,
- the *opposition incidences* of a patent, or the possibility for third parties to challenge the grant of a patent within a certain period of time provided by the applicable law and closely relates to the EPO's patent granting procedure. As opposition is a costly and risky process, a patent that is opposed can therefore be seen as an indicator of its higher market value [4].

In what follows, we shed some light on one of them – the family size –, without necessarily implying that the latter is exclusive or preferable to the others mentioned above. It is presented for illustrative purposes only and should ideally be supplemented by other types of indicators to provide a better and comprehensive view of patent values.

Triadic family patents are defined by the OECD as "the set of patents taken at the European Patent Office (EPO), the Japan Patent Office (JPO) and the US Patent and Trademark Office (USPTO) that protect the same invention" [5]. Since only patents applied for in all three offices are included, the measurement issues of home bias and influence of geographical location mentioned above are eliminated. The OECD triadic patent family indicator considerably improves the quality and international comparability of patent indicators [6].

Being those with the highest economic value and worth being protected in the three most important international markets, triadic patents usually stem from larger firms (like multinationals) which are able to bear the costs of the application processes and have made the strategic choice to give their invention the broadest possible protection. In the same spirit, at this triadic and therefore costly level of patent filing, only those technologies that are likely to be profitable on the market tend to feature in the triadic patent portfolio. When looking at the allocation of triadic patents by country, Belgium seems to be in line with other European economies such as Spain or the Scandinavian countries, but still far below our three neighbouring countries. Even when triadic patents are standardised by the population, the position of Belgium does not fundamentally improve compared to the group of reference countries, and stands even below average. This contrasts with the results of section 1.2. for 'regular' patents. Moreover, Belgian triadic patents per capita have tended fall back over time; that said, this observation also hold for most of the other EU countries considered. The sectoral allocation of Belgium's triadic patents shows that the most important technology is chemistry

1 The economic value of the patent holder is the discounted revenue flows generated by the patent over its lifetime. The social value of the patent relates to its contribution to society's stock of technology.

2 van Zeebroeck N. and B. Van Pottelsberghe de la Potterie (2001) further show that some filing strategies (such as the structure and quality of the drafted document, the filing of divisional applications and the route chosen) are positively associated with the different measures of patent value discussed here.

3 At the end of each period of the exclusive right of the patent, holders choose whether they renew and prolong the right to exclusivity. This can be opted in several geographical jurisdictions where the patent is protected, resulting in corresponding accumulated costs.

4 See OECD (2009).

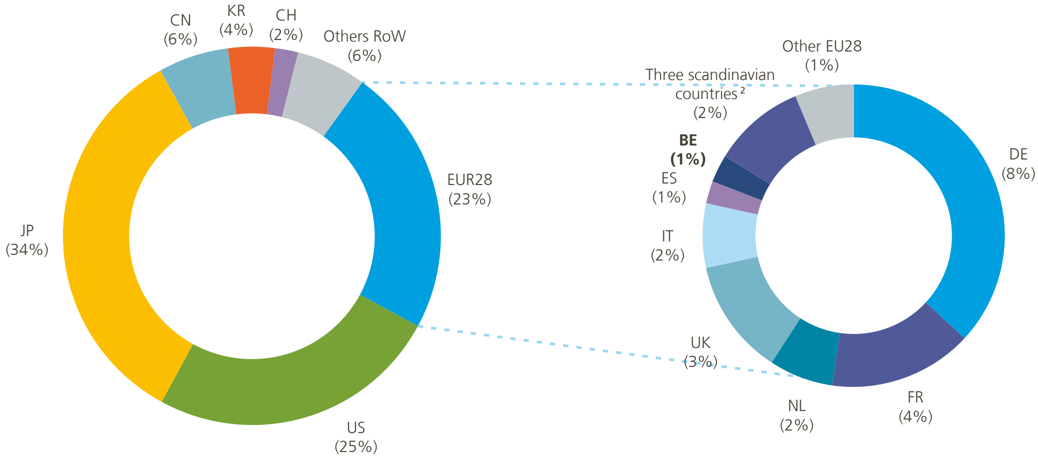
5 See extensive OECD work and database https://data.oecd.org/rd/triadic-patent-families.htm, based on Dernis, H. and M. Khan (2004).

6 de Rassenfosse G. and B. van Pottelsberghe de la Potterie (2009) further show that triadic patents are a good indicator of countries' research productivity compared to indicators of priority filings of patents, the latter being affected by variations in the propensity to patent across countries.

Chart 6

Share of countries in triadic patents[1]

(in % of all triadic patents, 2016)



Source: OECD Triadic Patent Families database, July 2020.

1 Following the OECD methodology (see Dernis, H. and M. Khan (2004) and OECD (2009)) to reflect the inventive performance of countries, triadic patent families are counted according to the earliest priority date (first patent application worldwide), the inventor's country of residence in order to reflect the local inventiveness of the local labour force (researchers, laboratories, etc.), and fractional counts.

2 Denmark, Finland, Sweden.

Table 8

Triadic patents per capita[1]

(divided by the population in millions of habitants, average over periods)

Country	2000-2004	2005-2009	2010-2014	2015-2016
CH	140.5	137.7	139.1	132.4
SE	87.4	97.1	66.8	67.4
NL	104.7	79.0	62.8	54.9
DE	86.2	74.2	59.5	52.9
DK	57.2	59.5	50.6	49.0
FI	73.6	53.9	49.1	44.7
LU	50.8	42.0	37.4	43.6
AT	34.5	44.7	45.2	40.5
BE	**46.4**	**45.0**	**39.4**	**32.6**
FR	46.0	44.8	37.8	29.5
UK	37.6	31.0	27.0	22.9
IE	18.1	19.9	18.0	19.5
IT	15.9	13.7	12.4	12.8
ES	5.4	5.9	5.1	5.9

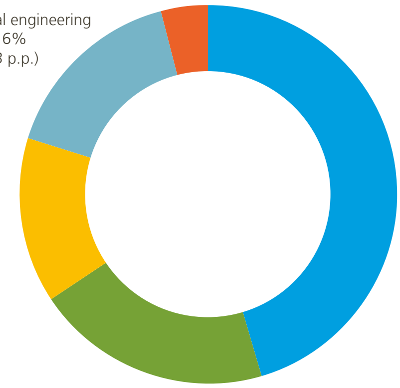
Source: OECD Triadic Patent Families database, July 2020.

1 Following the OECD methodology (see Dernis H. and M. Khan (2004) and OECD (2009)) to reflect the inventive performance of countries, triadic patent families are counted according to the earliest priority date (first patent application worldwide), the inventor's country of residence in order to reflect the local inventiveness of the local labour force (researchers, laboratories, etc.) and fractional counts.

Chart 7

Allocation of triadic patents by main technology fields in Belgium

(in % of Belgian triadic patents, average 2015-2016, figures in brackets are in percentage points and in comparison to the average share in 2000-2004)



Source: OECD Triadic Patent Families database, July 2020.

BOX 1

Licensing and complementary practices to patents

Going back to the original question as to why firms patent in the first place, it is obvious that the patentee may benefit from various advantages and perks. By benefiting from exclusive protection, the patenting company first and foremost gains the monopoly and privilege to use a technology and hold all the economic returns associated with its in-house exploitation[1]. In addition, patents also bring other types of rewards or revenues: they can be used strategically, for instance to stop incumbents from copying a technology or adopting it. In this way, patents can act as a counter-diffusing factor of knowledge flows. However, it may not always necessarily be the case, because getting a patent requires technical information about the invention to be disclosed to the public in the patent application document. Furthermore, patents can be marketed, meaning that the intellectual property right to use the new technology can be transferred to other companies. This opens the debate about other instruments used to protect intellectual property (IP).

1 This also contributes to giving firms an incentive to get involved in R&D and innovation efforts.

Besides the wish to hold a monopoly rent and prevent technology imitation, there are other reasons why firms engage in patenting. This ranges from improving their reputation – through the additional valuation from intangible assets – to conferring them with a bargaining power to better negotiate transactions around an invention. Results from a large sample of European SMEs at the EPO[1] show that, while traditional motives remain important (exclusive rights and protection from imitation), half of surveyed SMEs used the patent grant for subsequent transactional purposes with other firms like commercial contracts and licensing agreements. By allowing such forms of cooperation, licensing and other commercial agreements can be considered as a channel through which new technologies can spread across firms[2]. That said, information about licences are disclosed on a voluntary basis by EPO applicants, and the availability of data on licensing therefore remains scarce. Empirical studies are less frequently mentioned in the literature[3] and usually relies on surveys. The OECD further reports wide cross-industry differences in the use of licensing[4].

That said, not all licensing or other types of transactions necessarily involve a patent in the first place. The holding of a patent does actually *facilitate* licensing deals by protecting buyers against the expropriation of their invention, but a technology can be licensed without necessarily being protected by a patent: de Rassenfosse *et al.* (2016) estimate that about 20 % of technology transaction negotiations in Australia do not involve any patents. There is a large spectrum of IP tools used by companies, sometimes backing up one another: franchises, designs, trademarks, copyright, chips, secrecy arrangements, pools of patents, etc.

This goes without saying, well-functioning markets are an essential prerequisite for technology transactions to yield their largest expected welfare gains. However, potential imperfections may stem from information asymmetries generated by the complexity of patent filing processes and overlapping technologies in new fields of innovation, but also from strategic behaviour of firms towards patents. As observed in the first section of this article, patents have surged over the past decades in the European market[5]. This "patent boom" could certainly be associated with greater inventiveness, or the development of patent-intensive industries. But many other many factors can also explain it[6], such as the emergence of new innovative countries (e.g. China, South Korea), new disruptive technologies, the arrival of new actors like universities, the internationalisation of innovative firms which are increasingly targeting global markets and have a higher tendency to seek protection in key markets. But this patent surge could also reflect companies' strategies, not only through open innovation collaborations, but also through the take-up of 'defensive' approaches, where patents are used to secure incumbents' positions while leaving enough room to develop new technologies, and eventually of 'offensive' ones, where they intentionally and fully prevent their competitors from developing their inventions. Such strategic patenting is believed to substantially affect patent systems because it simultaneously leads to more patent filings and lower-quality applications: firms apply for more patents for a given invention or have a higher propensity to patent inventions of a lower quality[7].

1 The surveyed SMEs were interviewed in the first half of 2019. See European Patent Office (2019).
2 According to Shapiro (1985), there are three channels of technology diffusion: patent licensing, research joint ventures and imitation.
3 de Rassenfosse G. *et al.* (2017) refer to several of them.
4 The study dates to 2004 (OECD (2004). Pharmaceutical companies reported more largely inward than outward licensing and relatively low levels of cross-licensing compared to the other sectors, a possible reflection of large multinationals acquiring technologies from smaller start-ups. By contrast, the ICT sectors were found to be a heavier user of cross-licensing, maybe signaling the importance of technology sharing in this industry.
5 The WIPO also reports it to be the be the case at the USPTO and other offices worldwide.
6 See Guellec D. and B. van Pottelsberghe de la Potterie (2007).
7 See Danguy J. *et al* (2014); van Zeebroeck N. and B. van Pottelsberghe de la Potterie (2011).

Some of these practices, such as patent thickets[1] and patent trolls[2] are more concerning because of their possible detrimental effects on innovation and knowledge dissemination. Going back to the initial starting point of this article – the overall slowdown in productivity growth somewhat connected to a lack of technology diffusion – such practices deem attention and further research. A level playing field should be guaranteed to avoid an ever-growing gap ultimately stopping competitors leapfrogging the technology leaders.

1 According to Shapiro (2001), a “patent thicket” is “a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology. With cumulative innovation and multiple blocking patents, stronger patent rights can have the perverse effect of stifling, not encouraging, innovation”.

2 "Patent trolls" are patent owners (often investors who buy patents cheaply from failed companies) who use these rights to threaten companies with infringement actions and interlocutory injunctions, forcing them into financial settlements to avoid expensive litigation.

(which includes pharmaceuticals according to the OECD nomenclature), reflecting the importance of multinationals in that field.

3. Patents and productivity

Returning to the initial question that underpinned the exploration of Belgium’s innovative capacities, i.e. their connection with productivity growth, this section tentatively proposes a description of how patents and productivity growth unfolded. Beyond doubt, the link between the two variables is highly complex, and multiple channels are affecting the dynamics and the causality underlying their interactions. Originally, R&D expenditure lead to more economic growth (following the endogenous growth theory); patents are only one part of R&D efforts since they constitute one of the legal steps in the overall process associated with innovation. Still, they can also give some indication of a certain research productivity. An interesting starting point and tentative hypothesis stems from a part of the literature according to which patents and stronger protection were found to have a significant impact on firm-level productivity and market value (Bloom N. and J. Van Reenen (2002), Park W. (1999)[1]). Yet, Bloom N. *et al.* (2020) further show that research effort has risen substantially, while research productivity has sharply declined. This testifies that the relationship is far from being a simple one.

In this section, in a purely descriptive exercise, we look at the development of patents and productivity growth at the sectoral level in the case of Belgium and in other EU countries. The figures for patents are identical to those previously analysed, classified into their associated NACE code[2] and normalised by the number of people employed. Productivity growth is defined as the growth in the ratio of real value added over the number of people employed in each NACE sector. We considered the average number of patents produced in Belgium during an initial five-year period (2000-2005), against the subsequent average productivity growth over the longer-term period 2006-2016 in sectors associated with technological fields for which patents had been reported. Patents – as a downstream indicator of innovation, capturing the successful and commercially viable R&D efforts involved – could feed into productivity growth through various channels: a direct one, where the stock of innovations available to an economy is fostered thanks to the production of new technologies; and

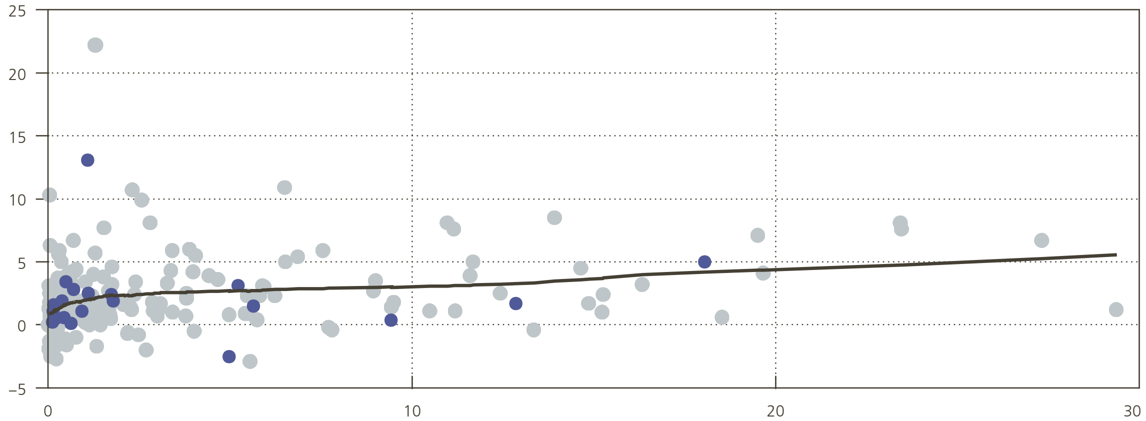
1 For the latter, it is somewhat mitigated by the findings in de Saint-Georges M. and B. van Pottelsberghe de la Potterie (2013).

2 One should note that patents can be assigned to several technology classes at the same time.

Chart 8

Patents and productivity growth in Belgium and in a selection of EU countries [1]

(x-axis: number of patents divided by employment (average, 2000-2005); y-axis: % productivity growth (average yearly growth rates, 2006-2016))



Sources: Eurostat, EPO (PATSTAT).

1 Belgium is in blue. The other countries in grey are Germany, France, the Netherlands, Denmark, Finland, Sweden, Spain, Italy, Austria, the United Kingdom.

more indirect ones, where, thanks to the disclosure of the information relating to the inventions, the other non-patenting firms that are active in the same sector end up adopting and benefiting from the new product or process invented, yielding overall gains for the sector at large. The latter channel could relate to a form of technology diffusion. Lags in both direct and indirect adoption of new technologies justify the proposed approach, which is to observe whether any innovation through patents would turn into future productivity gains.

The scatter plot has several upshots. First of all, it shows a large cluster composed of many sectors characterised by a low average number of patents (in 2000-2005), further associated with low average productivity growth (in 2006-2016). Within this group of industries, there is wide heterogeneity: for instance, in Belgium, while initially recording a low number of patents, the basic and fabricated metals sectors generate more productivity gains than manufacturing of motor vehicles, trailers and semi-trailers, or computer programming, consultancy, and information service activities. Secondly, in Belgium, the pharmaceuticals sector and the electronic and optical products sector stand out with a higher number of patents produced over the initial period considered – another reflection of Belgian sectoral specialisation in patents. These sectors tend to be subsequently associated with somewhat higher productivity gains. Overall, the slope of the trend associated with the scatter plot is slightly positive: it hints at the fact that, possibly, positive effects of patents translate into productivity gains through technology adoption within the sector is an assumption that should not be ruled out. We insist on the fact that this finding does not allow to draw definitive conclusions; rather we view it as a starting point to initiate in-depth research to further deepen the (*a priori* positive) association found, through a solid empirical evidence highlighting the mechanisms and dynamics at play.

This goes without saying, but caution is called for with the results yielded from this approach. First, while IP strategies and patent filings differ across firms, especially in terms of their size, they also vary widely across industries. As section 2.3. points out, there is a large variation in the propensity to patent across sectors, which is ultimately reflected in a greater or lesser number of patents per (NACE) sector in our analysis: Danguy J. *et al.* (2014) show that the sectoral discrepancies in patent applications partly reflect the variations in the appropriability and in the filing strategies adopted by firms. Secondly, the sectoral productivity growth observed can be influenced by many different determinants, such as the sectoral specialisation of patents, as well as the period under consideration[1] or competition issues relating to how concentrated sectors are. Thirdly, it is necessary to bear in mind that, on the patents side, the NACE codes are associated with the IPC sectors reported in patent documents, not systematically with the companies producing the patent[2]. In the same spirit, dividing the number of patents by the number of employed persons in each sector is a welcome step meant to normalise the sectoral patent volume by its underlying labour force. However, relying on the whole population of persons employed per sector is an imperfect metric since it is not the precise representation of the labour force associated with those firms that actually produced the patents. In further research, preference should be given to working with employment and, more generally, economic data at the level of the patenting firm[3]. Finally, next to linking patent data to firm-level economic statistics, exploiting data on firms' licence agreements would soundly back up the analysis of technology diffusion and productivity growth.

Concluding remarks

This paper seeks to understand how the innovative fabric of Belgium has developed and specialised over the last decades, through the lens of rich patent data. The justification for this assessment is to initiate an analysis of its potential relationship with productivity growth. The debate approached in this article confirms that innovation remains a core lever of productivity and economic growth. The importance of innovation and advanced research has been even more strongly emphasised with the COVID-19 crisis. Amongst other sectors also involved, massive research efforts in pharmaceuticals intended for health and therapeutic treatments to keep outbreaks of epidemics in check will prove central to developing new vaccines and quick testing tools. Therefore, and beyond the need to revive productivity growth, innovation is in the current context also closely interlinked with critical public health matters of the uttermost importance.

We first sketch a context by looking at European patents, which have grown in number over the last two decades. Since the sovereign debt crisis, Europe has confirmed its position as a strategic and attractive marketplace for innovation. When considering an overall ranking of all countries seeking to protect their innovations in the European market, applicants of European origin remain the main players, followed by the United States and Japan. Other Asian economies have successfully managed to rapidly penetrate the market, at the same time as the importance of some historical stakeholders has waned.

Belgium has managed to maintain a stable and relatively well-placed position over time. Its rank has even slightly improved if the size of the country is taken into consideration. That said, Belgium's neighbours or the Scandinavian countries still have a clear lead. Changing innovative dynamics and trends has revealed a surge of digital technologies (encompassing both digital communications and computer technologies at large), albeit with large cross-country differences. They tend to be in the hands of a concentrated pool of players and countries – with China and other Asian economies offensively involved in massive volumes of patent filings in the European market. Besides digital, patents in new medical technologies are quickly developing with promising fields in new medical devices. Patents in the sectors of energy and transport are also expanding through innovation in clean and sustainable transitions. By contrast, sectors like chemicals and pharmaceuticals remain amongst the

1 Notably, the period covering the average productivity growth (2006-2016) contains two crisis episodes – the 2008-2009 economic and financial crisis and the 2010-2012 sovereign debt crisis.

2 Data on patents were extracted from PATSTAT. Each patent document reports one or more IPC (or CPC) sector(s). These were translated into NACE codes following the concordance table between the IPC and NACE nomenclatures directly available in PATSTAT as developed by Schmoch U. *et al.* (2003). This concordance scheme has been elaborated and validated by matching IPC sub-classes to industries via an assessment of a representative sample of firm-owned patents. However, it should be noted that the conversion of IPC codes to NACE classes may not systematically be linked to the primary activity of the applicants, so sectors tend to reflect the particular patent technologies.

3 To do that, the names of patent applicants should first be harmonised and correctly linked to the other sets of databases of economic performance statistics at the firm-level. This matching involves several steps and in-depth work, which goes beyond the frame of this descriptive article. See Thoma G. and S. Torrisi (2007), the OECD work on the OECD HAN database and Lissoni F. *et al.* (2008) for an application of the matching of the inventor–professor from the KEINS database on academic inventors.

top innovative fields but seem to be maturing: more recently, they have shown a more subdued growth pace, while other fields have bloomed.

Secondly, we focus more particularly on Belgium and distinguish some of its typical key features by comparing it to a group of reference countries. There are several principal messages. There seems to be a persistence over time for Belgium to specialise in more mature technologies, with the top three patenting fields relating to other special machines, biotechnology and pharmaceuticals. These do not coincide with the fastest developing fields of innovation in the overall European market, and worryingly Belgium seems to be left out from the flourishing patch of digital innovations and other fast-growing fields without any clear sign of reallocation towards these breakthrough technologies.

That said, such a disadvantage is not irremediable: an optimistic stance is that the integration of digital applications (made possible by AI advances, for instance) into physical sectors characterising in part the patent specialisation in Belgium can broaden the opportunities for cross-fertilisation especially since boundaries between the use of technologies are becoming increasingly blurred (e.g. medical devices, implants and bionics made through 3D printing, autonomous vehicles integrating AI technologies). This opens the way for new opportunities offered to Belgian applicants to better position themselves by tweaking their relative advantage with the developing disruptive technologies. Moreover, one of the strengths found is the favourable positioning in pharmaceuticals. Belgium can be expected to be an important player in those fields in the future, as its strategic involvement in the development of new vaccines against COVID-19 has demonstrated. On top of that, the opportunities surrounding green technologies should be exploited in future research.

When considering the most important patent owners amongst Belgian residents, there is a high degree of concentration. Patents are determined by a few and/or large entities active in a handful of key sectors (e.g. chemicals, pharmaceuticals and biotech industries): broadly speaking, almost 40 % of Belgian patents filed at the EPO are concentrated in the hands of the top ten Belgian players. Some of them are co-owned by foreign entities following their mergers and acquisitions history; some have established laboratories abroad or are involved in collaboration projects with inventors located in other countries. This concentrated nature of patents brings some vulnerability, by being reliant on a few actors (domestically as well as internationally) and sectors upon which the whole patenting activity hinges. Retracing the full ownership structure of firms and their affiliates would help identify the exact connections between entities and provide a more comprehensive picture of how concentrated patenting activity in Belgium really is and the likely impact from internationalisation strategies.

Belgium tends to be highly involved in international collaborations in patents. Whatever form it takes, being highly integrated into global research networks is likely to encourage technology diffusion benefiting a small open country. Without necessarily being the sole producer of patents, Belgium contributes to developing advanced technologies and gains from foreign spillovers of such collaborations. It also mirrors recognition of the skills and value of Belgian inventiveness, as well as the attraction of Belgian researchers for foreign corporations seeking to work with them. What will be crucial is remaining closely involved in high-value technological innovations and being able to move up the ladder as new ones emerge (e.g. green tech, health medication and vaccines against COVID-19).

The focus on cross-border ownership of patents further highlights the ‘mixed’ form of patent ownership followed in Belgium, where the country owns numerous patents abroad, but its patents are even more closely controlled by international entities. Experience from other EU countries supports the fact that the more a country is involved in research and innovation, the more it tends to exert a form of control over it. In addition, the role of education makes a substantial contribution to providing enough capacity to absorb and use the new knowledge acquired, thanks to the availability of an adequately qualified labour workforce. Belgium’s position highlights that knowledge created by Belgian inventors, wherever they operate, is certainly well recognised and very much in demand, but it basically flows out towards their external owners, with Belgium losing its grip on the full benefits of returns on patents and innovation. Upstream, this calls for revamping education policies to enable better assimilation of the new skills related to emerging and fast-developing technologies (e.g. digital technologies where Belgium seems to be lacking in STEM skills).

Another key Belgian feature is the very active role of universities, which have become major patenting actors. Some are working together, showing that inter-university collaboration and clusters are successful in delivering new technologies. Belgian universities are a good showcase for the quality of researchers and the country's underlying inventive fabric. For future research, the involvement of universities in patenting could be further approached by analysing connections with companies. On the flipside, the importance of universities in Belgian patents could be a symptom of the relative weakness of business and SMEs in spawning innovation. It would be worth investigating the possible influence of the lack of business dynamism in Belgium.

The last section described how patents and subsequent productivity growth across sectors have evolved together, considering Belgium and other European countries. The link between the two variables is undoubtedly highly complex and caution is needed with this approach. But overall, this descriptive exercise suggests that the assumption of positive effects of patents translating into productivity gains should not be ruled out. This is a starting point for further deepening of the (*a priori* positive) association found and better understanding of the mechanisms and dynamics effectively at play.

Annexes

Annex 1 – Patents: main definitions and features of the associated processes

- Definition of a patent

According to the OECD (2009), "a patent is an intellectual property right issued by authorized bodies which gives its owner the legal right to prevent others from using, manufacturing, selling, importing, etc., in the country or countries concerned, for up to 20 years from the filing date. Patents are granted to firms, individuals or other entities as long as the invention satisfies the conditions for patentability: novelty, non-obviousness and industrial applicability".

In addition to the above-mentioned protection, WIPO (2015) adds that "the publication of a patent and in many countries patent applications give the public access to information regarding new technologies in order to stimulate innovation and contribute to economic growth".

Within the document accompanying each patent application, useful information can be found, such as the number and type of application, publication number, etc; the name and address of the inventor; the name and address of the applicant (usually the company employing the inventor); technical details regarding the invention (title, abstract, detailed description of the invention, how it is constructed, how it is used and what benefits it brings compared with what already exists); a list of claims (the clear and concise definition of what the patent legally protects); the codes corresponding to items in a technology classification; a series of dates (date of priority, application, grant, etc.) and a list of references to other patents or scientific literature considered as relevant to the determination of patentability of the invention.

- Possible routes of patents and offices

Following the OECD (2009) and WIPO (2015), a patent application may be filed via one of the following routes:

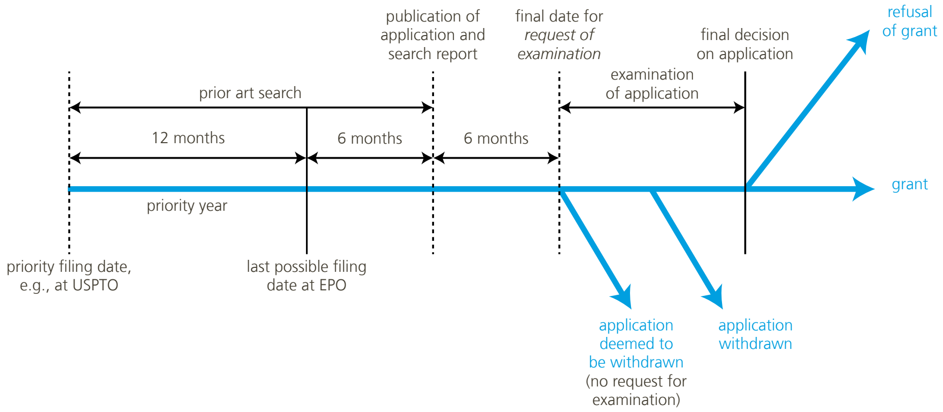
- National: when an inventor (an individual, company, public body, university, non-profit organisation) decides to protect an invention, the first step is to file an application with a national patent office – generally the national office of the applicant's country. After examination, the patent for an invention may be granted and enforced only in the country in which patent protection is requested in accordance with the law of that country. Corresponding applications covering the same invention can be filed in accordance with the respective national patent laws in different countries on an individual country-by-country basis.

- Regional: patent applications may (also) be filed at a regional patent office, for example the European Patent Office (EPO). Regional patent applications have the same effect as applications filed in the member states of the respective regional patent agreement. In certain regions, patents are granted centrally as a 'bundle' of national patents. In other regions, a single regional patent granted by the regional patent office has effect in the entire territory of that region. In order to validate regional patents in the EU Member States, provision of a translation of the granted patent into the national language may be required; this is for instance the case at the EPO (see also further).

- International: international applications may be filed with the national or certain regional patent offices of the contracting states of the Patent Cooperation Treaty (PCT), or directly at the international bureau of the World Intellectual Property Organization (WIPO) by any resident or national of a PCT contracting state. A single international patent application has the same effect as national or certain regional applications filed in each contracting state of the PCT. Although the major part of the patent application procedure is carried out within the international phase, a patent can only be granted by each designated state within the subsequent national phase.

Chart 9

Timeline of a typical patent from the national examination phase to the eventually enlarged regional protection



Source: Harhoff and Wagner (2005).

In the case of a patent in Belgium, the whole examination process may take from six months (national) to six years (regional/European) before it is granted.

- European patents: direct EPO and Euro-PCT applications

According to the OECD (2009), European patents can be obtained for all countries of the European Patent Convention by filing a single application at the EPO in one of the three official languages (English, French or German). European patents granted by the EPO have the same legal rights and are subject to the same conditions as national patents (granted by the national patent office). It is important to note that a granted European patent is a "bundle" of national patents, which must be additionally validated at the national patent office in order to be effective in member countries. The validation process may include the submission of a translation of the specification, payment of fees and other formalities required by the national patent office (once a European patent is granted, the competence is transferred to the national patent offices), which can end up being very costly depending on the number of countries where the patent proprietor wishes to validate the European patent.

Concerning the EPO, it is worth noting that it was created as to grant European patents based on a centralized examination procedure. It is not, however, an institution of the European Union. There is still at present no single grant of an EU-wide patent. However, recent legal steps were taken to establishing a "Unitary Patent System"[1] which provides a uniform patent protection in up to 25 EU Member States by submitting a single request to the EPO, for both the application procedure and the legal enforcement after grant. Its perks are that it would not only reduce the cost of patenting in Europe, it would also make the system more attractive[2]. The start of the new system is currently expected for the beginning of 2022.

1 Two EU Regulations provide the legal framework for the Unitary Patent system: i) EU Regulation No. 1257/2012 (OJ EPO 2013, 111) creates a "European patent with unitary effect", commonly referred to as "Unitary Patent"; and ii) EU Regulation No. 1260/2012 (OJ EPO 2013, 132) lays down the translation arrangements for Unitary Patents.

2 See Danguy J. and B. van Pottelsberghe (2011).

Next to direct filings of patents at the EPO, an international application for which the EPO is a designated office and which has been accorded an international filing date has, as from that date, the effect of a regular European application (Euro-direct application). Such international application, being equivalent to a regular European patent application, is referred to as "Euro-PCT application".

- Reference dates

Broadly speaking, there are four main reference dates (and for each, a corresponding patent document). An inventor seeking protection first files an application generally in his/her country of residence: this very first date refers to the 'priority date'. Then, he/she has a 12-month legal delay for eventually applying for protection of the original invention in other countries, referring to the 'application date'. The application is then published at least 18 months after the 'priority date', at the 'publication' date. Finally, it can take three to ten years for a patent to be granted ('granted date').

- Reference country

Patent documents include information distinguishing between the inventor's and the applicant's country:

- Patents following the *inventor's country* of residence indicate the inventiveness of the local labour force, laboratories and research facilities of a country. Opting for it helps give a better picture of a country's inventive performance.

- Patents following the *applicant's country* of residence refer to the ownership of an invention, regardless of where research facilities are actually located.

- Simple vs fractional counts of patents

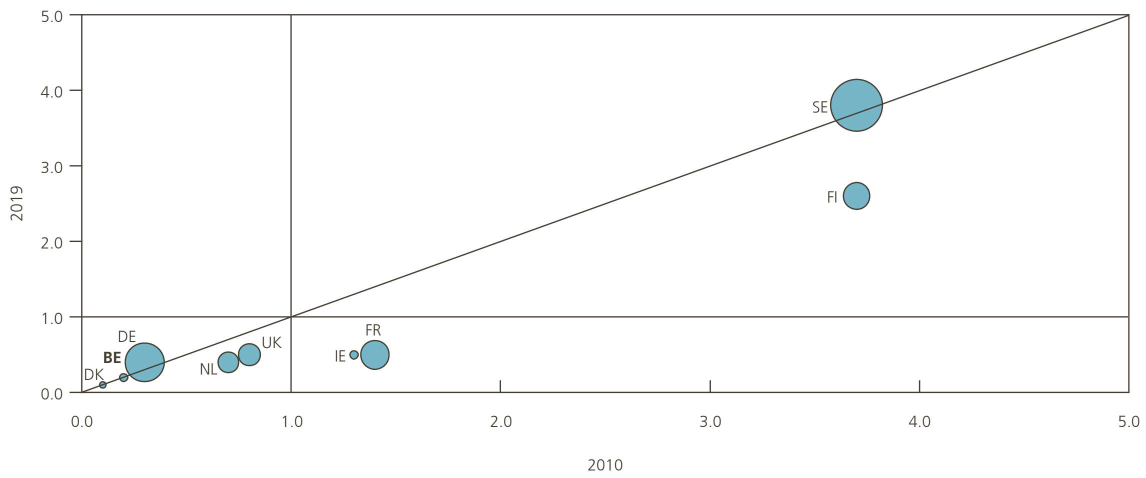
For a unique patent, many different applicants (or owners), as well as multiple inventors located in different countries, may be involved, so an alternative counting approach to the simple count of patents can be used.

Fractional counts enable multiple counts of the same patent to be avoided and better reflect the 'real' contribution of each country to a given patent. When applying a fractional count to patents, figures in absolute numbers may drop slightly which is consistent with its inherent calculation. If one application has more than one inventor, the application is divided equally amongst all of them and their corresponding country of residence (fractional counting), thus avoiding double counting.

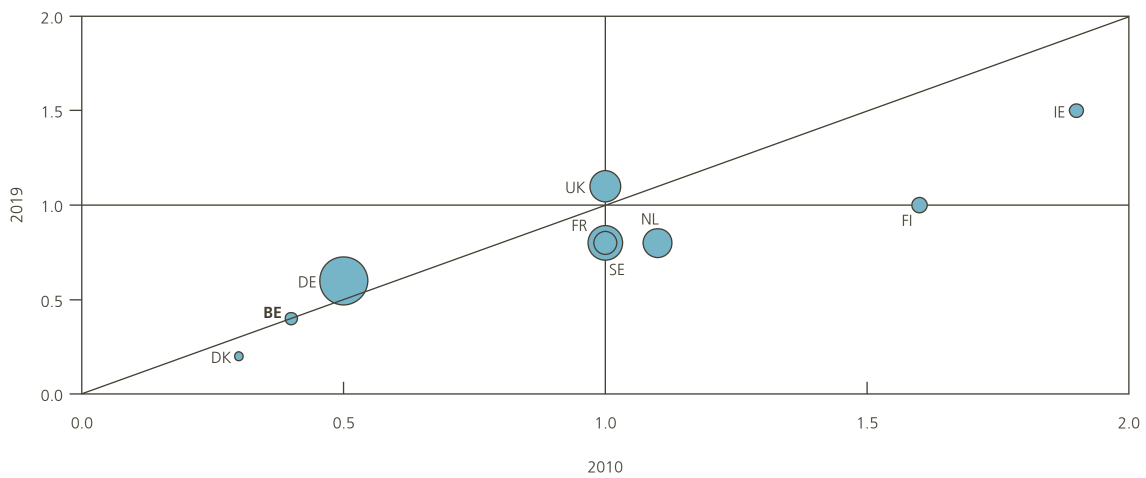
Annex 2 – Revealed Technology Advantage of patents of the top ten fields and environmental technologies of all countries at the EPO[1]

(2010 on the x-axis, 2019 on the y-axis, direct and Euro-PCT applications)

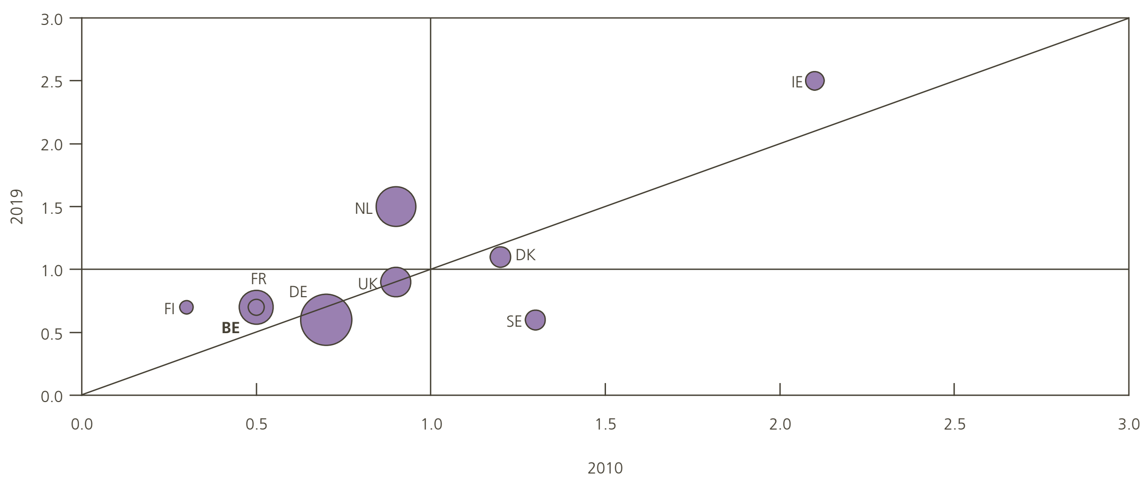
Digital communication



Computer technology

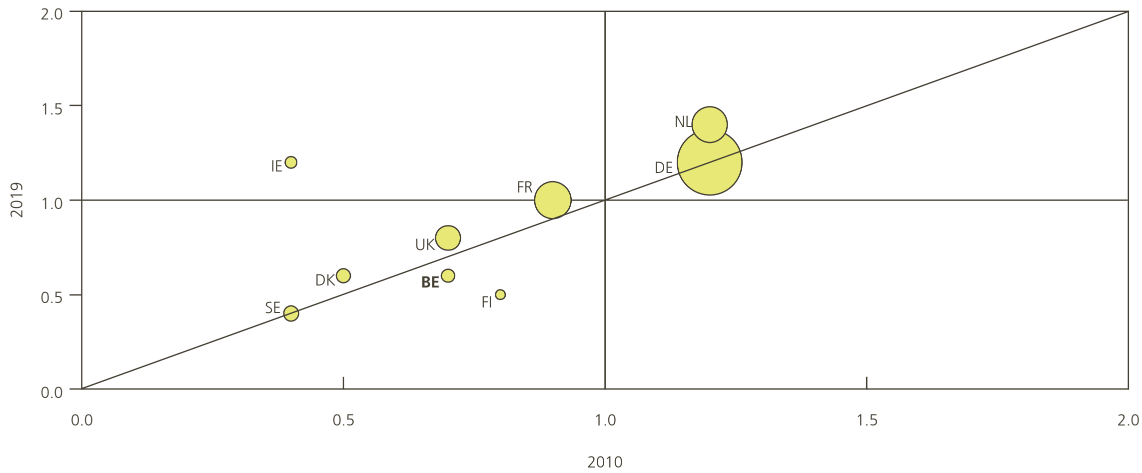


Medical technology

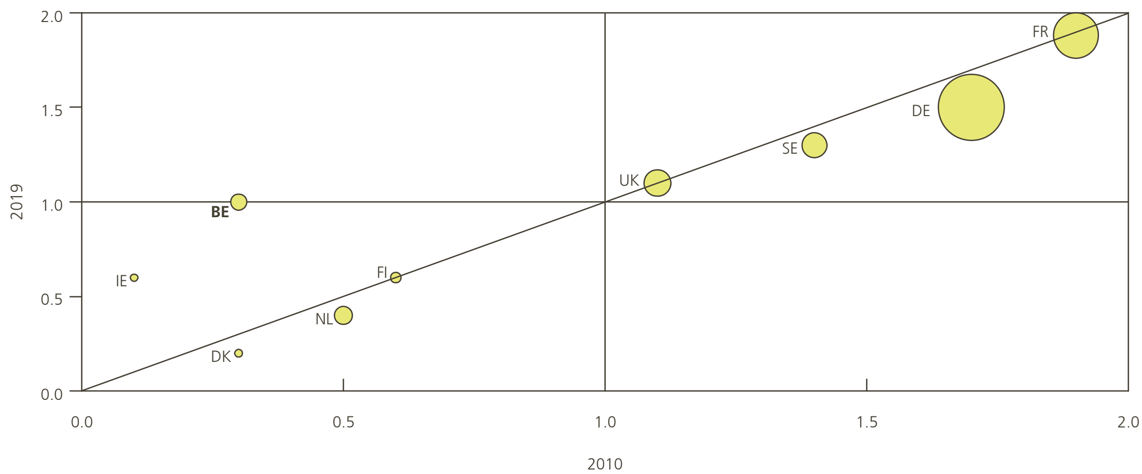


1 The size of the bubbles is proportional to the absolute number of patents of the country in the field of technology considered. An index above 1 signals a specialisation of patents in the sector considered (the higher, the more specialisation is reported). Countries above (below) the 45-degree line have reinforced (reduced) their specialisation in the technology field between 2010 and 2019.

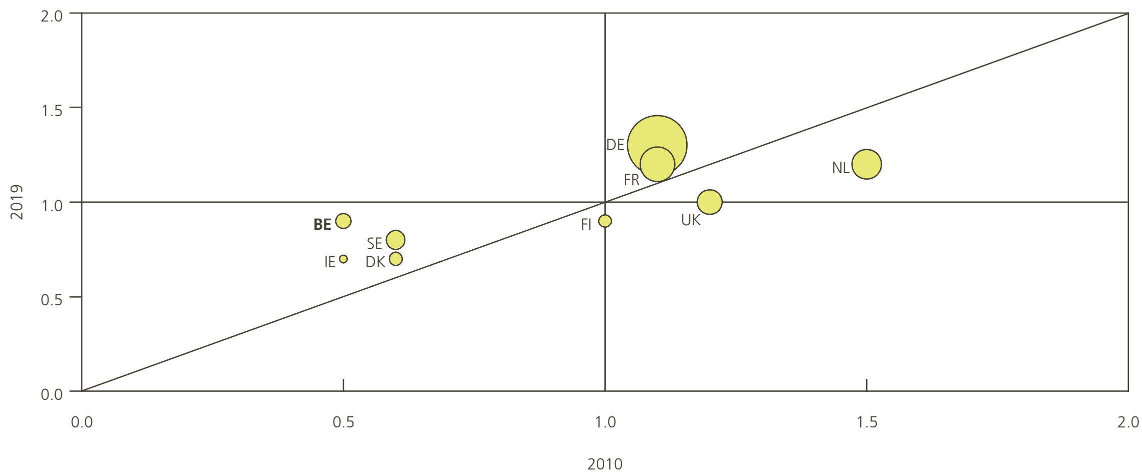
Electrical machinery



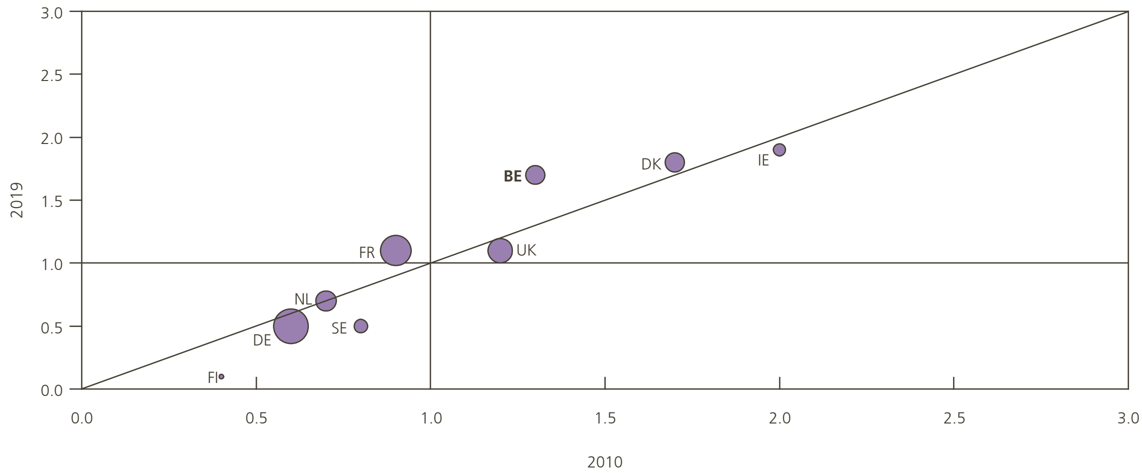
Transport



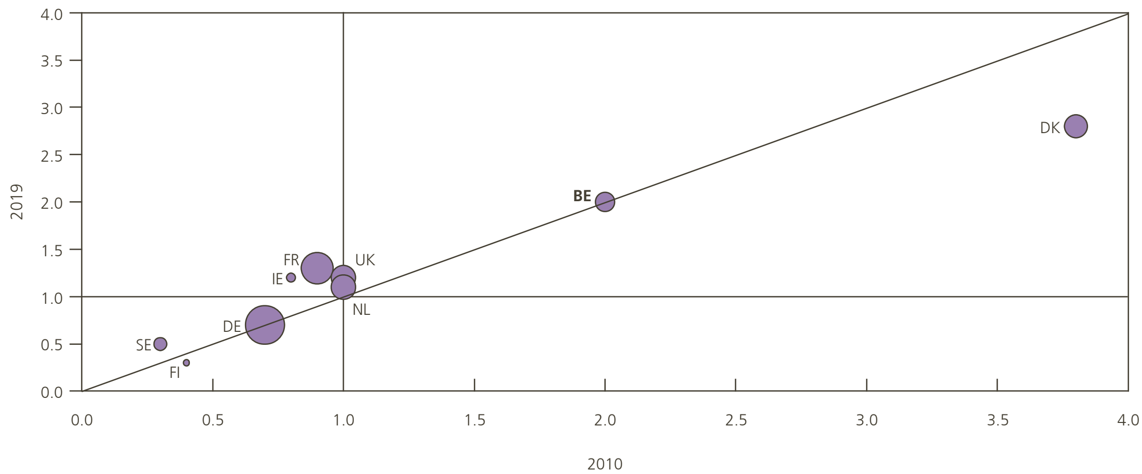
Measurement



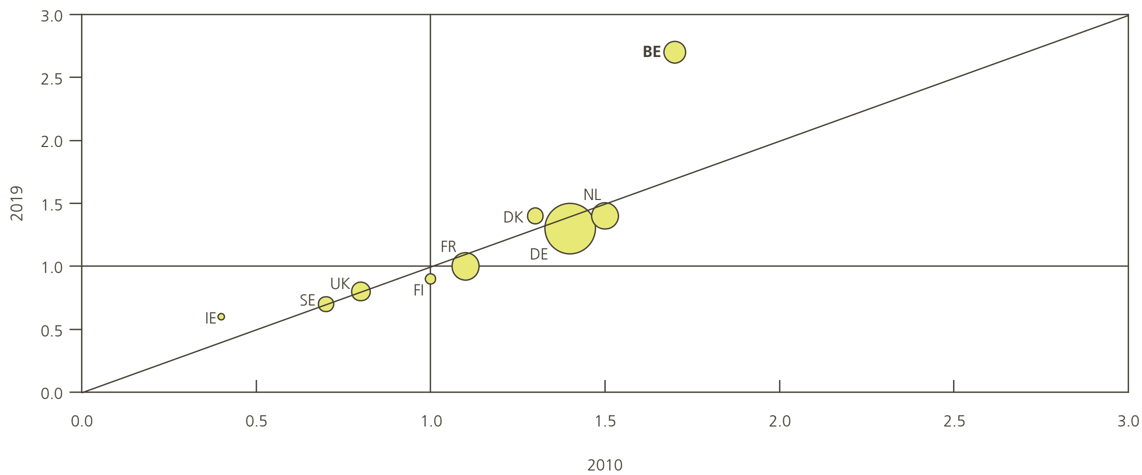
Pharmaceuticals



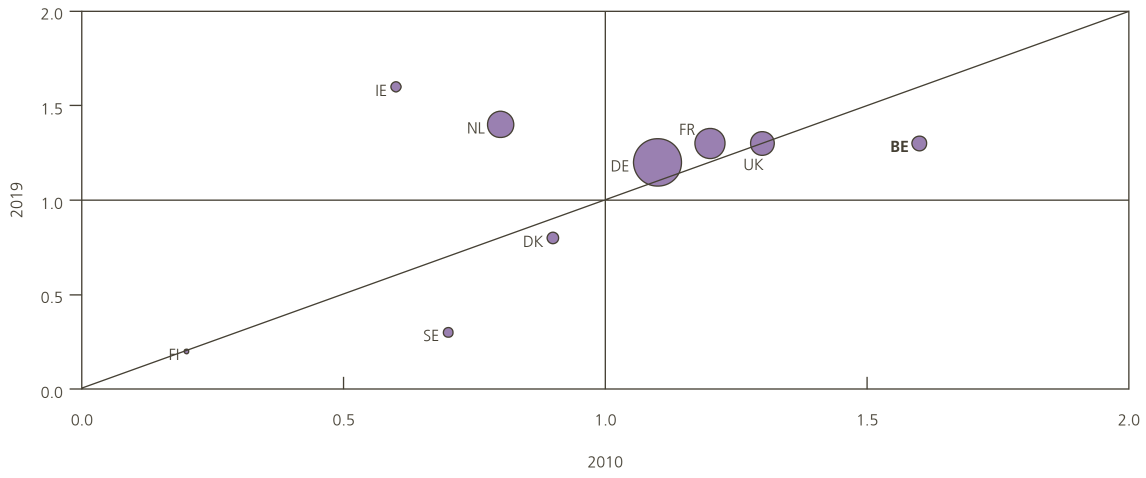
Biotechnology



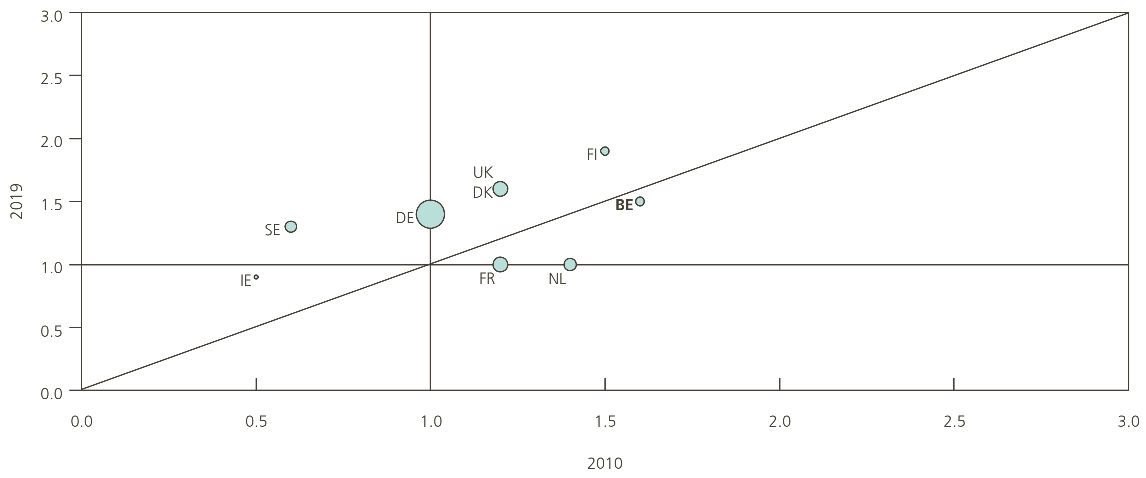
Other special machines



Organic fine chemistry



Environmental technology



Source: EPO.

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