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des brevets

Women's participation in inventive activity

Evidence from EPO data

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epo.org

Hungarian biochemist Katalin Karikó has spent 30 years researching messenger ribonucleic acid (mRNA). Her method to modify mRNA for safe use in the human body has paved the way for vaccines against coronavirus and other diseases, as well as prospective therapies for cancer and heart disease. Karikó won the 2022 European Inventor Award in the "Lifetime achievement" category.

Foreword

Currently, Europe is facing multiple challenges to public health, energy supply, its environment and geopolitical stability. The ability to meet many of these issues successfully depends more than ever on creativity and innovation. Our ability to shore up our economies also depends on a vibrant innovation sector supported by effective intellectual property protection. Industries that make intensive use of intellectual property rights (IPR), for example, already contribute 45% of the GDP of the EU. They are also more resilient in times of economic crisis.

This is a time when we must therefore do everything we can to nurture and empower diverse talent in the innovation sector. However, we know that these aspirations are not always met. The history of science and invention is indeed full of remarkable women, whose inventions have changed our lives – from Marie Curie and her pioneering research into radioactivity, to the key role played by Katalin Karikó's in developing mRNA vaccine technology used most recently to fight the COVID-19 pandemic. Yet women scientists have historically been denied equal opportunity, and they remain under-represented among inventors named on patent applications.

Drawing on the EPO's cutting-edge patent data, this study seeks to present an up to date and accurate picture of gender and patenting, as it stands today. It aims to provide key insights into the state-of-play of innovation by women in Europe, which can be used by policymakers and businesses.

It shows that real progress has been made in recent decades, with some European countries and industries leading the way towards more inclusiveness. However, there is still clear evidence of a persistently and disproportionately low number of women inventors. This gap is wider in Europe than in other parts of the world, especially in some Asian countries where high shares of women inventors constitute a major force for innovation. It has deep-rooted causes spanning the culture, educational systems and job markets in different countries.

Increasing women's participation in science thus remains a major challenge for Europe to address, as well as a key factor in its future sustainability and competitiveness. To help support a progressive agenda, this study also identifies some positive trends and measures that can be taken, such as supporting the mobility of women scientists and accelerating the career of star inventors among them. Continuing to raise awareness of this issue and its consequences is also of the utmost importance.

The EPO intends to fully play its role by highlighting the successes of women inventors, and informing the public debate with evidence on the inventor gender gap. By providing this insight, we can help ensure that the innovation and IP sectors lead the field in diversity and inclusion.

António Campinos
President, European Patent Office

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List of abbreviations

EPC	European Patent Convention
EPO	European Patent Office
IBM-GNR	Global Name Recognition produced by IBM
IP	Intellectual property
IPC	International Patent Classification
mRNA	Messenger ribonucleic acid
PATSTAT	EPO worldwide patent statistics database
PCT	Patent Cooperation Treaty
PRO	Public research organisation
R&D	Research and development
SSA	Social Security Administration
STEM	Science, technology, engineering and mathematics
UKIPO	United Kingdom Intellectual Property Office
USPTO	United States Patent and Trademark Office
WGND	Worldwide Gender Name Dictionary
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WIR	Women inventor rate

List of countries

AT	Austria
BE	Belgium
BG	Bulgaria
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
NL	Netherlands
NO	Norway
PL	Poland
P.R. China	People's Republic of China
PT	Portugal
R. Korea	Republic of Korea
RO	Romania
RS	Serbia
SE	Sweden
SI	Slovenia
SK	Slovakia
TR	Turkey
UK	United Kingdom
US	United States

Executive summary

While women's contributions to science and technology have been increasing in recent decades, parity with men has still not been reached. This study examines women's participation in patenting activity at the EPO in the 38 contracting states to the European Patent Convention (EPC).[1] The analysis focuses on all European patent applications submitted between 1978 and 2019, with occasional extensions until 2021, where possible. Using disambiguated inventor data and attributing gender to individual inventors based on their names, the analysis provides evidence on the presence of women inventors across different countries, time periods, technology fields and patent applicant profiles.

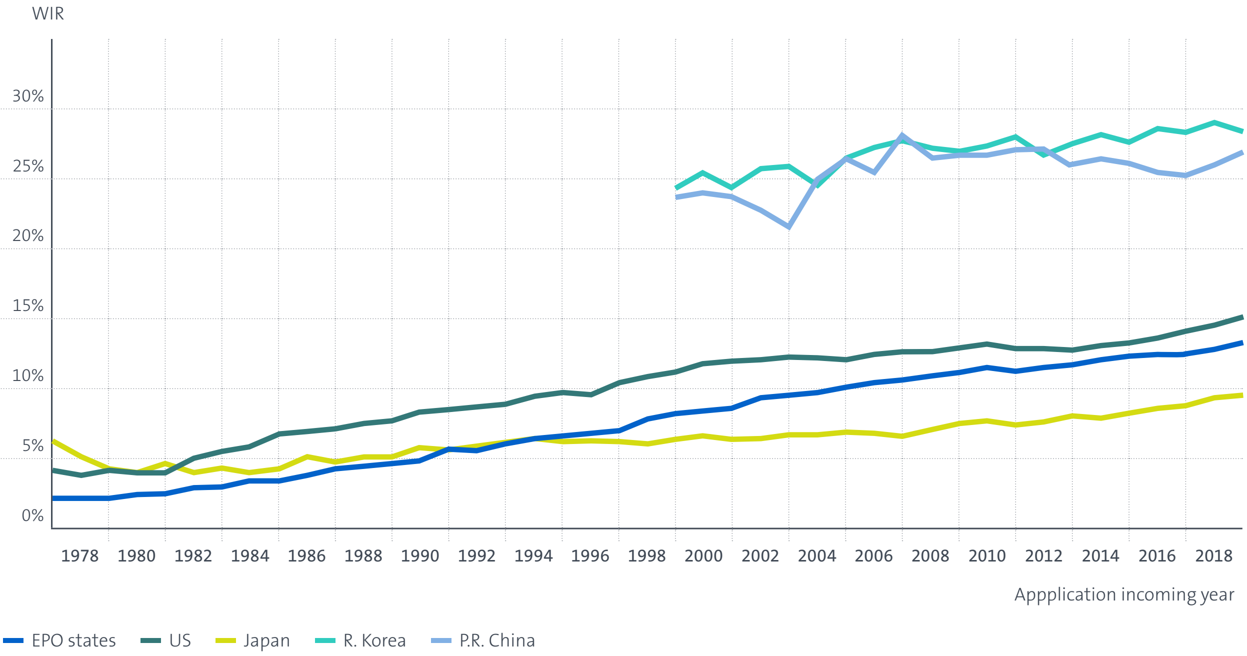
1 The data exclude Montenegro, which acceded the EPC on 1 October 2022, after this study was prepared.

Key findings

1. The share of women inventors has increased steadily over time but is still below parity with that of inventors who are men. In EPO countries, the women inventor rate (WIR), which measures the percentage of women inventors among all inventors in patent applications in a given year, increased from around 2% in the late 1970s to more than 13% in 2019.

Figure E.1

WIR, 1978–2019

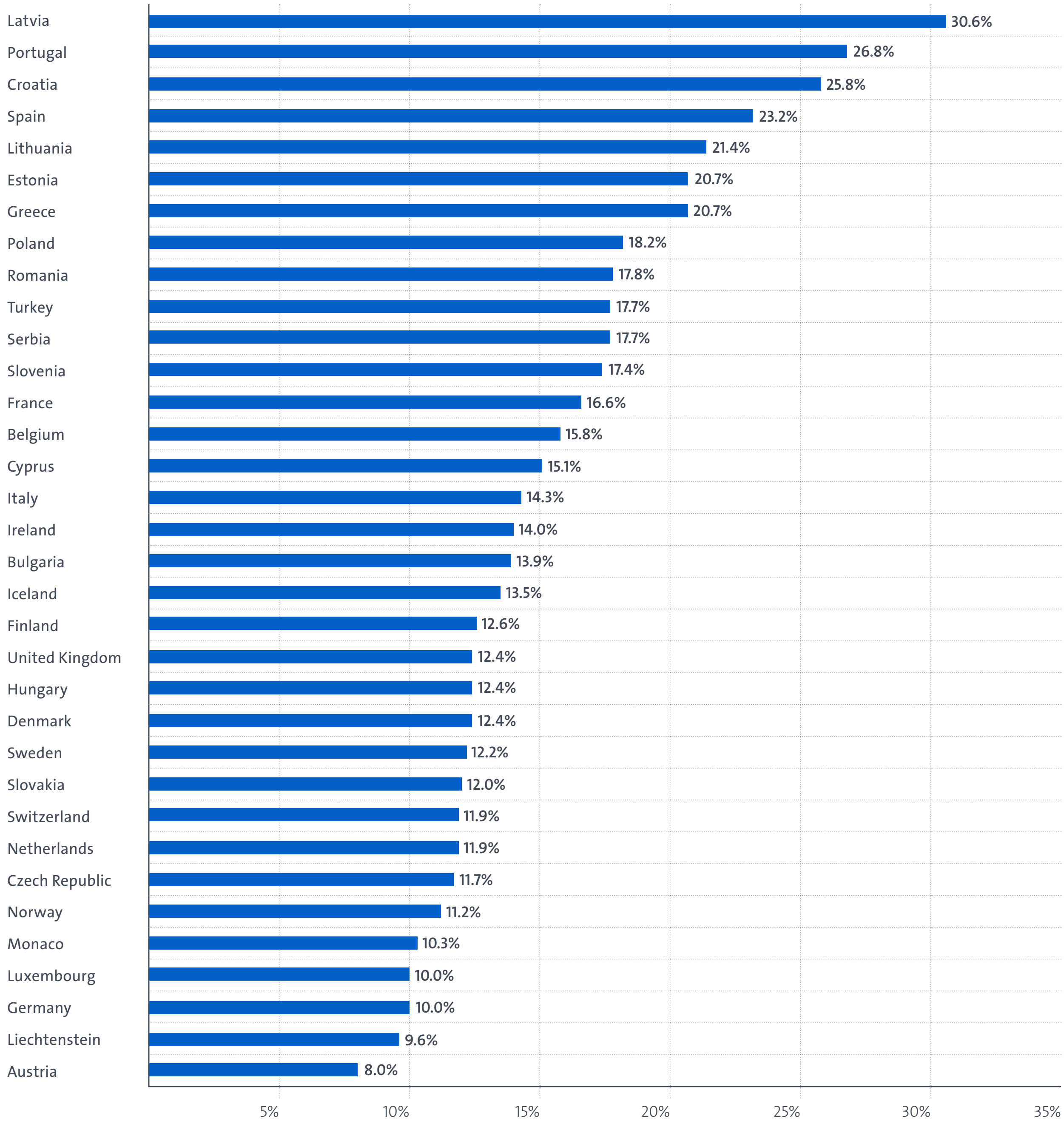


Source: author's calculations

2. In 2019, the WIR in EPO countries (13.2%) is well above that in Japan (9.5%) but below the US WIR (15.0%). P.R. China and R. Korea show much higher shares of women inventors (26.8% and 28.3% in 2019, respectively), although the estimates are less robust than for other countries. Among EPC contracting states, Latvia (30.6% in 2010-2019), Portugal (26.8%), Croatia (25.8%), Spain (23.2%) and Lithuania (21.4%) have the highest WIR values, while Germany (10.0%), Luxembourg (10.0%), Liechtenstein (9.6%) and Austria (8.0%) have the lowest.

Figure E.2

WIR by EPO country, 2010–2019



Source: author's calculations

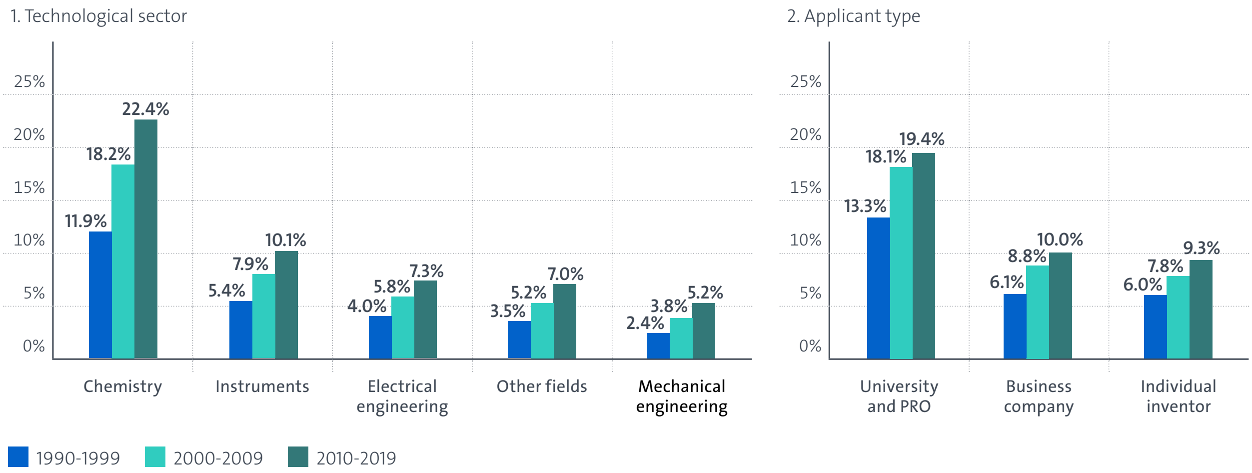
3. Differences across EPO countries can largely be explained by those countries' technology specialisations and the contributions of universities and public research organisations (PROs) to patenting activity.

   a. Chemistry stands out as the technology sector with the highest share of women inventors. The WIR in the 2010–2019 period reached over 22%, while the values in other technology sectors ranged from 10.1% in Instruments to 5.2% in Mechanical engineering. Within the Chemistry sector, Biotechnology and Pharmaceuticals have WIR values over 30%.

   b. Patent applications from universities and PROs have a significantly larger share of women inventors than their counterparts from companies. The WIR of 19.4% for this segment in 2010–2019 significantly exceeds that of individual inventors (9.3%) and private companies (10.0%).

Figure E.3

WIR in EPO countries by technological sector and applicant type, 2010–2019



Source: author's calculations

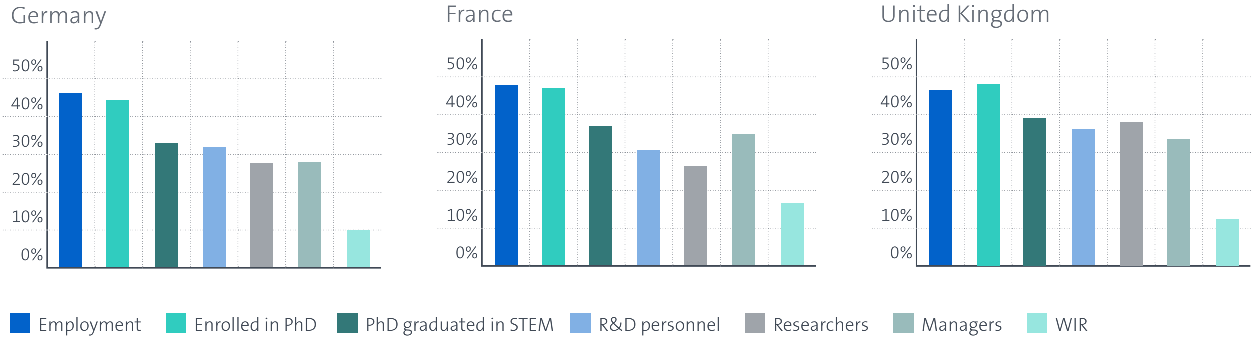
4. There is a consistent pattern of a decreasing share of women in segments ranging from total employment to PhD enrolment, to PhD graduates in STEM, to R&D personnel and researchers, to patenting. This confirms the diagnostic of a "leaking pipeline" issue, whereby women in EPO countries face increasing obstacles when progressing in STEM careers. Further analysis shows that women inventors, on average, produce fewer inventions than inventors who are men, which is partly due to their lower seniority.

5. Women are more likely to be found in inventor teams than among individual inventors, but they tend to have less senior positions in such teams than men. This reflects the increasing division of intellectual labour that accompanies the accumulation of knowledge, especially in technology fields in which women inventors tend to specialise, and bodes well for the future of women in patenting.

6. Women are also over-represented among inventors whose names and surnames are infrequent in their country of activity and more frequent abroad, which indicates a higher WIR for migrant women inventors than for native ones. This suggests that support for international mobility may give women more opportunities to engage in inventive careers.

Figure E.4

Comparison of WIR with women's shares in total employment, PhD enrolment, PhD graduates in STEM, R&D personnel, researchers and managers, 2010–2019



Source: author's calculations

1. Introduction

While women's contributions to science and technology have been increasing in recent decades, parity with men has still not been reached. As a result, society is missing out on many goods, drugs and services due to the low participation of women in inventive activities. According to recent research, for instance, patenting in the United States could quadruple if women, minorities and children from low-income families became inventors at the same rate as men (Bell et al., 2019). It also shows that a lack of women inventors translates into reduced breadth and inclusivity of technology (Nielsen et al., 2017; Koning et al., 2021; Jaravel and Einiö, 2021).[2] For example, an analysis of US biomedical patents by Koning et al. (2021) showed that women's patents are more likely to focus on women-specific health problems and men's patents on men-specific ones.

This study specifically focuses on women's participation in patenting activity at the EPO in the 38 contracting states to the European Patent Convention (EPC). Drawing on patent data encompassing all European patent applications between 1978 and 2019, with occasional extensions until 2021, the study aims to provide policymakers and the general public with relevant insights and evidence on the contribution of women to technological innovation and its development over time, and the gaps that remain to be bridged to exploit the full potential of women inventors in Europe.

Assessing women's participation in patenting is useful not only to account for this gender gap, but also to understand its causes and consequences. Unlike most indicators of women's participation in STEM activities, patents provide a precise measure of the output of inventive activities at the individual level. The wealth of information available in patent data therefore enables fine-grained analysis of the activities of women inventors, including their distribution across industries and geographies, the science and technology fields in which they specialise, as well as their position in scientific teams and collaboration networks.

About the gender gap in patenting

The low participation of women in patenting has been attributed to a variety of factors. First and foremost, women who choose any type of career, and especially those in the STEM professions, face tougher selection than men.[3] This explains the "leaking pipeline" phenomenon, by which invisible barriers filter out women STEM graduates first from research jobs and subsequently from the upper echelons of their organisations. Typically, women academics or senior R&D staff are rare compared with women STEM students, and their under-representation increases in proportion to the seniority of the position (Alper, 1993; Delgado and Murray, 2021).

Women at universities have fewer links to industry and are confined to more traditional academic career models than men. Available evidence shows that women academics submit about 40% fewer patent applications than men, despite a similar scientific productivity (Ding et al., 2006). In addition, when it comes to inventions that are both described in scientific publications and patented, women credited as authors in the publications are less likely than their co-authors who are men to be credited as inventors in the corresponding patents (Lissoni et al., 2013; 2020).

Low recognition extends to business R&D, where women earn less than men although they contribute as much to the development of high-quality inventions (Hoisl and Mariani, 2017). Evidence from US patents suggests that women inventors are less likely than men who invent to obtain and maintain patent rights (Jensen et al., 2018; Reshef et al., 2021) and that their patents are characterised by a smaller average number of claims and citations (Jensen et al., 2018).

2 An extensive summary of this research avenue is presented in a post by Matt Clancy on the innovation blog "What's new under the sun", https://mattsclancy.substack.com/p/gender-and-what-gets-researched?r=3iwbj&utm_campaign=post&utm_medium=email

3 STEM stands for science, technology, engineering and mathematics.

Outline of the report

This report uses data from patent applications at the European Patent Office (EPO) to examine the contribution of European women to inventorship. In particular, gender is attributed to EPO inventors based on their names, allowing the computation of a "women inventor rate" (WIR) and other statistics across countries, sub-national regions, technologies and applicants, as well as over time. Section 2 presents an overview of recent research on women's inventorship and describes the methodology for gender attribution. Section 3 presents results per country and over time, while section 4 looks at the composition effects of women's contributions by technology and type of applicant. Section 5 analyses women inventors' individual productivity and participation in inventor teams. Section 6 presents a conclusion.

2. Methodology

For this study, all patent applications included in PATSTAT (the EPO worldwide patent statistics database) and filed at the EPO between 1976 and 2019 are considered, which is a total of 3 945 992 applications. For some statistics, data from 2020 and 2021 have been included (thus adding 159 294 applications, all of which with at least one inventor residing in an EPC country).

The study methodology follows Toole et al. (2019, 2021) and consists in attributing gender to roughly 93% of disambiguated inventors (4 158 000 individuals) based on the inventors' names (see Box 1).[4] Patents and inventors are in turn assigned to countries according to the inventor address, based on the address data in PATSTAT. As reported in Table 1, the attribution rate is highest for EPO countries (98%), followed by the US (95%) and Japan (93%). Other Asian countries have lower attribution rates: 83% for India, 69% for R. Korea and 59% for P.R. China.

See Annex 1 for further information about the patent and inventor data preparation, gender attribution and inventor disambiguation processes and other conceptual issues.

Table 1

Gender attribution rate by inventor country of residence (for disambiguated inventors)

	Attribution (%)	Number (x 1 000)
All countries	**92.6**	**4 158**
All EPO countries	**97.8**	**1 653**
Selected EPO countries:		
Germany	98.2	543
France	98.0	257
Sweden	97.5	66
Italy	98.0	116
Switzerland	97.7	79
Netherlands	95.9	91
UK	97.7	214
Selected non-EPO countries:		
US	95.2	1 095
P.R. China	58.8	111
Japan	92.5	883
R. Korea	68.6	149
India	83.1	38

Note: EPC contracting states are: Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Germany, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovenia, Slovakia, Spain, Sweden, Switzerland, Turkey and United Kingdom. The study data exclude Montenegro, which was not yet an EPC contracting state when this report was prepared.

4 Attributing gender on the sole basis of the inventors' names has its limitations, especially when it comes to Asian inventors both in Asian countries and elsewhere. With the rise of patenting in such countries, and the increasing migration flows of Asian inventors to North America, Europe and Australia, this will soon become a critical issue. One possible way forward is to merge this dataset with the inventors' public profiles (from social media or institutional websites) and/or administrative data, in line with what academic researchers have been doing with historical data or for relatively limited samples over the past few years. This would require solving not only the technical problems associated with such a demanding data linkage effort, but also the legal and ethical issues associated with the handling of sensitive data.

Box 1: Overview of recent studies on women's inventorship

Whatever its origins, the gender gap in patenting has been extensively documented in recent years. In the absence of inventors' gender information on patents, patent attribution requires name analysis.

Naldi et al. (2004a, 2004b) made one of the first attempts in this direction. The authors collected 8 291 different names (with associated gender) from different sources such as dictionaries, calendars, books, internet sites, record offices and telephone directories, for six European countries. Based on those names, they successfully attributed a gender to around 97% of 100 000 inventors with addresses in the selected countries, as per EPO patents filed in 1998. Frietsch et al. (2009) extended the analysis to all EPO patents until 2005 for 14 countries. Sugimoto et al. (2015) considered all USPTO granted patents (1976-2013) and determined the inventors' gender by comparing their names to several worldwide name information lists (such as Wikipedia and WikiName) and some country-specific gender information lists (such as the US census) plus additional semantics for hard-to-genderise Asian names. Their success rate in assigning gender was around 90% for US-resident inventors (higher for European countries, lower for Asian ones). Also for the US, Delgado et al. (2019), Delgado and Murray (2021, 2018) and Reshef et al. (2021) counted the gender occurrences of each name in the US Social Security Administration (SSA), starting from the beginning of the 20th century, and computed the frequency of its attribution to men and to women. They then attributed inventors a gender if their name was unambiguously attributable to a man or a woman.

Quite recently, a number of intellectual property (IP) offices have also engaged in gender attribution efforts. To date, the most comprehensive one is that of the UK Intellectual Property Office, which, in 2016, examined all patents included in PATSTAT (UKIPO, 2016). The authors of this study used two different external sources of genderised names: first, census data (US SSA and the UK Office for National Statistics); second, all Facebook public profile pages with both name and gender information (Tang et al., 2011). Attribution rates were around 80-90% for the US, Japan, the UK, Germany, France and Italy, but were much lower for P.R. China (27.90%), Republic of Korea (29.09%) and Chinese Taipei (11.62%).

The World Intellectual Property Organization (WIPO) produces gender information for inventors listed on Patent Cooperation Treaty (PCT) patents, based on a dictionary of 6.2 million names for 182 different countries (recently updated to include approximately 25 million names; Lax-Martinez et al., 2021). As explained by Lax-Martinez et al. (2016, 2021), the information sources include social security registers and national statistical offices of various countries, Wikipedia lists and even manual checks by WIPO officials. Attribution rates are mostly over or close to 90%, not only for Western countries (97% for the US, 99.2% for Germany, 98.9% for the UK) but also for Asian ones (94% for Japan, 92.1% for R. Korea, 88.3% for P.R. China and 88.9% for India). More recently, the USPTO published both a report and its sequel for inventors from the PatentsView database (Toole et al., 2019, 2021). The methodology of the study made it possible to attribute gender to roughly 93% of inventors (3 244 813 individuals), a figure that rises to 96% for US residents and falls to 90% for Japan, 72% for India, and 51% for P.R. China.

Spanish scientist Elena García Armada has developed a battery-powered exoskeleton for children with disabilities. The adaptable device features a network of small motors with sensors, software and machinery which work together as mechanical joints. It allows young patients to walk during rehabilitation sessions, reducing muscle degradation and medical complications. García Armada won the 2022 European Inventor Award in the “Popular Prize” category.

3. Women's inventorship worldwide and in EPO countries

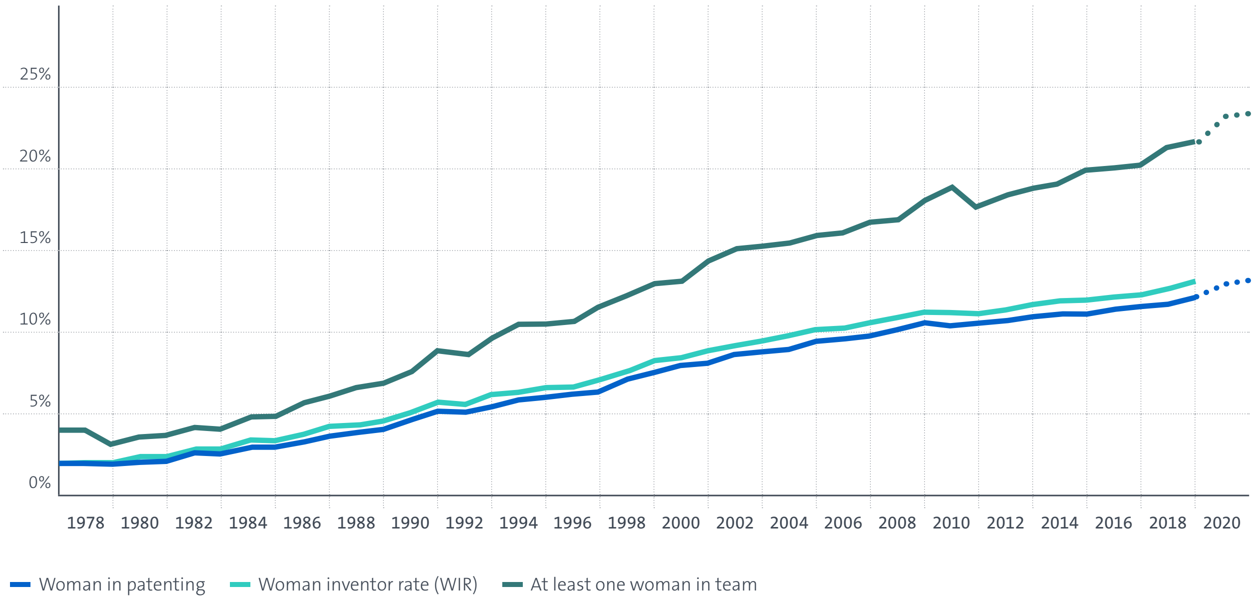
Various metrics can be used to evaluate the patenting activity of women across regions and over time. The principal metric is the women inventor rate (WIR), which measures the percentage of women inventors and requires disambiguated inventor data. In addition, two other metrics can be considered (following Delgado et al., 2019; Delgado and Murray, 2021; Martinez et al., 2016; Toole et al., 2019): women's share of patents, which does not require disambiguated inventor data but attributes each patent fractionally to each inventor appearing on it and aggregates all women's shares across patents; and the share of patent applications that include at least one woman inventor, which does not require inventor disambiguation either. Yearly computations for all three metrics are presented by year of application for European patents at the EPO, so as to avoid truncation in the most recent years.

As shown in Figure 1, the WIR for EPO countries has increased consistently in recent decades, from around 2% in the late 1970s to over 13% in 2019. Women's share of patents follows a similar but slightly lower path. This difference in levels can be explained in two ways. First, it could simply be the case that women are less productive inventors than men, meaning they produce fewer patents per head (further explored in Section 5). Second, the difference may be due to women's over-representation in large teams, which translates into a lower share of patents due to fractional counting of inventors' contributions. In turn, this over-representation may be explained by the women inventors' specialisations in technology fields in which teamwork is the norm (further explored in Section 4).

Women's share of patent applications and share of inventor teams including at least one woman are metrics that can be extended until 2021 due to availability of data. Overall, both metrics have been increasing further in the most recent years. However, the share of inventor teams including at least one woman, which is systematically higher, is increasing faster than the WIR. This clearly implies that the increase of women's patenting activity must be attributed to an increase in their participation in inventor teams, rather than to the production of "solo" patent applications.

Figure 1

Women's participation in patenting in EPO countries, various measures, 1978–2021

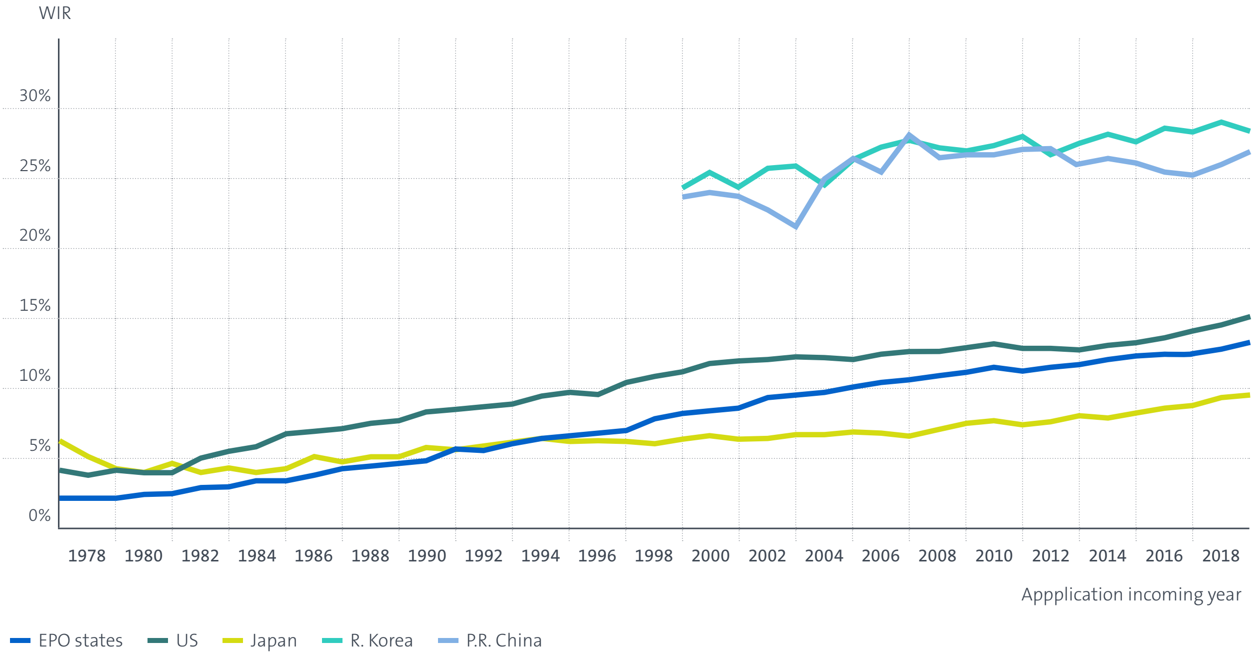


Source: author's calculations

Figure 2 compares the ensemble of EPO countries with a number of other major contributors to patenting worldwide. The WIR in EPO countries (13.2%) is slightly lower than in the United States (15% in 2019), in line with the findings of Toole et al. (2019), but higher than in Japan (9.5%). Note however that it is significantly lower than in P.R. China (26.8%) and R. Korea (28.3%), which exhibit the highest WIR levels among the top innovation centres.[5]

Figure 2

WIR in EPO countries compared with top countries, 1978–2019



Source: author's calculations

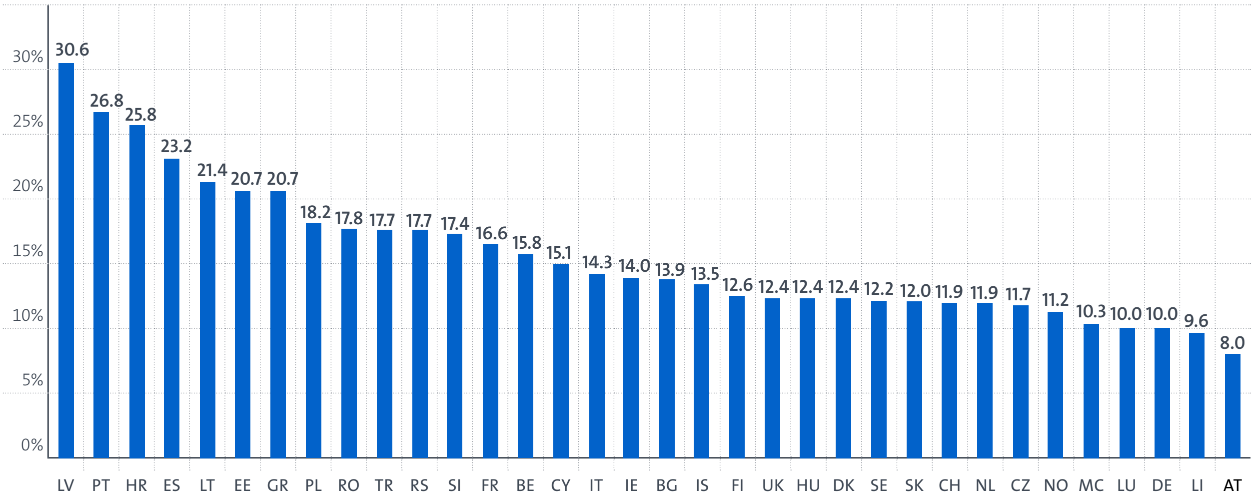
5 This result should be interpreted with caution, because gender attribution for these two Asian countries is relatively poor and is based on less strict criteria for identifying women, which may translate into low precision (high number of false positives).

Figure 3 provides details on the WIR across EPO countries, for the 2010–2019 period by priority year.[6] The highest WIR levels are recorded in Latvia (30.6%), Portugal (26.8%), Croatia (25.8%), Spain (23.2%) and Lithuania (21.4%). Interestingly, Austria (8.0%), Germany (10.0%) and the Netherlands (11.9%), which are among the top 10 patenting countries at the EPO (see EPO Patent Index 2021), are at the bottom of the ranking. Yet, differences are also considerable among larger patenting countries, with France (16.6%), Belgium (15.8%) and Italy (14.3%) scoring much better on this metric.

Once again, cross-country differences may depend on composition effects, which are further investigated in the next section. The countries with a higher WIR may be patenting more in technological fields with higher women's participation, or depend more, for patenting, on universities and public research organisations (PROs) rather than companies, the former being possibly more open to women's participation, due to historical reasons or public regulation.

Figure 3

WIR by EPO country, 2010–2019 (priority year)



Note: 34 out of 38 countries are featured in this Figure. Albania, Malta, North Macedonia and San Marino are excluded, having too few patent applications with inventors' addresses in the country during the period analysed. The study data also exclude Montenegro, which was not yet an EPO contracting state when this report was prepared.

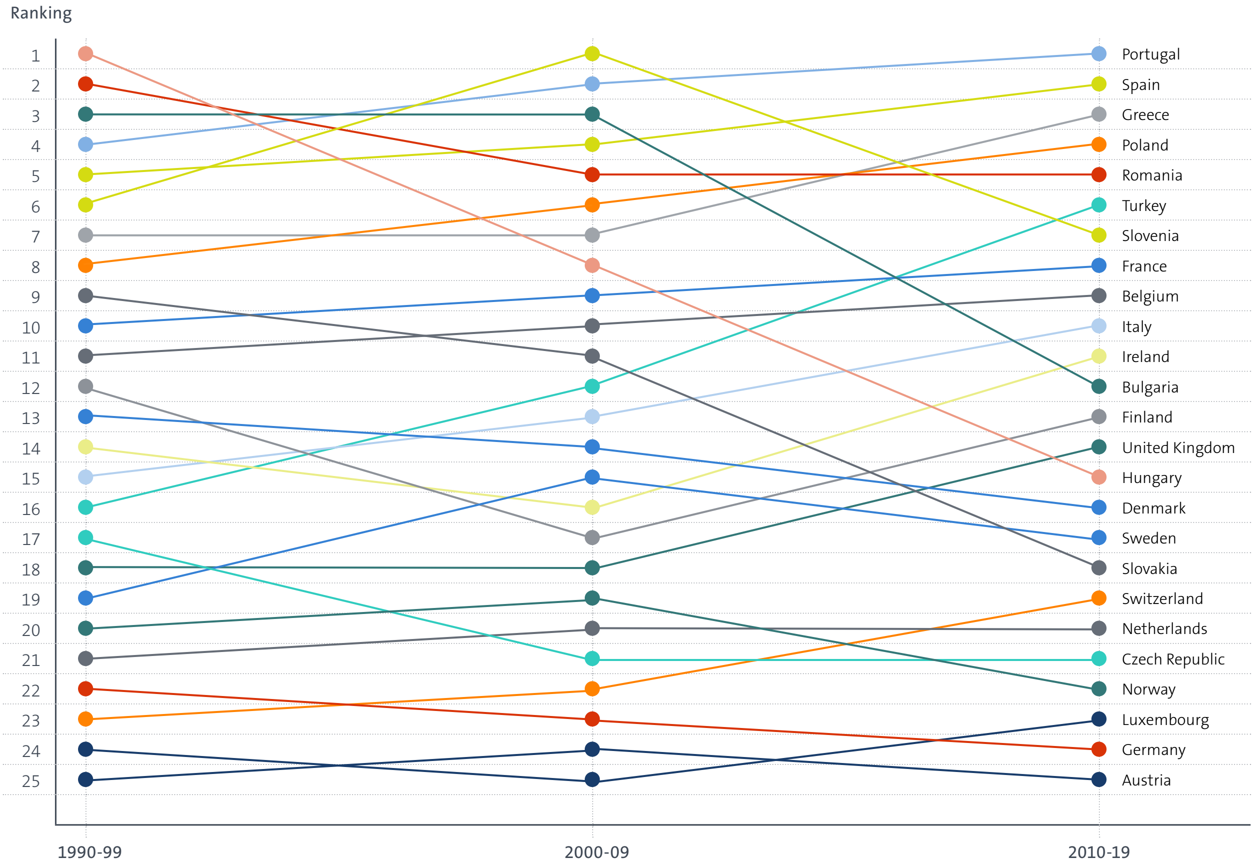
Source: author's calculations

6 The priority date is the first date of filing of a patent application for a given invention. It is essential for determining whether any subsequent application for the same invention can still be assessed as novel. It also makes it possible to determine whether the subject-matter of a patent application is prior art on a particular date.

Figure 4 shows the evolution of country rankings for three 10-year periods (1990–1999, 2000–2009 and 2010–2019), with various positions appearing to be rather stable over time. In the most recent period, Portugal, Spain and Greece presented the highest WIR values. Hungary, Slovakia and Bulgaria show the largest drop in rankings over time from their top positions in the 1990s. The country that shows the most significant improvement is Turkey, climbing from 16th position in the 1990s to 6th in the 2010s.

Figure 4

Ranked gender balance in the 25 largest patenting EPO countries by WIR, 1990–2019



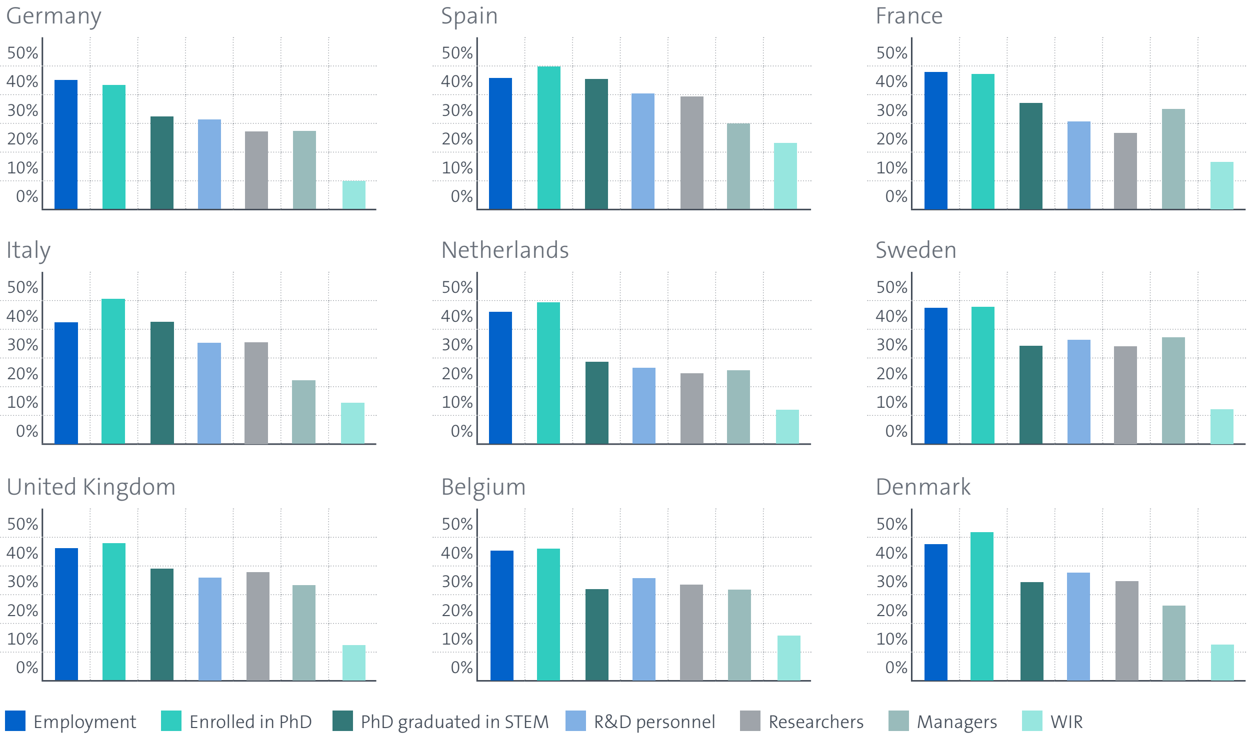
Source: author's calculations

Besides comparing the WIR across countries and over time, it can also be compared to indicators of women's participation in other types of related economic and scientific activities, such as women's share of total employment, among PhD enrolment, among PhD graduates in STEM, among R&D personnel, among researchers and among managers. Figure 5 reports the results of this exercise for nine EPO countries (which are the largest in terms of patenting at the EPO).

Several stylised facts emerge. The main, and very striking, result is that in all nine countries the share of women among inventors in European patent applications is significantly lower than in any of the other activities. In all nine countries the share of women in total employment is above 40% and sometimes even above 50%, but always a multiple of their share among inventors (WIR). Data for PhD enrolment show a similar picture. PhD graduates in STEM present a slightly different picture: in some countries, notably Germany, Belgium and Sweden, the share of women falls to around 30%, while elsewhere it remains high and above 40% (as in Italy, Spain and especially the Netherlands). The share of women further decreases when looking at data on R&D personnel and researchers, with a few exceptions (Spain and the UK). This suggests that the "leaking pipeline" mechanism is at work: women are less represented among PhD graduates in STEM and then further hampered in their careers as researchers. At the same time, though, the leaking pipeline alone cannot explain the low WIR values observed in all countries. Even the lowest shares of researchers and R&D personnel are still multiples of the WIR in the countries concerned. For example, in Germany women account for 27% of all R&D staff, almost three times its WIR, while the proportion between the two metrics is still 2 to 1 for France. Even among managers, usually an occupation highly dominated by men, women's shares are around 2–3 times bigger than among inventors.

Figure 5

Comparison of WIR with women's shares in total employment, PhD enrolment, PhD graduates in STEM, R&D personnel, researchers and managers, 2010–2019



Notes: Employment: Share of women in the labour force (% of total labour force) – source: World Bank. PhD enrolment: Share of women enrolled in tertiary education, ISCED 8 programmes (PhD) – source: Eurostat. PhD graduated in STEM: Share of women graduated at doctoral level, in STEM (science, maths, computing, engineering), among population aged 25-34 – source: Eurostat. R&D personnel: Total R&D personnel (head counts), % women – source: UNESCO. Researchers: Researchers (head counts), % women. Managers: Women's share of employment in senior and middle management (%) – source: World Bank (ILOSTAT database). WIR: Women inventor rate.

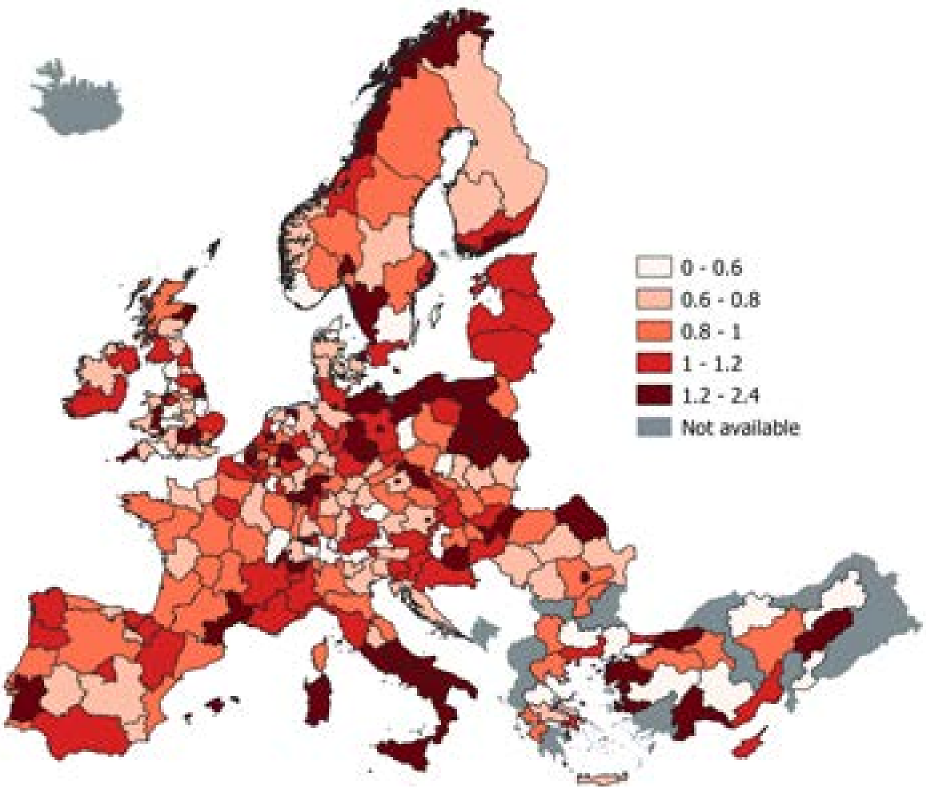
Source: author's calculations

Finally, Figure 6 provides geographical information on the WIR across all regions (NUTS2) of EPO countries.[7] In particular, it maps the ratio between the WIR as calculated for each region and the WIR calculated at the national level for the country to which the region belongs. Darker zones indicate regions with higher WIR values compared with the national average and lighter zones regions with lower values. The first observation is that the degree of regional heterogeneity is remarkable. Most regions' WIR ratio is below 80% of the national average and a few regions have a WIR value that is twice as high as the national average. The latter is the case for some peripheral regions with relatively low patenting activity, such as southern Italy or eastern Poland, but also for some of the largest innovation hubs in Europe, such as London, the Capital Region of Denmark (which includes Copenhagen) or Lazio (the region of Rome in Italy). Indeed, with a few exceptions, such as Lombardy (the region of Milan in Italy), most of the large national innovation hubs have a WIR which is above the national average or at least very close to it.

Very high WIR values in peripheral regions may be statistical artifacts, due to paucity of observations (so that a handful of observations can make a big difference). High WIR values in large national innovation hubs may be due to a mix of different factors: a specialisation in technological fields where women inventors are relatively well represented; the weight carried by patents from universities, which reserve more opportunities for women scientists than the private sector; and possibly some genuine sociological factors, such as a higher acceptance of women in professions dominated by men. However, it may also be the case that locational advantages, such as the necessity of physical proximity to other inventors and researchers in order to access their knowledge, are more important for women than for men. Women, relative to men, are less likely to move across locations and participate in conferences and seminars away from their residence (Delgado et al., 2019).

Figure 6

Ratios of WIR across NUTS2 regions of EPO countries, 2010–2019



Source: author's calculations

7 Annex 2 lists all NUTS2 regions, together with the number of inventors identified, the regional WIR and the WIR gap.

Serbian-American bioengineer Gordana Vunjak-Novakovic has opened new horizons in regenerative medicine with her method for growing new tissue outside the body using a patient‘s own cells. The approach is safer, more precise and less intrusive in facial reconstruction, and holds promise for replacing damaged lung and heart tissue. Vunjak-Novakovic won the 2021 European Inventor Award in the “Popular Prize” category.

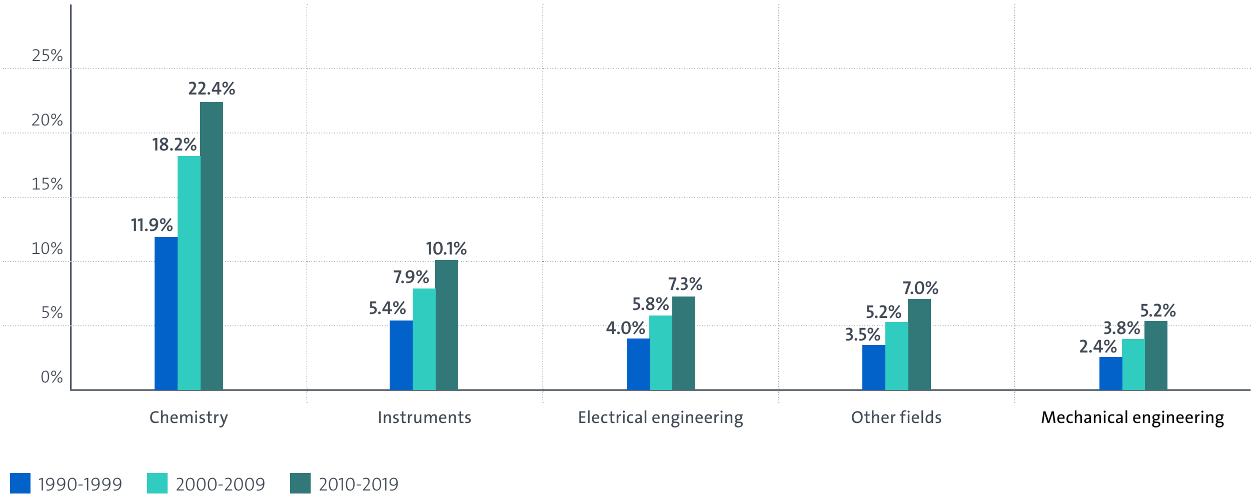
4. Composition effects: technology and applicant type

This section looks at the variations of the WIR by technological sector and by applicant type to explore whether these factors can explain the differences in WIR values across countries.

Figure 7 presents WIR values across five broad technological sectors (see Schmoch, 2008) for three 10-year time intervals. Across all five sectors, women's shares increase over time. Chemistry stands out as the sector with by far the highest WIR (around 22% in the 2010–2019 period), which is four times higher than the value in the sector with the lowest WIR, Mechanical engineering (5.2%). Chemistry also shows the most remarkable growth over time, especially around the turn of the century, jumping from 11.9% to 18.2%. This might be explained by various factors, ranging from women's educational preferences, which in turn may be affected by role models in the family (Hoisl et al., 2022), to the working conditions in different economic sectors and their impact on the work-family balance. Instruments (10.1%), Electrical engineering (7.3%) and Other fields (7.0%) show WIR values closer to Mechanical engineering than to Chemistry.

Figure 7

WIR across technological sectors, 1990–2019



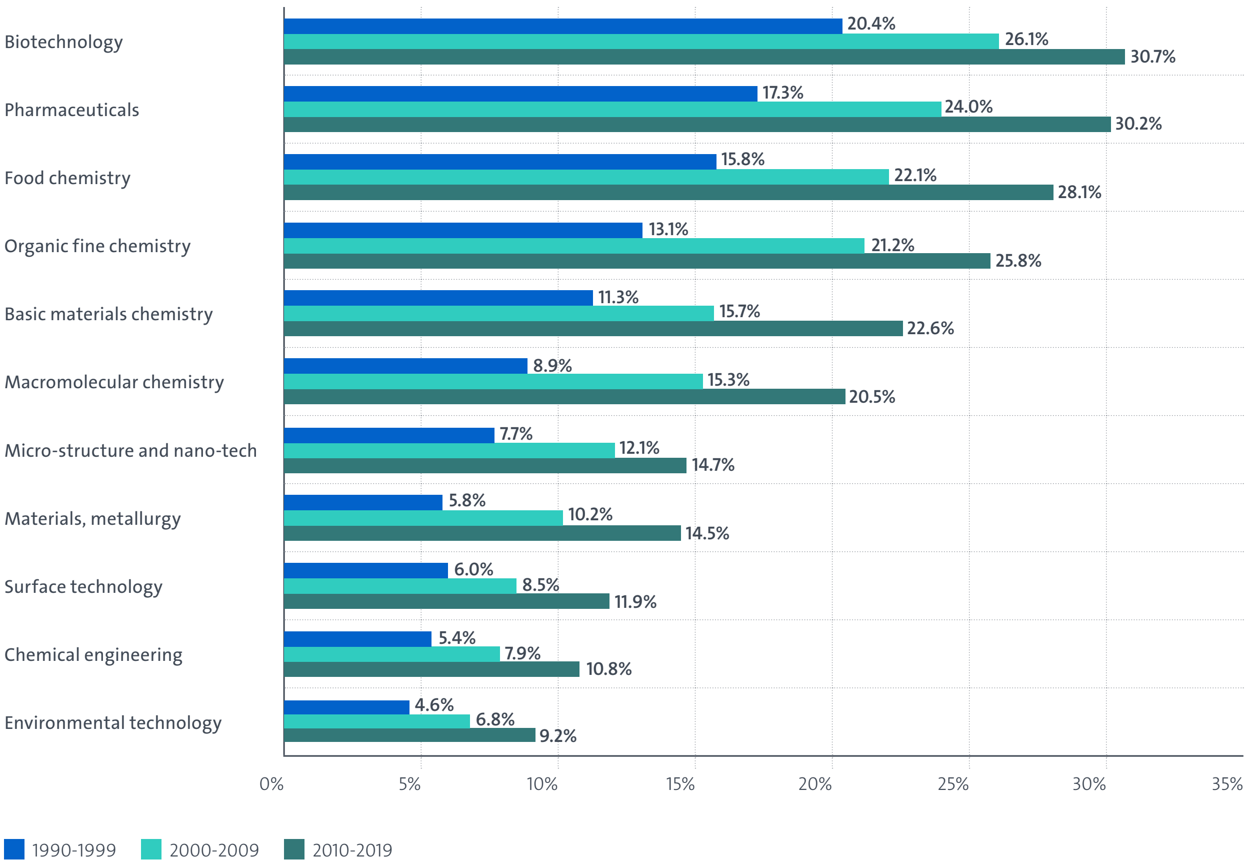
Notes: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

Source: author's calculations

Figure 8 breaks Chemistry down into a number of smaller technology fields (see Schmoch, 2008). It shows that the WIR is highest in Biotechnology and Pharmaceuticals, which both have more than 30% women inventors in the most recent period, and, to a lesser extent, in Food chemistry (28.1%) and Organic fine chemistry (25.8%), Basic materials chemistry (22.6%) and Macromolecular chemistry (20.5%). Chemical engineering (10.8%) and Environmental technology (9.2%) show the lowest rates of women inventors within the Chemistry sector.

Figure 8

WIR across technological fields in Chemistry, 1990–2019



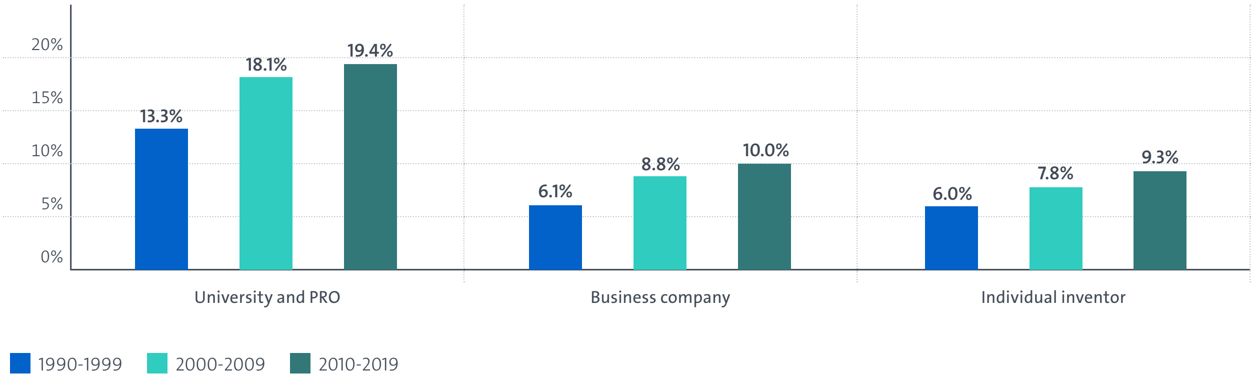
Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

Source: author's calculations

Various sources suggest that women are over-represented on university patents relative to those filed by companies (Delgado and Murray, 2018; Martinez et al., 2016; Toole et al., 2019). Figure 9 reports the WIR for different types of patent applicants, distinguishing between individual inventors, companies, and universities and PROs (including hospitals, non-profit organisations and governmental agencies). The latter host the largest proportion of women inventors, close to 20% in the 2010–2019 period and two times larger than the WIR for companies (10.0%) and individual inventors (9.3%). This may once again reflect women's educational preferences for chemistry and the life sciences as well as the importance of universities and PROs among patent applicants in these fields. However, it may also have to do with women's preference for working at universities and PROs, which offer less gender-biased working and social conditions compared with those of companies employees or, possibly, individual inventors (who are likely associated with small firms and start-ups). Indeed, as Table 2 shows, the WIR among university inventors is systematically higher than among companies or individual inventors, irrespective of the technological field chosen.

Figure 9

WIR by applicant type, 1990–2019



Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

Source: author's calculations

Table 2

WIR by applicant type and technology field, 2010–2019

	WIR			Difference	
	Individual Inventor (1)	Company (2)	University and PRO (3)	(3) - (1)	(3) - (2)
Electrical machinery, apparatus, energy	4.1	4.4	11.7	7.6***	7.2***
Audio-visual technology	5.6	5.0	7.2	1.6***	2.2***
Telecommunications	5.8	5.2	6.8	1.0	1.6***
Digital communication	4.6	7.0	6.8	2.2**	-0.2
Basic communication processes	4.2	3.8	6.2	2.0	2.3***
Computer technology	6.3	6.7	9.1	2.8***	2.4***
IT methods for management	6.5	8.6	10.6	4.1***	2.0**
Semiconductors	6.0	7.8	13.7	7.7***	5.9***
Optics	6.9	6.8	9.7	2.8***	2.9***
Measurement	5.7	4.6	10.7	5.0***	6.1***
Analysis of biological materials	17.5	20.2	27.9	10.4***	7.7***
Control	6.4	4.3	8.6	2.2**	4.4***
Medical technology	9.1	9.3	14.5	5.4***	5.2***
Organic fine chemistry	20.3	19.9	25.6	5.3***	5.7***
Biotechnology	21.3	25.1	30.8	9.5***	5.7***
Pharmaceuticals	20.0	23.3	30.9	10.9***	7.5***
Macromolecular chemistry	10.9	14.8	23.9	13.0***	9.1***
Food chemistry	16.0	22.9	29.2	13.2***	6.2***
Basic materials chemistry	11.6	16.7	23.1	11.5***	6.4***
Materials, metallurgy	7.5	9.8	18.6	11.1***	8.8***
Surface technology	5.6	8.8	14.4	8.8***	5.6***
Micro-structure and nano-tech	12.9	9.3	18.4	5.5***	9.1***
Chemical engineering	5.4	7.2	17.2	11.8***	10.0***
Environmental technology	5.5	6.5	13.8	8.3***	7.3***
Handling	6.5	3.8	7.3	0.8	3.5***
Machine tools	3.0	2.7	7.7	4.7***	5.0***
Engines, pumps, turbines	3.4	3.3	7.0	3.6***	3.7***
Textile and paper machines	7.3	6.4	18.9	11.6***	12.5***
Other special machines	5.6	4.9	13.0	7.4***	8.1***
Thermal processes and apparatus	3.6	4.6	8.6	5.0***	4.0***
Mechanical elements	3.4	2.7	6.1	2.7***	3.4***
Transport	4.9	3.6	6.0	1.1**	2.4***
Furniture, games	9.2	5.8	9.8	0.6	4.0***
Other consumer goods	14.0	8.2	11.9	-2.1**	3.7***
Civil engineering	4.5	2.9	6.7	2.2***	3.8***

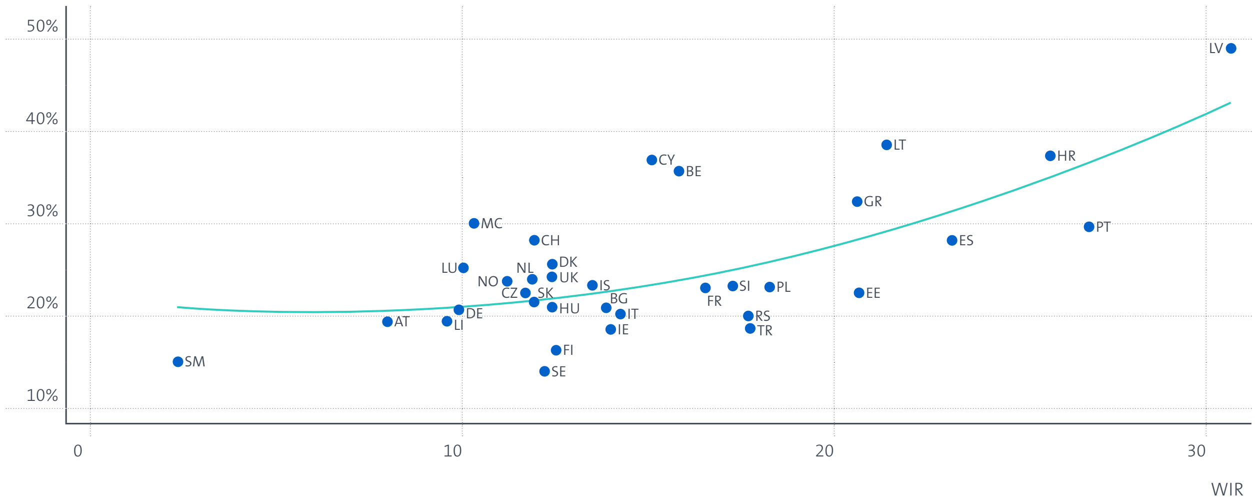
Econometric analysis confirms that both the technology specialisation of a country and the contribution of universities and PROs to its patenting activity determine that country's WIR. Figure 10 relates the WIR values of a country to its patent specialisation in Chemistry (Figure 10 a)) and to its share of patent applications that stem from universities and PROs (Figure 10 b)), for the 2010–2019 period. Both relationships are clearly positive, and a quadratic OLS regression estimates that a country's technological specialisation can explain over 35% of the cross-country variation in WIR ($R^2 \geq 0.36$), and that universities and PROs make a similar or even stronger contribution, explaining 59% of the variation ($R^2 \geq 0.59$). The two pieces of evidence are also clearly correlated.

Figure 10

Cross-country analysis of the correlation of the WIR with specialisation in Chemistry and with university and PRO patenting, 2010–2019

a) WIR vs specialisation in Chemistry, 2010–2019

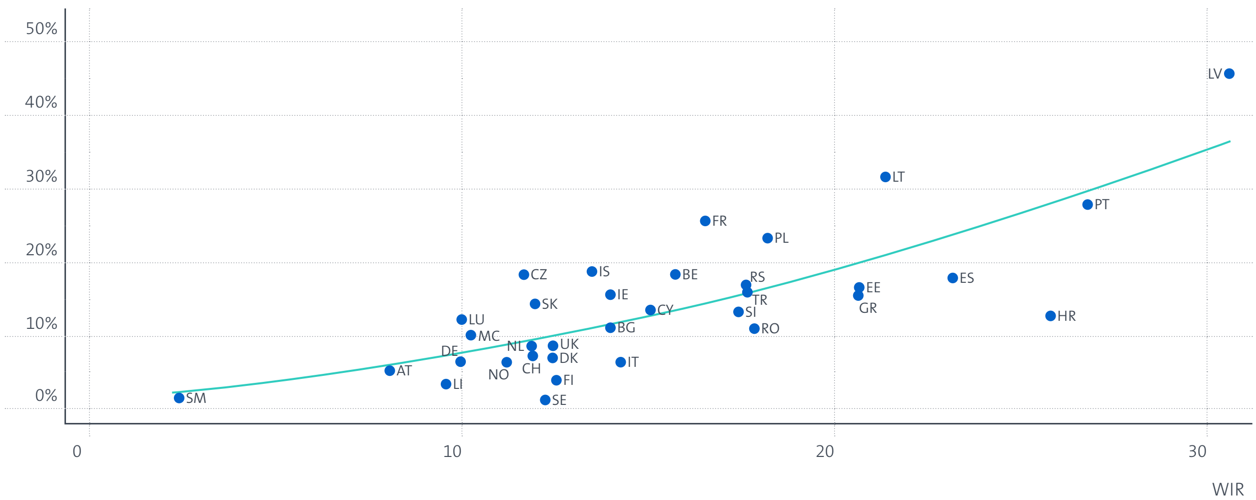
Share of patent applications in Chemistry



R-squared=.362

b) WIR vs patenting by universities and PROs, 2010–2019

Share of patent applications from universities and PROs



R-squared=.593

Source: author's calculations

Scientists Madiha Derouazi (Switzerland) and Elodie Belnoue (France) have developed a platform to produce therapeutic anti-cancer vaccines. Derouazi established AMAL Therapeutics to commercialise the platform in 2012. Seven years later Boehringer Ingelheim acquired the company, with patents contributing significantly to AMAL's value as a biotech start-up. The team won the 2022 European Inventor Award in the "Small and medium-sized enterprises" category.

5. Productivity, impact and role of women in teams

Metrics such as the WIR are informative about women's participation in patenting, but say little about women inventors in terms of productivity (e.g. number of patent applications filed throughout their careers), the type of patent applications they contribute to (e.g. technical and economic impact of patent applications), and their roles within and across inventor teams or networks (e.g. the extent to which they hold leadership positions or are visible within the inventor community). This section provides insights into these aspects.

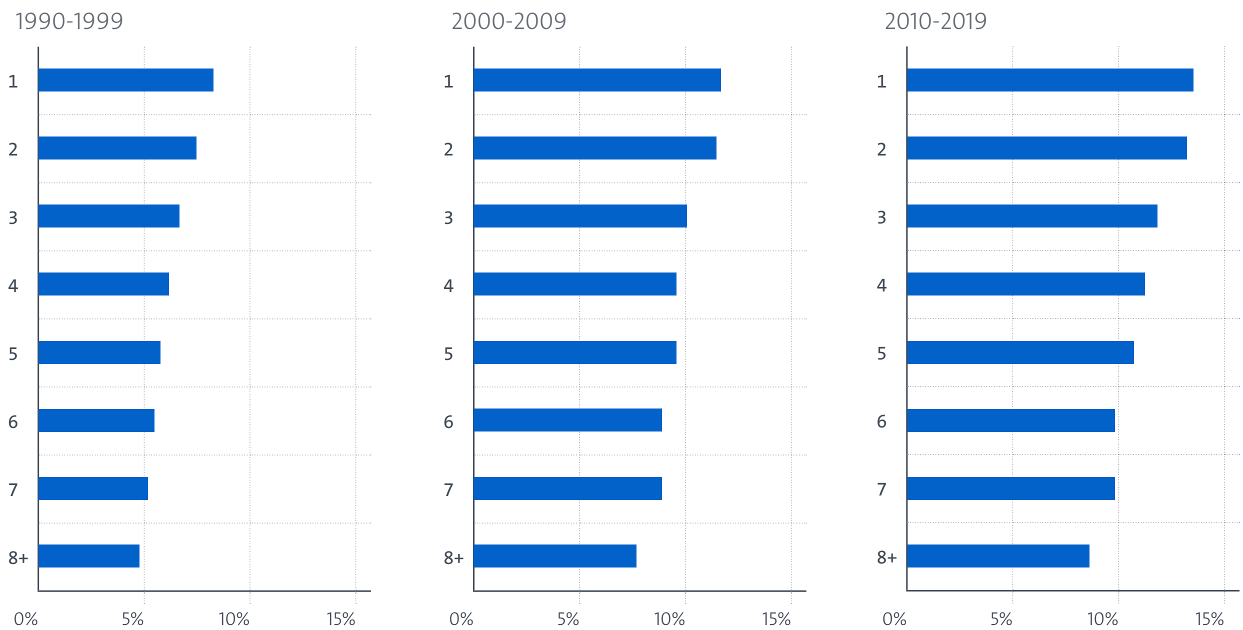
5.1 Productivity and impact

Assuming that talent is equally distributed across men and women (Bell et al., 2019), women inventors' productivity, leadership and visibility could differ, on average, from that of inventors who are men for a number of reasons. These include barriers to promotion within corporate labs or to tenured positions in academia or, for independent inventors or academic ones, fewer business connections, with less opportunity for women to access intellectual property protection (Ding et al., 2009).

Covering the same three decades as the previous sections, Figure 11 reports the WIR for different groups of inventors based on their productivity, i.e. the number of patent applications in which the person is mentioned as an inventor within the respective observation period. For all periods, WIR values decrease with the number of patent applications per inventor. The WIR reaches its maximum for inventors with just one patent application and its minimum for those with eight or more patent applications. This clearly indicates that women are over-represented among the less prolific inventors, and under-represented among the most productive ones.

Figure 11

WIR across groups of inventors by their productivity in EPO countries, 1990–2019



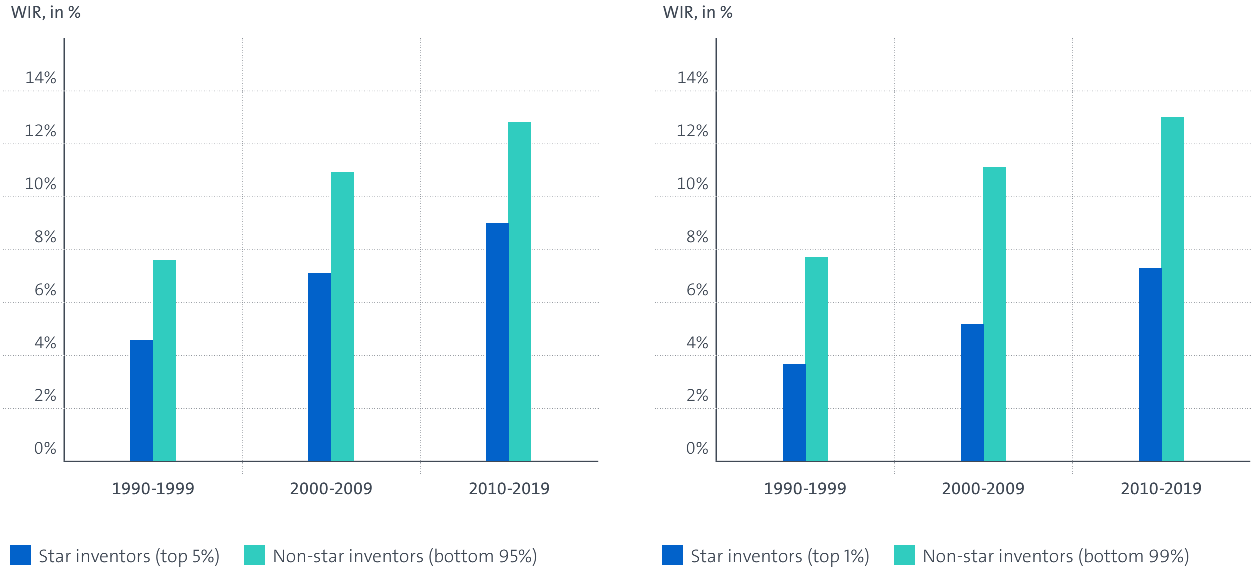
Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

Source: author's calculations

However, the analysis presented in Figure 11 does not take into account productivity variations across technologies. Inventors with the same number of patents in a given period could appear in different deciles had they filed these patents in one or another technology (for example, the average number of patents per person in Mechanical engineering is generally lower than in Chemistry). To the extent that women are over-represented in some technologies and under-represented in others, composition effects need to be taken into account. For this reason, Figure 12 focuses only on the top inventors of the productivity distribution, the "star inventors", who are in the top 5% and top 1% of the patent-per-person distribution of each technological field. The Figure shows that as with productivity ranking, there are also fewer women inventors and that this relationship does not depend on composition effects.

Figure 12

WIR among star inventors, 1990–2019



Note: Data used correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

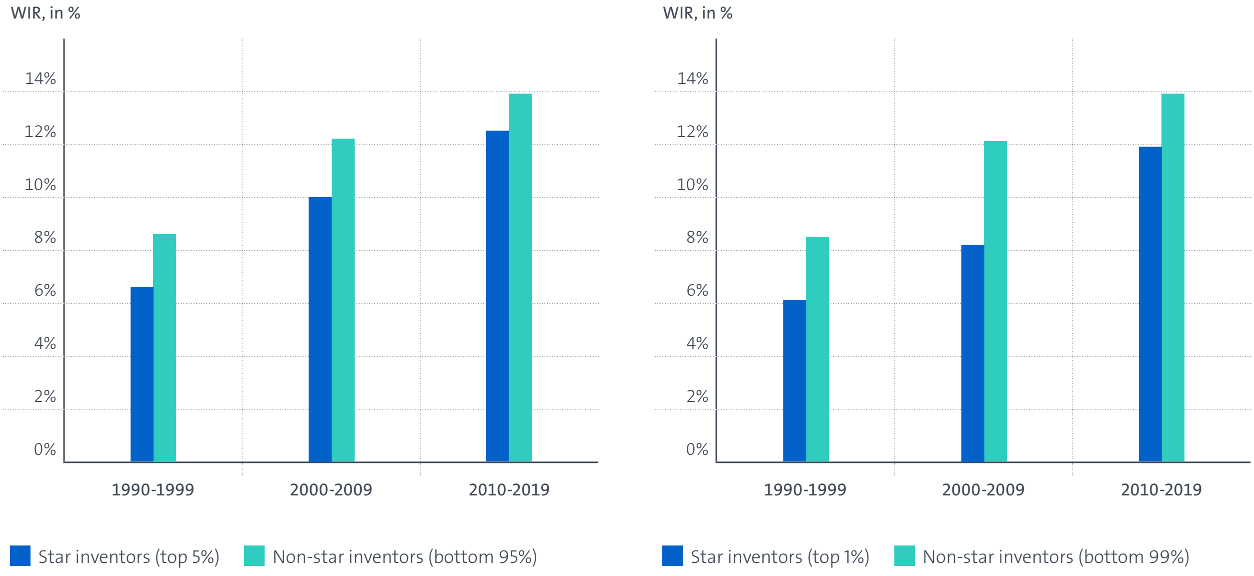
Source: author's calculations

The above analysis has established that women tend to produce fewer patents than men, even when controlling for different technology fields. However, since the calculations were restricted to specific time windows, the results do not necessarily show seniority effects. Even so, participation by women in patenting is relatively new, so some of the most productive inventors in a given time window may have accumulated knowledge and experience that allow them to be more productive within that window. This issue is dealt with in Figure 13, which reproduces the statistics of Figure 12 after excluding all inventors whose first patent had a priority year before the initial year of each 10-year time window. In this way, only inventors who entered the profession in that same time window are considered. After eliminating the seniority effect, the differences in WIR between star and non-star inventors become smaller. This suggests that, at least in part, the productivity gap between men and women declines over time, with more women reaching more senior positions. However, the speed of the convergence will depend on how easy or difficult it will be for women to advance in their careers.

Patent applications may also differ in terms of breadth of protection and economic or technological impact. Therefore, the following analysis aims to establish whether women, on average, produce "different" patents from men.

Figure 13

WIR among star inventors, excluding experienced inventors, 1990–2019



Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

Source: author's calculations

Figure 14 uses different qualitative indicators based on Squicciarini et al. (2013), namely:

— the number of claims per patent

— the number of citations received by the patent (forward citations) in the five years following the priority date

— the patent's family size (number of patents filed worldwide with the same priority, i.e. protecting the same invention)

— the patent's generality, which – broadly speaking – captures the patent's impact across the technological spectrum as measured by the distribution of its forward citations across all the technological fields (the more concentrated in a technological field the citations, the lower the generality, and vice versa)

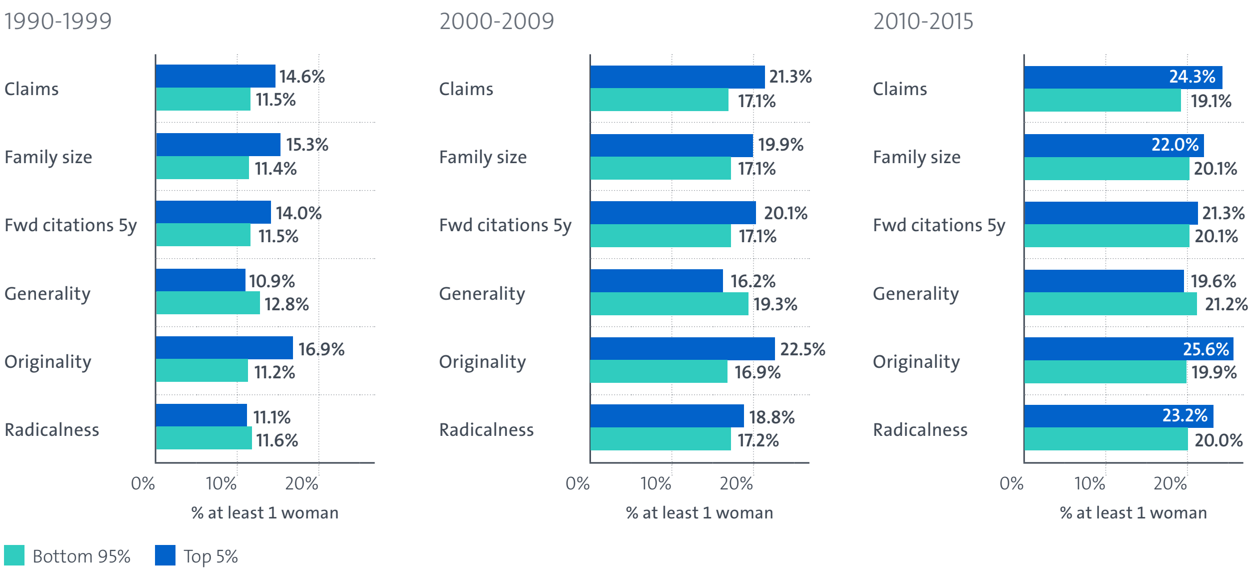
— the patent's originality, which – broadly speaking – captures the extent to which a patent recombines previously unrelated pieces of knowledge, as measured by the distribution of its citations of the prior art across all the technological sectors (the more concentrated in a technological sector the citations, the lower the originality, and vice versa)

— the patent's radicalness, which – broadly speaking – captures the extent to which it is based on knowledge from outside the technology to the advance of which it contributes (as measured, technically, by the number of technological sectors appearing in its citations of the prior art, but not among the sectors to which the patent itself belongs)

For each indicator, patents in the top 5% and the bottom 95% of the indicator's distribution within each technological field are presented separately (for example, the 5% most original patents versus the remaining 95%). The share of patent applications that include at least one woman is then calculated for each group of patent applications. For a majority of indicators and time periods, no clear pattern emerges. This suggests that, in contrast to productivity, women do not appear to be over- or under-represented in groups of patent applications that differ in terms of breadth of protection or economic or technological impact. To put it differently, while women tend to produce fewer patents than men, their inventions are as good as and sometimes better than those of men. This suggests that gender differences are not due to some ex ante distribution of talent and effort, but to a different distribution of opportunities.

Figure 14

Share of patent applications including at least one woman across different patent indicators



Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries. The last time window is reduced to the 2010–2015 period (instead of 2010–2019) so as to avoid truncation when using forward citations (5y).

Source: author's calculations

5.2 Teamwork

The importance and size of inventor teams vary across technologies. Patents in pharmaceuticals and biotechnology are more likely than those in other fields to result from teamwork and especially from large teams of inventors. In general, the more science-based a technology is, the more important and the larger an inventor team is. This also explains why inventor teams on university patents are larger than those on companies' patents.

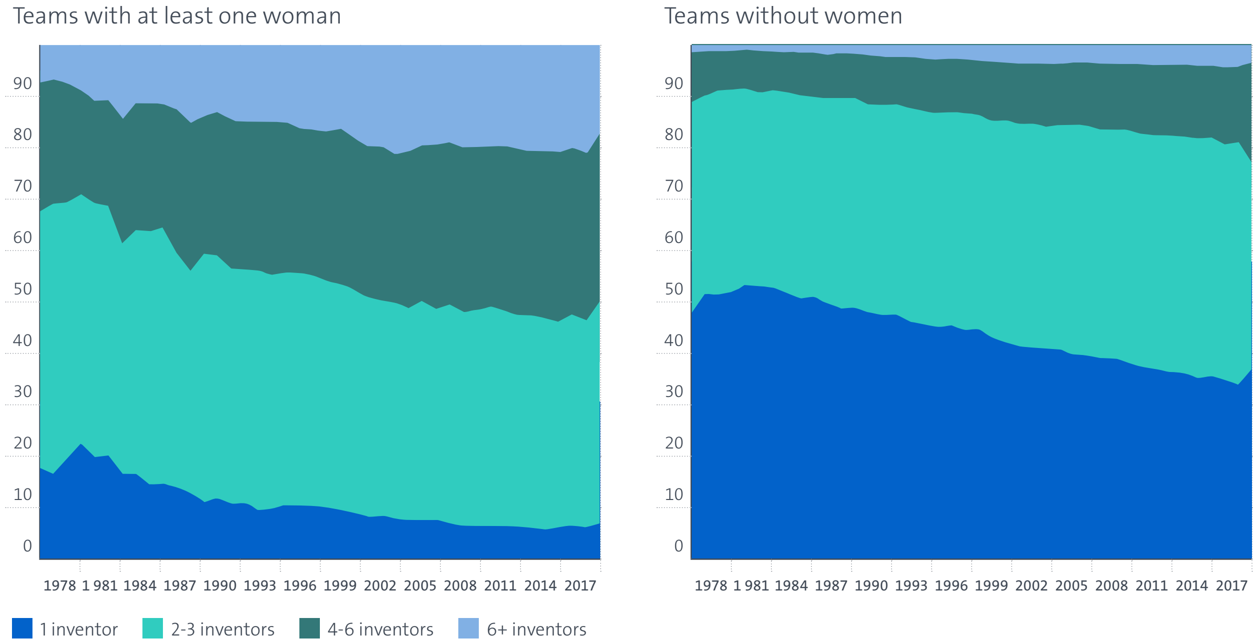
From this it can be inferred that over-representation of women on university and pharma/biotech patents translates into their over-representation on patents listing more than one inventor. This is clearly illustrated by Figure 15. Patent applications listing at least one woman among their inventors are more likely to be produced by teams, rather than by individual inventors. Teams that include women inventors also tend to be larger than those that include only men. Even more strikingly, the share of patent applications with larger teams, comprising four or more inventors, grew faster over time if a woman was involved.

The preponderance of women in teams and particularly in large ones begs the question of their role in such teams: how often do they lead the teams or, conversely, how often do they play a more operational, possibly marginal role? Unfortunately, the sample provides no direct information on the position of women in patent applications, which would require access to their CVs or to their social security data. However, at least two types of information entirely contained in patent data can still provide some indication as to their role within the team.

First, inventor networks are calculated and inspected to establish whether women occupy more or less central positions. An inventor network is a graph in which nodes are inventors and ties are collaboration instances (Breschi and Lissoni, 2004). In the simplest form of such a network, two inventors are tied when they have co-invented at least once. Several inventor networks are calculated, one for each five-year interval between 1980 and 2019, by considering all patent applications filed in each time interval, in all EPO countries. Based on different measures derived from social network theories (Borgatti and Everett, 2006), it is then possible to examine the centrality of each inventor to the network.[8]

Figure 15

Distribution of patent applications across team sizes with and without women, 1978–2019



Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

Source: author's calculations

8 Centrality is simply calculated as the number of each inventor's ties (degree centrality). This may run from zero to N-1, where N is the number of nodes (inventors) in the network. In practice, the most central inventor never reaches more than a small fraction of N-1.

Second, for each patent produced by a team in a given year the most senior inventor in the team is identified, based on the number of patent applications each inventor has produced in the previous years. This will be zero for all inventors at their first patent application, and greater than zero for all those with at least one former patent application (Akcigit et al., 2018).

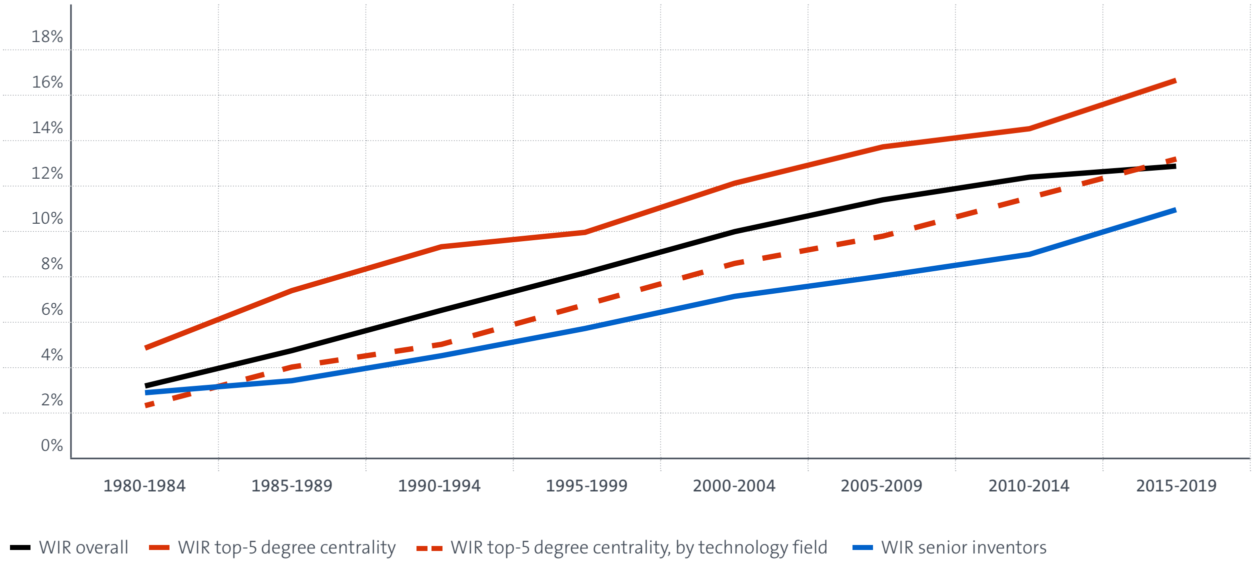
Figure 16 presents WIR values calculated for all inventors, for five-year time windows, and compares them with the WIR of: (1) the top 5% most central inventors in the network, (2) the top 5% most central inventors (with the top 5% computed also per technology field) and (3) the subset of inventors comprising only the most senior ones in each team.

The Figure shows that women are over-represented among highly central inventors in the network, since the WIR values are higher for this inventor sample (red line) than for all inventors (blue line). However, this difference can be fully explained by the over-representation of women in teamwork-intensive technology fields. If this composition effect is taken into account and the WIR for highly central inventors in technology-specific networks is considered, the WIR values among the most central inventors (dashed red line) actually fall slightly below the general WIR (red line) for many time periods. This suggests that women are no more or less central than men.

However, the analysis also confirms that women are less senior than men. WIR values calculated for the sample of the most senior inventors (green line) are lower than the overall WIR. This suggests that team leaders are more often men than women.

Figure 16

WIR among the most central and leading inventors in a network, 1980–2019



Source: author's calculations

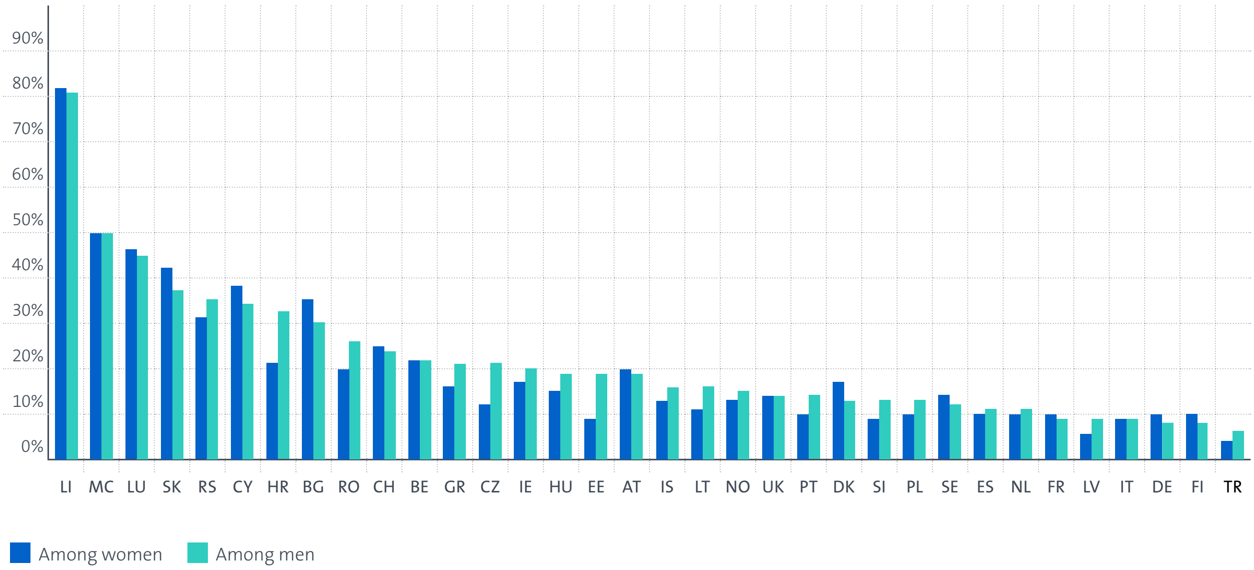
5.3 Internationalisation

The analysis is extended to the capacity of women inventors to reach out to inventors in other countries, that is, their degree of internationalisation.

Figure 17 explores this aspect by looking at the average share of unique co-inventors residing in a foreign country, separately for men and women, across a selection of EPO countries for the 2010–2019 period. In many countries the average level of internationalisation is higher among men than women. There are notable exceptions, however, including Austria, Finland, Denmark and Switzerland, and even some very large countries such as Germany and France.

Figure 17

Share of international co-inventors among inventors by EPO country, 2010–2019



Note: 34 out of 38 countries are featured in this figure. Albania, Malta, North Macedonia and San Marino are excluded, having too few patent applications with inventors' addresses in the country during the period analysed.

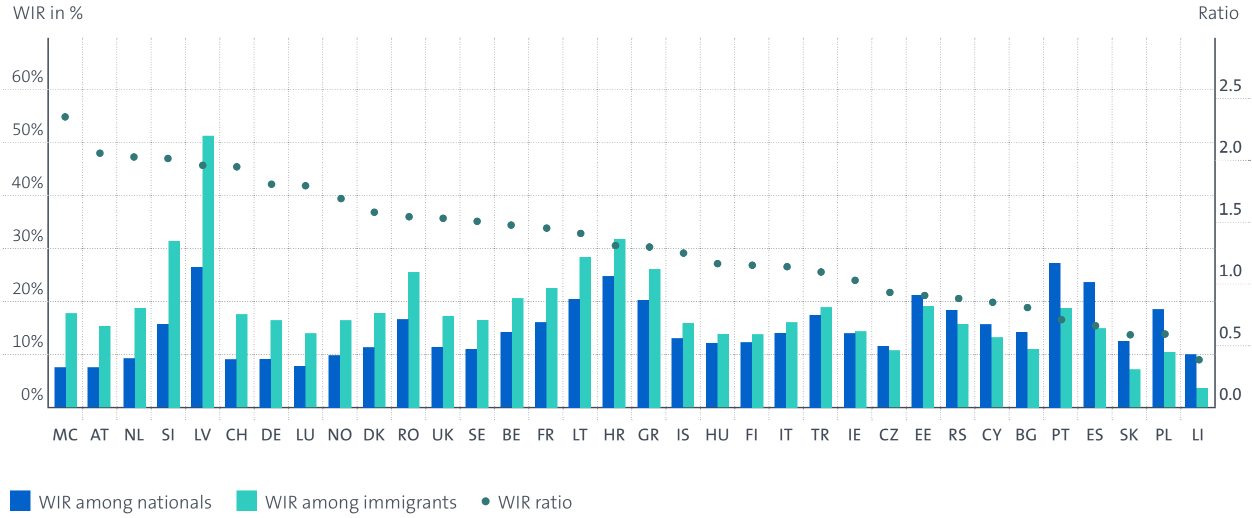
Source: author's calculations

Another way to measure the internationalisation of inventors is through their mobility (temporary or permanent). This is relevant for two reasons. First, international mobility of STEM workers, and in particular inventors, is on the rise and contributes distinctively to knowledge circulation worldwide (Breschi et al., 2017; Useche et al., 2020). It is fuelled both by general migratory movements and by multinational companies' international recruitment and assignment policies (Kerr et al., 2016). At the same time, Delgado et al. (2019) find, for the US, that women inventors are more geographically constrained in their ability to access knowledge than men. The proposed explanation is that women take a disproportionate share of family responsibilities, limiting their ability to move abroad and team up with foreign colleagues (within and across organisations). Once again, technological progress could stand to gain from the removal of a gender gap, this time in terms of international mobility.

Figure 18 shows WIR values for immigrants and nationals for a selection of EPO countries in the 2010–2019 period, and the ratio between the two. The migration status of inventors is estimated using name and surname analysis.[9] The Figure clearly shows that, in many countries, WIR values are higher among immigrants. It can be concluded, therefore, that for many EPO countries the international mobility of inventors is a clear contributor to closing the gender gap in patenting.

Figure 18

WIR among immigrants and nationals, 2010–2019



Source: author's calculations

9 Performed using IBM-GNR, as described in step 2 of the gender attribution methodology in Annex 1. However, here both the name and surname of inventors are used. If neither is considered frequent in the country where the inventor resides (within-country frequency lower than 90), they are labelled as an immigrant (for details, see Coda-Zabetta et al., 2021 and Lissoni and Miguelez, 2021).

Portuguese engineers Nuno Correia and Carla Gomes from INEGI have led the development of a mooring platform for floating solar farms. The system tracks the sun, rotating each solar panel to optimise efficiency. Correia and Gomes have developed the system under contract from technology company SolarisFloat, which will commercialise it. The Portuguese team were finalists at the 2022 European Inventor Award in the "Small and medium-sized enterprises" category.

6. Conclusion

The report presents an in-depth study of women's participation in patenting at the EPO in the 38 EPC contracting states[10] to better understand the presence of women inventors across different countries, time periods, technology fields and applicant types.

The contribution of women to patenting has been growing consistently over time. Even so, it is far not only from being fully balanced with that of men, but also from catching up with the share of women among STEM researchers and graduates. Since researchers' incomes are strongly related to their contributions to patenting (Bell et al., 2019), this clearly puts women in a disadvantaged position. This gap also harms society's technological progress, as new technologies may be missing due to women's lower access to patenting. This translates into many human needs that remain unfulfilled.

Two main stylised facts stand out from the analysis. First, the gender gap varies appreciably across technologies and types of applicants: the more science-based a field (in particular, the closer to the life sciences) and the higher the weight of universities and public laboratories in patenting, the larger the share of women. This suggests that the fields where the gender gap is more acute could usefully borrow from those where it is weaker, in terms of work practices and cultural acceptance. The same applies to companies relative to universities.

Second, the presence of women in patenting increases with the importance of teamwork, although women remain under-represented among team leaders. Despite persistent differences across technologies, the importance of teamwork and collaboration is growing in all fields, due to the increasing division of intellectual labour that accompanies the accumulation of knowledge. This trend bodes well for the future of women in patenting and should be supported by appropriate policies and human resource management practices. Efforts to stimulate the international mobility of women scientists could be a promising lever in this context, in light of the higher women inventor rates observed among migrant inventors.

10 The data exclude Montenegro, which acceded the EPC on 1 October 2022, after this study was prepared.

Annex 1 – Methodology

A.1.1 Conceptual issues

The methodology aims to match EPO inventors' names to various lists of worldwide names for which gender is already known (usually with an indication of probability). When carrying out this task, a number of obstacles had to be overcome.

First, **the gender of some names varies with language**. "Andrea" provides a typical example, being an Italian man's name, but a woman's one in most other languages. In principle, the relevant language should be safely inferred from the individual's country or region of residence. However, for inventors this is less and less a safe guess, due to the extent and continuous increase of migration in highly skilled and in particular STEM professions, mainly towards patent-intensive countries (Fink and Miguelez, 2017; Lissoni and Miguelez, 2021). Unfortunately, as the nationality or country of birth of inventors is not available, it is necessary to infer their potential migratory background by name analysis.

Second, **certain names are gender-neutral** (such as "Yannick" in French, or "Tracy" in English), for which unfortunately there is no remedy unless the inventor's personal information can be recovered, which is not possible for a large-scale study like ours.

A third difficulty arises from the **English transliteration of names originally written in non-Latin alphabets, especially East-Asian ones**. With transliteration, the original name's gender may be lost. For patents within the same simple family (patents covering the same invention in different offices) it would be possible, in principle, to recover and genderise the name as written in the original alphabet. But this is not the case for patents that are not also filed in the inventor's home country or country of origin (if migrant). The rise of Asian inventorship makes this methodological issue well worth investigating in the future.

Finally, great importance is attached to the disambiguation of inventors. In a nutshell, disambiguation consists in identifying as the same person **two or more inventors with the same or similar names, but different addresses** while at the same time taking care not to introduce false positives, that is, wrongly identify as the same person two distinct inventors (Pezzoni et al., 2014).[11] Only very few of the surveyed studies use disambiguated data, the main exception being Toole et al. (2021, 2019). This comes at a cost. First, absent disambiguation, it is impossible to calculate individual productivity (number of patents per inventor) and compare men with women in this respect. Second, it is impossible to know whether the number of women inventors is under- or over-estimated relative to that of inventors who are men, as this depends on whether women are, respectively, more or less productive than men (or are under- or over-represented in high-patenting fields). Last but not least, it is impossible to trace inventors over time or in space and then produce a gender analysis of careers, mobility and collaborations. Disambiguated data helps to overcome these limitations.

11 In short, two key parameters for assessing the quality of disambiguation exercises are precision (share of false positives over total cases, where a false positive originates from treating as one two different individuals) and recall (share of false negatives, which originate from treating a single individual as two different ones). The more restrictive the disambiguation criteria used, the higher the precision, often at the cost of low recall. The criteria used by PATSTAT to assign inventors their *person_id* are extremely restrictive (exact match of name-surname combination and address), which implies high precision and very low recall. This requires further disambiguation, aimed at increasing the recall rate without compromising precision.

A.1.2 Patent and inventor data

This study considers all patent applications included in PATSTAT and filed at the EPO between 1976 and 2019: a total of 3 945 992 patent applications. In particular, all documents with "EP" as application authority are selected from PATSTAT, excluding those with application kind code "D2", which are "artificial applications" according to PATSTAT documentation. While only the inventors with addresses in a European Patent Convention (EPC) country are ultimately selected for our gender analysis, the gender attribution exercise is applied to all inventors listed on all patent applications, irrespective of their address.[12] This is done in order both to create a database for further research and to produce some internal diagnostics on the effectiveness of our attribution exercise.

For some statistics, the period covered also includes 2020 and 2021 (adding 159 294 applications, all of which with at least one inventor with residence in an EPC country).

Time-wise, the patents are classified according to their EPO priority date, with some exceptions in which the incoming year of the application at the EPO is used.[13] The IPC classification, which we re-elaborate where necessary by reclassifying patents in a broad technological field, as per Schmoch (2008), is used to categorise patent applications by technology.

Inventors are initially identified based on their PATSTAT identifier (*person_id*), which is unique for all inventors with exactly the same name and address. After gender attribution, however, they are further disambiguated in order to increase recall (reduce the false negatives) (Pezzoni et al., 2014).

Inventors' information contained in patent data is precious, but it may come with errors that could affect both gender attribution and inventor disambiguation. Despite applications to the EPO being among the most complete and detailed (in terms of the quality and quantity of the information publicly provided), errors remain. Some of the main problems and the ways they are addressed in this report are presented below.

1. The first and foremost issue when using inventor data for economic analysis is that inventors' names are not disambiguated, as pointed out in the previous subsection. This is why we used an improved (and adapted) version of the Massacrator algorithm (Pezzoni et al., 2014), as described in section 3.3.

2. Visual inspection also enabled us to identify certain cases where name and surname had flipped position in PATSTAT. This affects disambiguation only to a limited extent, but it may be problematic for gender attribution. While "FROOME, Christian" is clearly a man, "CHRISTIAN, Froome" cannot be attributed, since "Froome" does not exist in any available gender dictionary. Some of these cases can be identified and the name and surname flipped (e.g. "FROOME, Christian" and "CHRISTIAN, Froome" receive the same inventor identifier after disambiguation), but a broader correction is beyond the scope of the present work.

3. It is not uncommon for the name-surname field to include other information and stop words, such as the name/address of the inventor's employer (e.g. "c/o Philips Corp. Int. Prop. GmbH") or their title (e.g. "Dipl. Wirt. Ing."). In this case we apply several cleaning heuristics that significantly reduce the influence of these words. Yet, the problem persists in a number of cases.

4. Finally, precision of the address field (which helps us with the disambiguation of inventors' names) may differ, too. The address field is empty in only 0.015% of cases. Yet, addresses with street level precision constitute "only" 62% of all records. Despite this, address information in EPO patents is the most detailed among the largest patent offices (for example, the USPTO only collects information on the city of residence of the inventor).

12 For the list of EPC countries, go to https://www.epo.org/about-us/foundation/member-states.html (last accessed on 30 May 2022).

13 The priority date is the filing date of the very first patent application for a specific invention, irrespective of the patent office where the application was filed. Application incoming year instead refers to either the filing year of the European patent application (for applications filed direct with the EPO (Article 75 EPC)) or the year of entry into the European phase (for international (PCT) patent applications (Article 158(2) and Rule 107 EPC)).

A.1.3 Methods

Gender attribution

The main sources of information on the gender of names are:

1. the Global Name Recognition system, a name search technology produced by IBM ("IBM-GNR" below). This system uses a database produced by the US immigration authorities in the first half of the 1990s, when they registered all names and surnames of all foreign citizens entering the US, along with their nationality and gender. The database contains around 750 000 full names, plus country-sensitive orthographic and abbreviation rules (Breschi et al, 2017). Each first name and surname is assigned to one or (more often) several countries of likely origin (c_i, with i=1...n), along with information on its cross-country and within-country frequency. First names are also assigned to gender, again in probabilistic terms (probability *p* of being a woman's name and *1-p* of being a man's name), irrespective of c_i. IBM-GNR also provides some information on the worldwide frequency of names, 5% of which are too rare for any statistics to be reliable ("rare names").

2. the Worldwide Gender-Name Dictionary ("WGND" below), produced by WIPO. It currently includes 25 million names from 182 different countries. For each name and country contained in the dataset, a gender is provided for that country, based on previous gender studies found in the literature as well as information from national public statistical offices – see Lax-Martínez et al. (2016) and Lax-Martinez et al. (2021) for details.

The gender attribution is performed in two rounds and four steps (more details in Toole et al., 2019, which uses the same methodology):

Step 1: Based on the IBM-GNR and excluding rare names, all inventors are classified as women (men) whose name's *p* (*1-p* for men) is 97% or more. This threshold is reduced to 95% if the name is highly frequent in the IBM-GNR library, and to 90% if, on top of this, it is associated, for the specific inventor, with a genderised middle name. In this way, it is possible to attribute gender to 80.62% of the initial number of 3 674 314 unique name+surname combinations.

Step 2: For the remaining inventors, the WGND is used, which allows conditioning gender on the inventor's country of origin. To infer this the inventor's residence (which could be misleading in the presence of large migration flows) is ignored and instead the IBM-GNR's *ci* list (list of countries in which the inventor's name has non-zero frequency) is used. Then, the inventor's surname is examined and the country in the *ci* list associated to the highest cross-country frequency is selected. Afterwards, a gender is assigned to each inventor, conditional on the gender information provided by the WGND for the associated country. This completes the first round of gender attribution.[14]

Step 3: A second attribution round is performed for those inventors who, at the end of the first round, still have non-genderised names and whose surnames are associated with countries of origin with poor gender attribution levels (typically Asian countries, chiefly P.R. China, Chinese Taipei, Singapore, Macao, Hong Kong, R. Korea and India). For these inventors, step 1 is rerun but with lower thresholds for gender attribution (60% for P.R. China, Chinese Taipei, Singapore, Macao and Hong Kong, 70% for R. Korea and 80% for India).

The steps above result in a gender attribution of 3 432 646 unique name+surname combinations (93.42% of the total unique name+surname combinations). This translates into 93.9% gender attribution of PATSTAT's *person_id* – see Table 1.

14 In the infrequent case in which an inventor is not associable to any country of likely origin, the country of residence of his/her first patent ever at EPO is used – for which, again, disambiguation is crucial.

Disambiguation

Disambiguation is performed next, following Pezzoni et al. (2014). In a nutshell, the inventors' names, surnames and addresses are cleaned and parsed first. Next, all inventors are fuzzy-matched based on the similarity of strings containing their cleaned names and surnames. Finally, the matches thus obtained are further filtered on the basis of 20 criteria, grouped into six families: network ties (based on co-invention instances; see Breschi and Lissoni, 2009), geographical proximity, patent applicant's *person_id*, patent's field of technology, citations and others. If, as a result of disambiguation, a given inventor is assigned more than one gender (as when two inventors with similar names, but different gender are identified as the same person), the observation is split so as to increase precision and avoid bias in our calculations of gender statistics.[15]

As a result of disambiguation, the count of inventors in the dataset decreases from the original 7 215 925 (number of *person_ids* in the PATSTAT sample) to 4 489 587 unique inventors (number of unique identifiers created by the algorithm), 92.57% of whom are attributed a gender. [16]

Gender attribution coverage

Table A.1 shows the result of our gender attribution steps. The share of genderised inventors is high (more than 90%, regardless of whether measured at the level of *person_id* or after disambiguation). Attribution is noticeably higher if we restrict the analysis to EPO countries (which are the focus of this report). In fact, non-attribution rates concentrate in Asian countries, particularly in P.R. China, R. Korea, India and, to a lesser extent, Japan.

Table A.1

Gender attribution rate by inventor country of residence (disambiguated inventors and PATSTAT's *person_id*)

	1	2	3	4
	By disambiguated inventor		By *person_id*	
	Attribution %	# (x 1 000)	Attribution %	# (x 1 000)
All countries	**92.6**	**4 158**	**94.0**	**6 784**
All EPO countries	**97.8**	**1 653**	**98.2**	**2 685**
Selected EPO countries:				
Germany	98.2	543	98.7	907
France	98.0	257	98.2	426
Sweden	97.5	66	97.8	105
Italy	98.0	116	98.5	195
Switzerland	97.7	79	98.2	127
Netherlands	95.9	91	96.5	151
UK	97.7	214	98.2	337
Selected non-EPO countries:				
US	95.2	1 095	95.7	1 990
P.R. China	58.8	111	59.8	137
Japan	92.5	883	93.3	1 348
R. Korea	68.6	149	74.6	217
India	83.1	38	84.6	52

Notes: EPC contracting states are: Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Germany, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovenia, Slovakia, Spain, Sweden, Switzerland, Turkey and United Kingdom. The study data exclude Montenegro, which was not yet an EPC contracting state when this report was prepared.

15 The alternative solution would be to assign the gender of the most productive inventor. This is problematic, as men tend to be more productive, on average, in patent data, so this could slightly bias downwards women's contribution to inventorship.

16 Note that, compared with Pezzoni et al.'s (2014) original application of the algorithm, some improvements in data preparation have been introduced, such as considering the whole list of patents produced by inventors from all patent offices, in order to build their network of co-inventors (instead of relegating this to the EPO co-inventors) or introducing geocoding to match potential pairs of names to be disambiguated.

Annex 2 – List of regions, number of inventors and WIR

Table A.2

List of regions, number of inventors and WIR

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
AT11	270	8.1	1.0
AT12	2 773	6.3	0.8
AT13	3 540	14.8	1.9
AT21	943	5.4	0.7
AT22	3 951	8.2	1.0
AT31	4 895	6.3	0.8
AT32	996	3.6	0.5
AT33	1 651	8.8	1.1
AT34	1 712	4.4	0.5
BE10	1 660	18.6	1.2
BE21	3 578	13.9	0.9
BE22	855	11.3	0.7
BE23	2 932	18.7	1.2
BE24	4 007	17.5	1.1
BE25	1 444	8.0	0.5
BE31	1 195	17.9	1.1
BE32	902	17.2	1.1
BE33	1 453	13.5	0.9
BE34	247	8.1	0.5
BE35	386	16.6	1.1
BG31	21		
BG32	34	11.8	0.9
BG33	22		
BG34	22		
BG41	323	11.8	0.9
BG42	41	7.3	0.5
CH01	6 751	15.2	1.3
CH02	5 762	9.4	0.8
CH03	7 629	15.0	1.3
CH04	8 138	12.4	1.1
CH05	4 397	6.0	0.5
CH06	2 948	6.3	0.5
CH07	947	11.1	0.9

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
CY00	137	15.3	1.0
CZ01	931	14.1	1.2
CZ02	494	8.7	0.7
CZ03	388	11.3	1.0
CZ04	172	10.5	0.9
CZ05	800	14.8	1.3
CZ06	820	9.6	0.8
CZ07	469	11.7	1.0
CZ08	255	9.8	0.8
DE11	22 016	6.9	0.7
DE12	14 433	10.1	1.0
DE13	9 230	7.5	0.8
DE14	8 387	8.4	0.8
DE21	27 450	10.1	1.0
DE22	2 484	4.8	0.5
DE23	4 225	6.9	0.7
DE24	3 842	8.0	0.8
DE25	10 252	8.0	0.8
DE26	4 698	9,2	0.9
DE27	6 117	6.0	0.6
DE30	8 925	13.2	1.3
DE40	2 933	9.9	1.0
DE50	1 057	10.5	1.1
DE60	4 718	16.4	1.7
DE71	13 255	14.7	1.5
DE72	2 616	9.1	0.9
DE73	1 923	5.6	0.6
DE80	1 035	16.5	1.7
DE91	5 351	10.3	1.0
DE92	5 572	10.8	1.1
DE93	2 294	7.9	0.8
DE94	3 279	5.5	0.6
DEA1	12 871	13.4	1.4
DEA2	12 168	11.2	1.1
DEA3	4 901	10.0	1.0
DEA4	5 582	6.7	0.7
DEA5	7 409	6.8	0.7

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
DEB1	2 194	7.8	0.8
DEB2	529	6.2	0.6
DEB3	8 375	14.8	1.5
DEC0	1 653	11.5	1.2
DED2	3 903	10.6	1.1
DED4	1 756	7.9	0.8
DED5	1 127	14.4	1.4
DEE0	1 723	13.1	1.3
DEF0	4 462	11.2	1.1
DEG0	3 170	10.2	1.0
DK01	7 737	17.1	1.4
DK02	977	8.4	0.7
DK03	2 217	7.4	0.6
DK04	3 651	8.4	0.7
DK05	993	6.4	0.5
EE00	647	21.0	1.0
EL30	970	23.6	1.1
EL41	2		
EL42	12		
EL43	74	13.5	0.7
EL51	38	21.1	1.0
EL52	247	17.4	0.8
EL53	9		
EL54	13		
EL61	23	4.3	0.2
EL62	4		
EL63	87	18.4	0.9
EL64	23	13.0	0.6
EL65	8		
ES11	976	2.5	1.1
ES12	401	19.0	0.8
ES13	208	18.3	0.8
ES21	3 043	23.7	1.0
ES22	985	23.5	1.0
ES23	118	14.4	0.6
ES24	1 224	24.7	1.1
ES30	6 154	24.7	1.1

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
ES41	680	21.0	0.9
ES42	272	16.5	0.7
ES43	63	17.5	0.8
ES51	8 602	22.8	1.0
ES52	2 317	21.1	0.9
ES53	191	29.8	1.3
ES61	2 326	23.9	1.0
ES62	453	17.9	0.8
ES64	2		
ES70	178	16.3	0.7
FI19	3 649	8.2	0.7
FI1B	8 416	14.5	1.2
FI1C	2 250	13.0	1.1
FI1D	2 046	10.0	0.8
FI20	14		
FR10	36 362	18.3	1.1
FR21	885	12.0	0.7
FR22	1 785	15.9	1.0
FR23	2 259	12.4	0.8
FR24	2 976	14.7	0.9
FR25	940	12.2	0.7
FR26	1 385	14.2	0.9
FR30	2 889	17.7	1.1
FR41	1 764	14.7	0.9
FR42	3 379	15.5	0.9
FR43	1 908	8.0	0.5
FR51	3 814	13.8	0.8
FR52	5 295	13.8	0.8
FR53	1 175	9.5	0.6
FR61	3 541	15.4	0.9
FR62	5 805	15.3	0.9
FR63	571	14.9	0.9
FR71	19 330	16.4	1.0
FR72	2 682	16.0	1.0
FR81	2 523	23.0	1.4
FR82	7 212	17.2	1.0
FR83	50	16.0	1.0

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
FRY1	14		
FRY2	18		
FRY3	6		
FRY4	66	13.6	0.8
FRY5	2		
HR03	57	14.0	0.6
HR04	374	26.2	1.1
HU10	2 060	11.8	1.0
HU21	208	11.5	0.9
HU22	159	5.0	0.4
HU23	147	15.6	1.3
HU31	181	14.4	1.2
HU32	236	17.8	1.4
HU33	336	13.4	1.1
IE01	1 600	11.0	0.8
IE02	4 664	15.4	1.1
IS00	1		
IS01	268	14.2	1.0
IS02	67	16.4	1.1
ITC1	5 535	14.1	1.0
ITC2	86	15.1	1.1
ITC3	1 485	15.4	1.1
ITC4	14 881	12.8	0.9
ITF1	659	17.9	1.3
ITF2	87	24.1	1.7
ITF3	1 376	23.4	1.7
ITF4	1 031	20.0	1.4
ITF5	80	17.5	1.2
ITF6	301	22.9	1.6
ITG1	818	19.7	1.4
ITG2	305	27.9	2.0
ITH1	539	4.3	0.3
ITH2	668	11.5	0.8
ITH3	5 389	10.0	0.7
ITH4	1 866	10.6	0.7
ITH5	7 527	13.1	0.9
ITI1	3 973	15.4	1.1

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
ITI2	496	10.9	0.8
ITI3	1 176	11.8	0.8
ITI4	3 569	22.6	1.6
LI00	4		
LT00	411	22.6	1.0
LU00	1 023	9.8	1.0
LV00	558	30.5	1.0
MC00	3		
NL11	601	14.0	1.2
NL12	426	8.2	0.7
NL13	289	3.8	0.3
NL21	1 618	7.0	0.6
NL22	2 869	10.2	0.9
NL23	272	6.3	0.5
NL31	1 920	15.3	1.3
NL32	3 946	12.0	1.0
NL33	5 837	11.7	1.0
NL34	347	13.0	1.1
NL41	17 502	11.7	1.0
NL42	3 563	14.3	1.2
NO01	2 250	15.9	1.4
NO02	120	9.2	0.8
NO03	1 086	9.7	0.9
NO04	1 035	5.4	0.5
NO05	1 031	6.6	0.6
NO06	938	12.0	1.1
NO07	178	18.5	1.7
PL11	793	24.0	1.3
PL12	2 336	22.4	1.2
PL21	1 771	11.7	0.7
PL22	830	14.0	0.8
PL31	254	24.4	1.4
PL32	315	14.0	0.8
PL33	108	26.9	1.5
PL34	116	17.2	1.0
PL41	653	16.1	0.9
PL42	189	23.3	1.3

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
PL43	199	2.5	0.1
PL51	944	16.9	0.9
PL52	134	9.0	0.5
PL61	259	18.1	1.0
PL62	114	22.8	1.3
PL63	649	23.3	1.3
PT11	1 764	28.9	1.1
PT15	59	23.7	0.9
PT16	762	22.2	0.8
PT17	932	24.9	0.9
PT18	172	34.9	1.3
PT20	31	12.9	0.5
PT30	9		
RO11	154	17.5	1.0
RO12	149	13.4	0.8
RO21	159	22.6	1.3
RO22	24	12.5	0.7
RO31	78	15.4	0.9
RO32	411	25.1	1.4
RO41	57	12.3	0.7
RO42	358	11.5	0.6
SE11	7 959	12.3	1.0
SE12	4 112	11.7	1.0
SE21	1 297	5.6	0.5
SE22	5 313	12.6	1.0
SE23	6 133	14.3	1.2
SE31	1 280	9.5	0.8
SE32	394	11.9	1.0
SE33	717	10.5	0.9
SI03	775	17.2	1.0
SI04	1 222	17.5	1.0
SK01	269	13.4	1.1
SK02	338	12.1	1.0
SK03	132	9.8	0.8
SK04	167	9.6	0.8
TR10	3 423	19.6	1.1
TR21	220	7.7	0.4

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
TR22	45	20.0	1.2
TR31	300	22.7	1.3
TR32	21		
TR33	779	6.5	0.4
TR41	650	16.6	1.0
TR42	725	20.6	1.2
TR51	542	16.6	1.0
TR52	35	2.9	0.2
TR61	63	20.6	1.2
TR62	47	19.1	1.1
TR63	19		
TR71	22		
TR72	34	14.7	0.9
TR81	4		
TR82	6		
TR83	32	6.3	0.4
TR90	14		
TRA1	33	6.1	0.4
TRA2	4		
TRB1	35	34.3	2.0
TRB2	8		
TRC1	23	0.0	0.0
TRC2	5		
TRC3	2		
UKC1	990	9.9	0.8
UKC2	1 054	14.1	1.2
UKD1	243	6.6	0.5
UKD3	1 335	10.7	0.9
UKD4	813	6.6	0.5
UKD6	1 217	12.1	1.0
UKD7	1 013	24.9	2.0
UKE1	716	20.0	1.6
UKE2	731	13.3	1.1
UKE3	671	7.7	0.6
UKE4	1 291	8.9	0.7
UKF1	3 070	9.1	0.7
UKF2	1 354	9.5	0.8

NUTS2	# Inventors 2010-2019	WIR 2010-2019	WIR ratio 2010-2019
UKF3	440	5.9	0.5
UKG1	1 522	6.3	0.5
UKG2	1 150	6.0	0.5
UKG3	1 839	8.6	0.7
UKH1	7 702	13.9	1.1
UKH2	3 120	15.6	1.3
UKH3	1 472	10.7	0.9
UKI3	6 223	14.2	1.2
UKI4	1 876	14.4	1.2
UKI5	402	8.7	0.7
UKI6	579	12.1	1.0
UKI7	1 396	13.8	1.1
UKJ1	13 232	17.4	1.4
UKJ2	5 531	7.8	0.6
UKJ3	2 775	7.4	0.6
UKJ4	975	8.4	0.7
UKK1	4 829	6.8	0.6
UKK2	695	4.5	0.4
UKK3	262	17.9	1.5
UKK4	506	7.9	0.6
UKL1	815	8.7	0.7
UKL2	1 230	14.7	1.2
UKM2	1 992	9.5	0.8
UKM3	766	13.3	1.1
UKM5	1 089	14.6	1.2
UKM6	237	10.5	0.9
UKN0	1 005	14.1	1.2

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