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EPO Women's participation in inventive activity study

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EPO study on women inventors

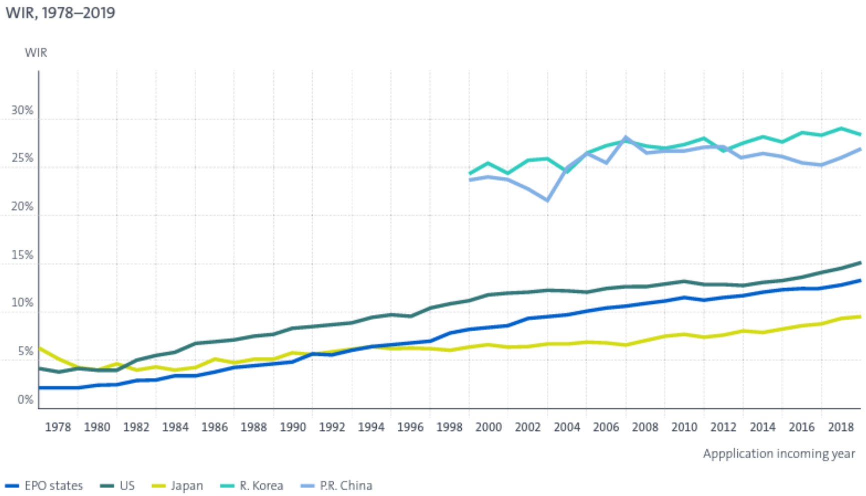
Focus on women's participation in inventive activities in EPO member states**,** as measured by the **women inventor rate (WIR)**

Methodology aligned on **USPTO reports** on women inventors (Toole et al., 2019, 2021)

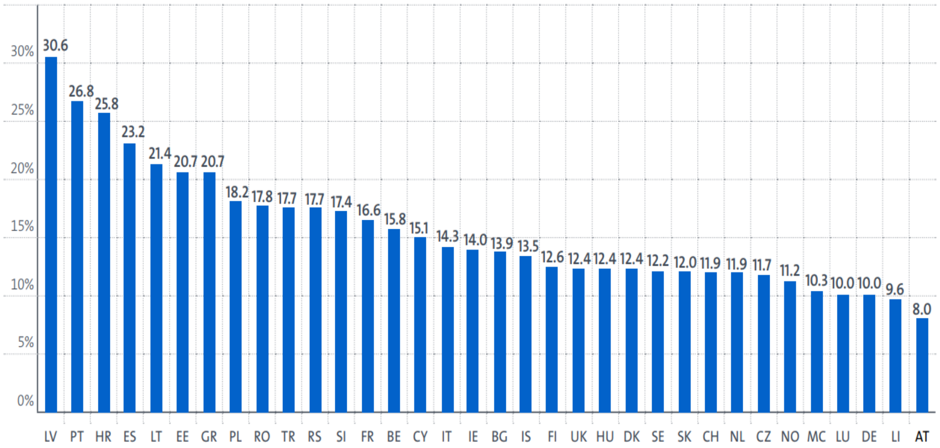
- Gender attributed **based on the inventors' names**
- Patents and inventors are **assigned to countries according to the inventor address**
- Inventors are **disambiguated** (using names, addresses, and 20 filtering criteria (eg network ties, geographical proximity etc)

A persistent gender gap in innovation activities

WIR over time, 1978–2019

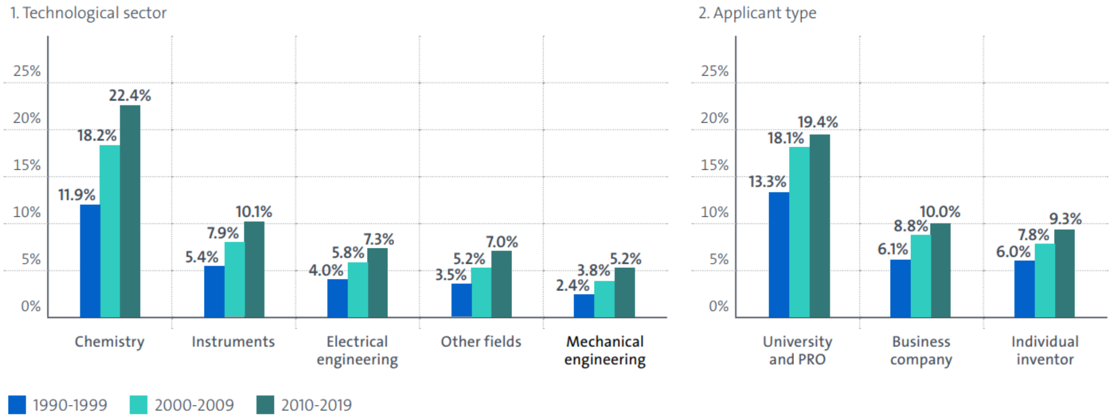


WIR by EPO country, 2010–2019

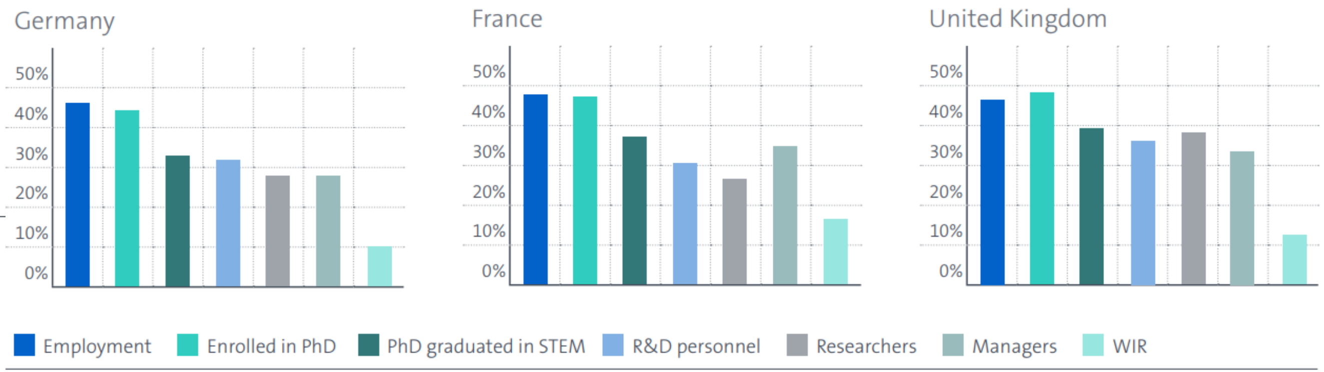


Specialisation patterns and the “leaking pipeline”

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



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



TRIBUTE TO WOMEN INVENTORS LINKED WITH THE US

Gordana Vunjak-Novakovic (RS/US)
Advances in tissue engineering
Lifetime achievement winner 2021

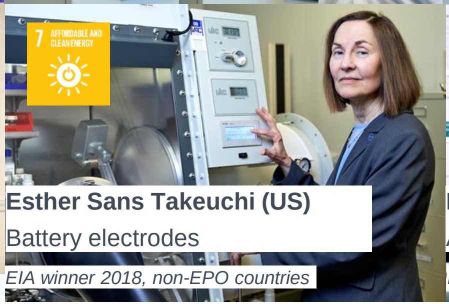
Katalin Karikó (HU/US)
Modified mRNA
Lifetime achievement winner 2022

Laura van't Veer (NL)
Gene-based breast cancer test
EIA winner 2015, SMEs

Helen Lee (UK/FR)
Diagnostic tests
EIA winner 2016, Popular Prize

Sumita Mitra (IN/US)
Restoring smiles
EIA winner 2011, non-EPO countries

Erin Smith (US)
AI to detect Parkinson's
Young Inventors Prize winner 2022



Esther Sans Takeuchi (US)
Battery electrodes
EIA winner 2018, non-EPO countries

Marta Karczewicz (PL)
Advances in video compression
Lifetime achievement finalist 2019

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Women's participation in inventive activity

Evidence from EPO data

November 2022

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.

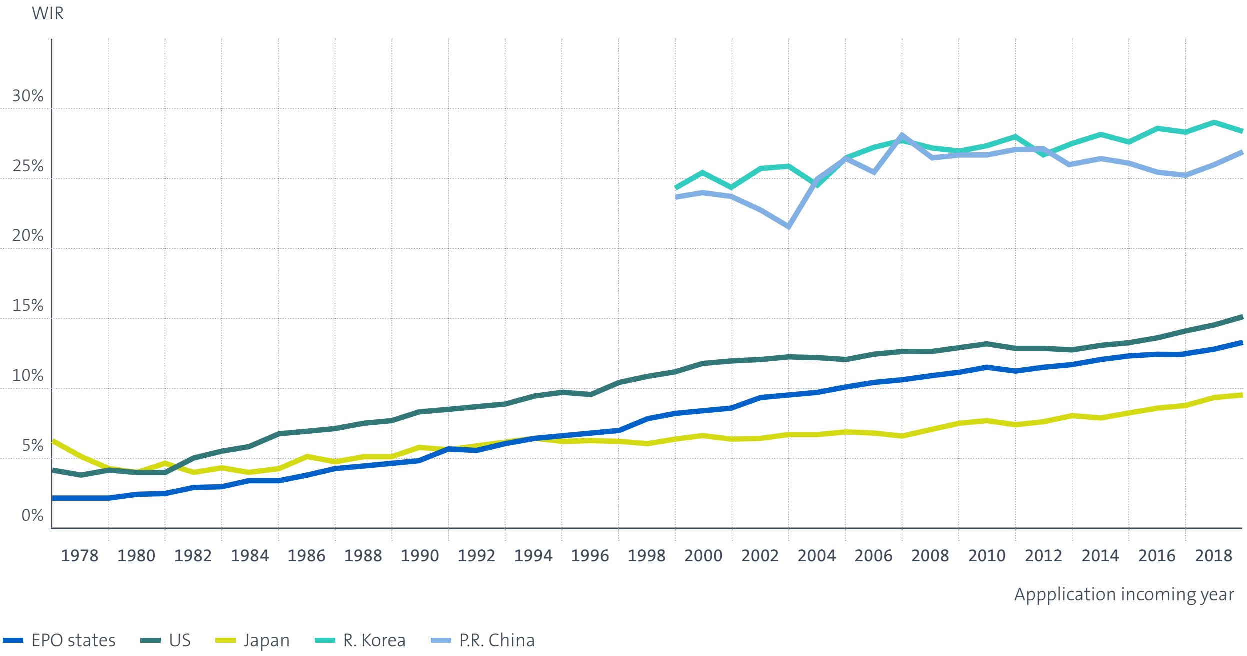
1 The data exclude Montenegro, which acceded the EPC on 1 October 2022, after this study was prepared.

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

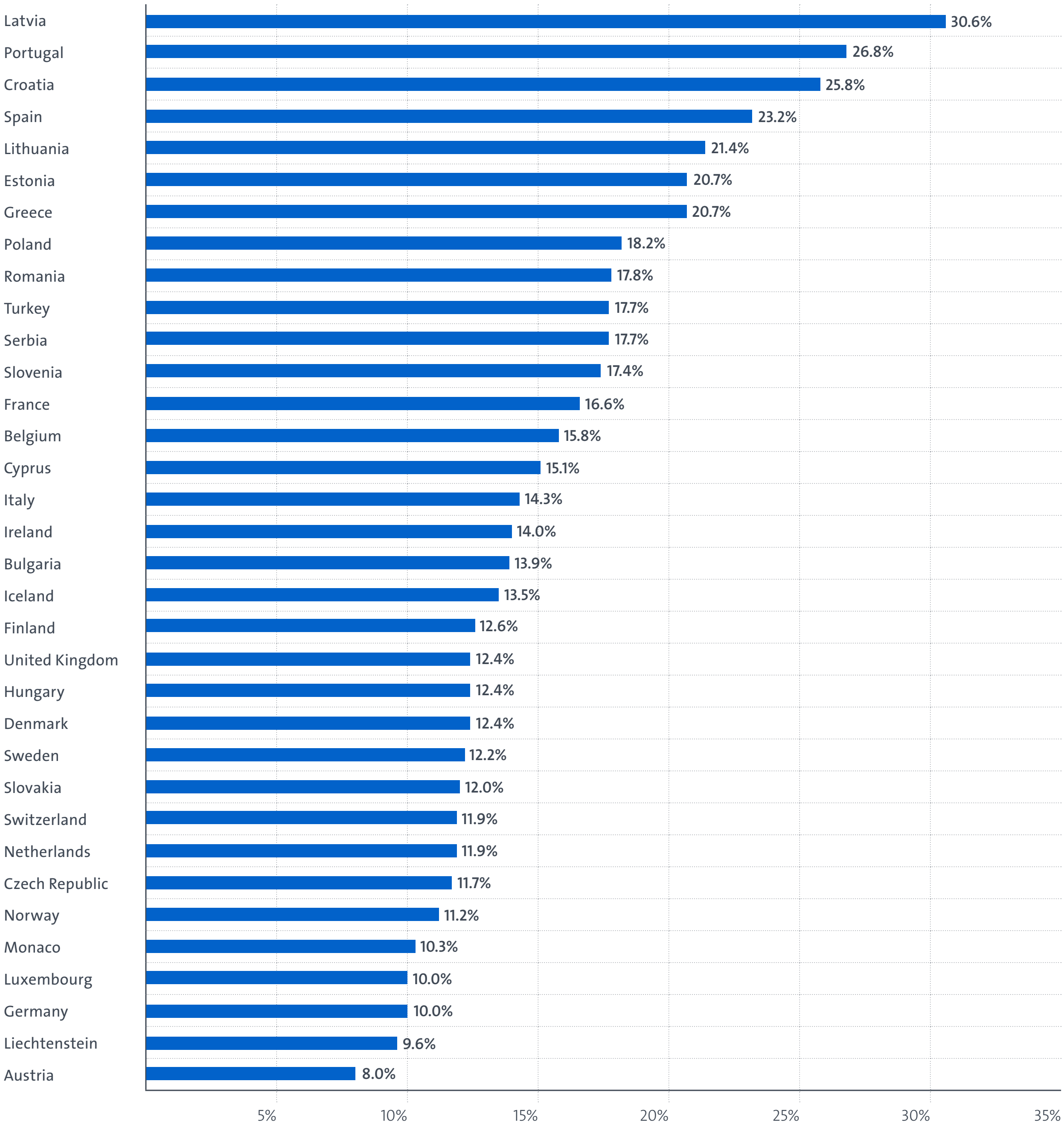


Source: author's calculations

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

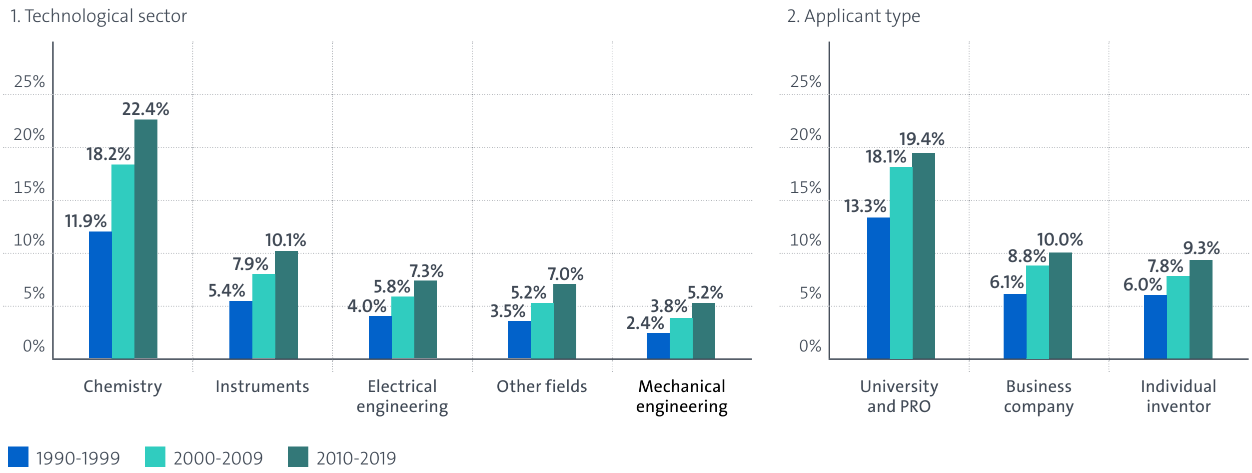
3. Differences across EPO countries can largely be explained by those countries' technology specialisations and the contributions of universities and public research organisations (PROs) to patenting activity.

   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

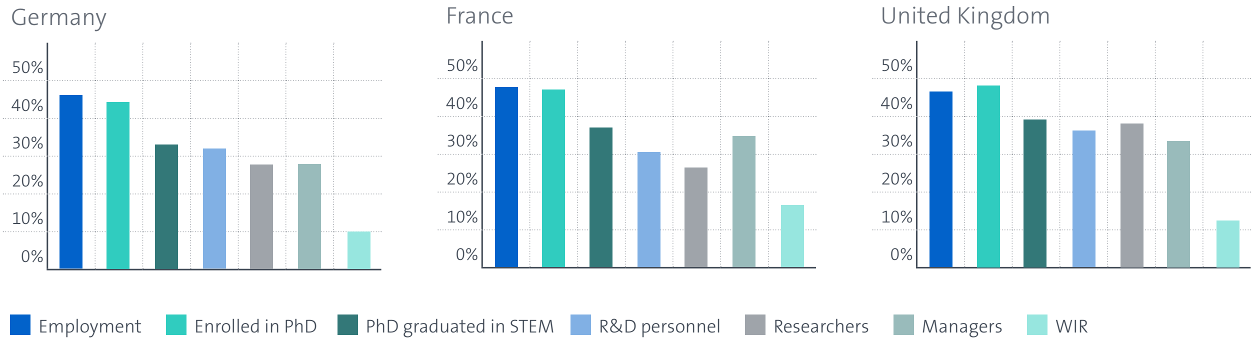
4. There is a consistent pattern of a decreasing share of women in segments ranging from total employment to PhD enrolment, to PhD graduates in STEM, to R&D personnel and researchers, to patenting. This confirms the diagnostic of a "leaking pipeline" issue, whereby women in EPO countries face increasing 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

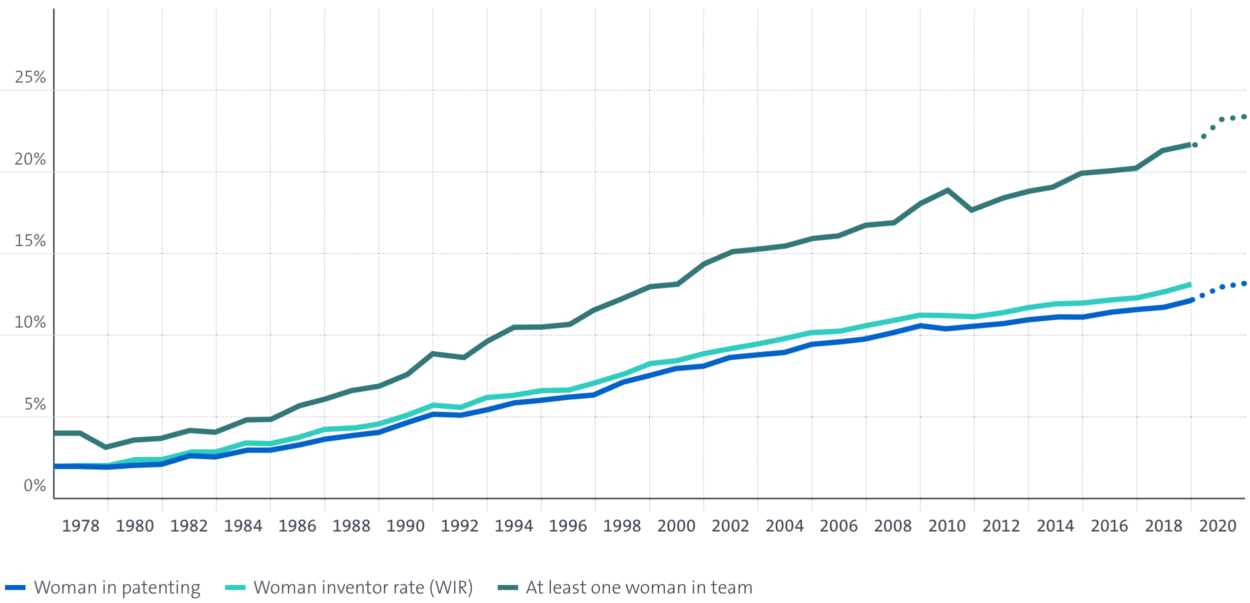
Various metrics can be used to evaluate the patenting activity of women across regions and over time. The principal metric is the women inventor rate (WIR), which measures the percentage of women inventors and requires disambiguated inventor data. In addition, two other metrics can be considered (following 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

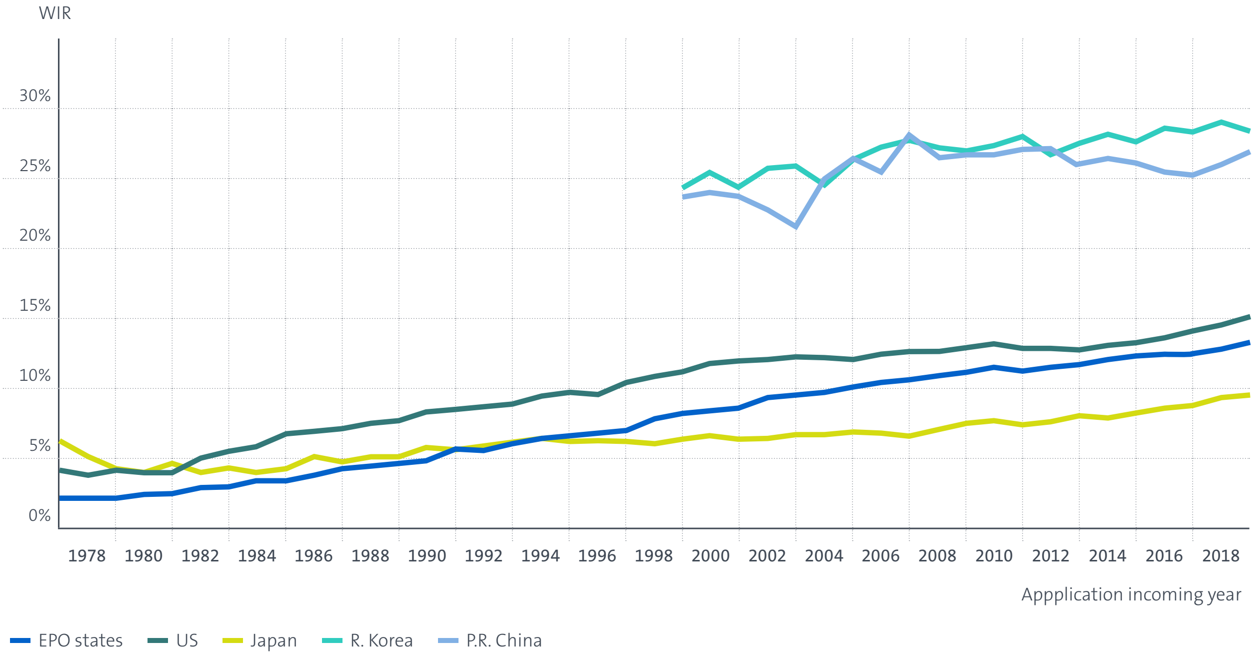


Source: author's calculations

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

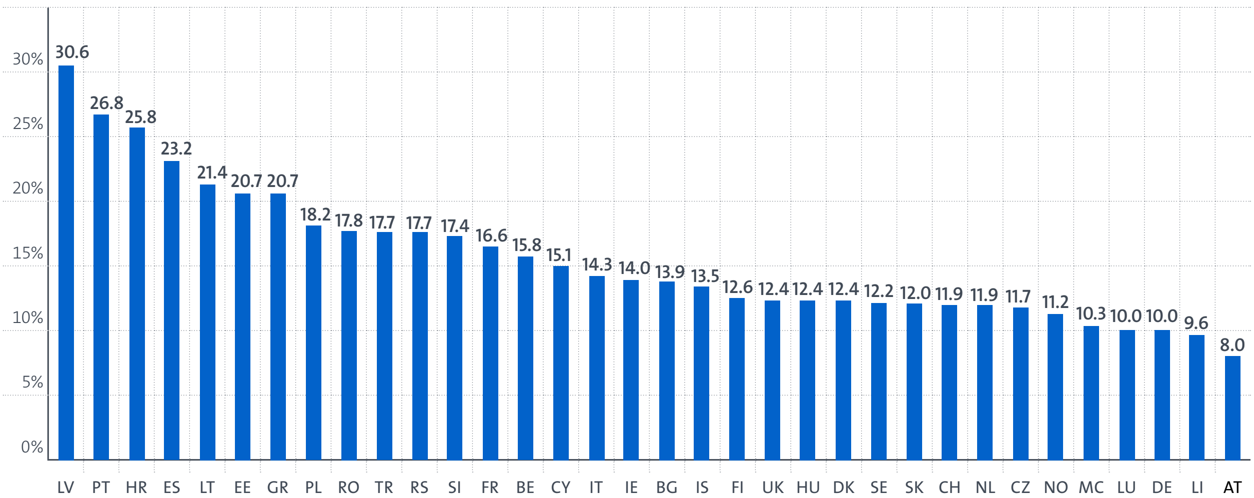
5 This result should be interpreted with caution, because gender attribution for these two Asian countries is relatively poor and is based on less strict criteria for identifying women, which may translate into low precision (high number of false positives).

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.

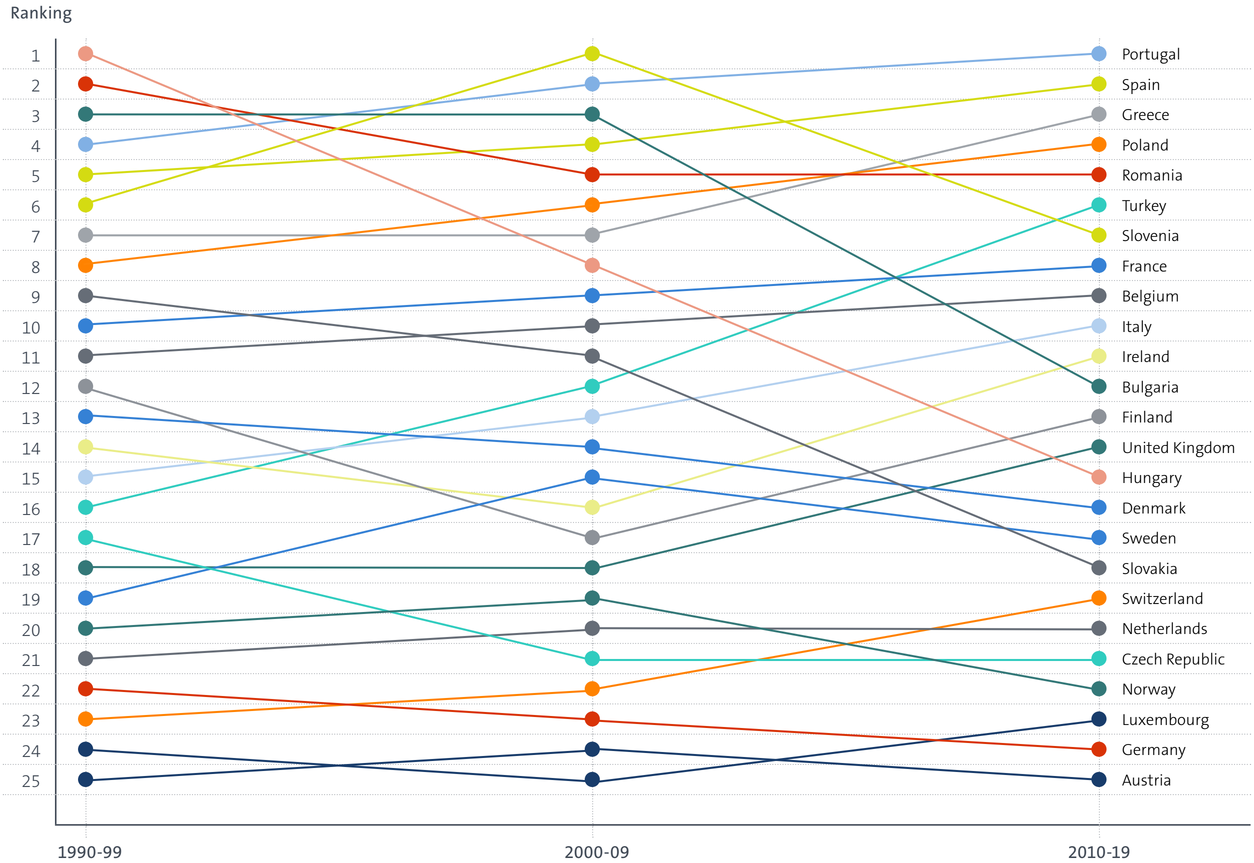
Source: author's calculations

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



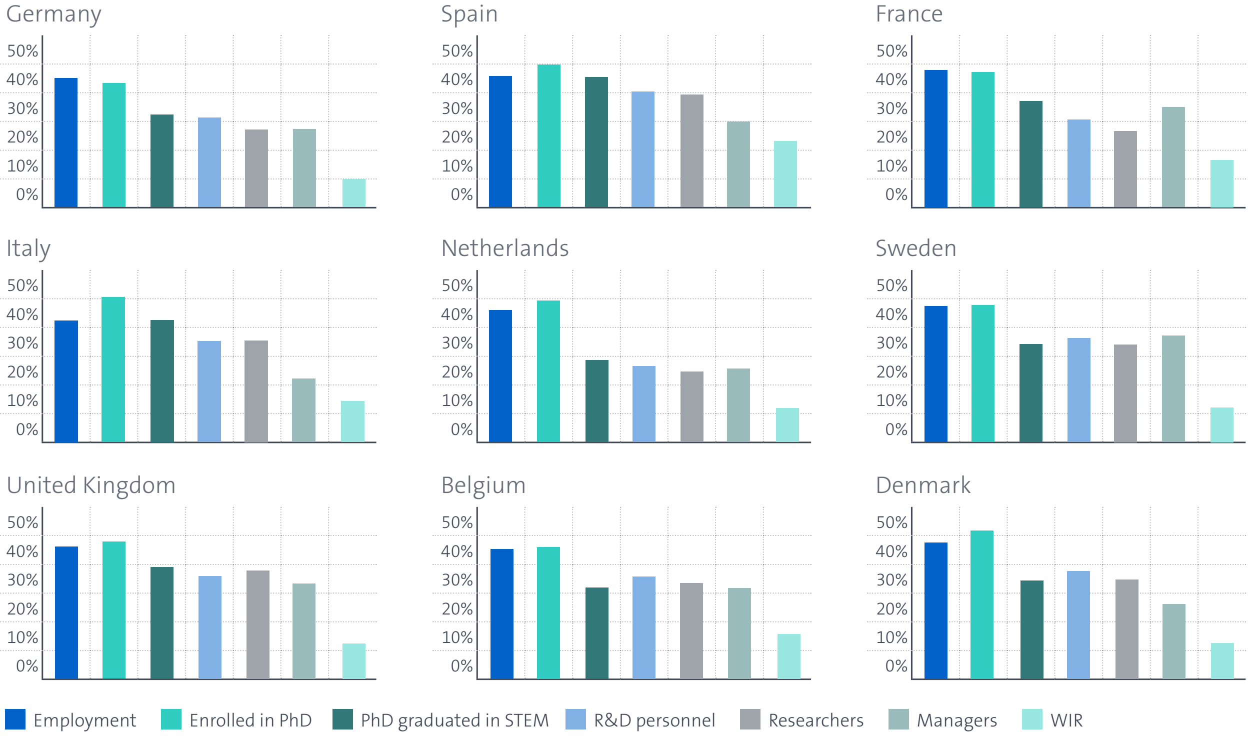
Source: author's calculations

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.

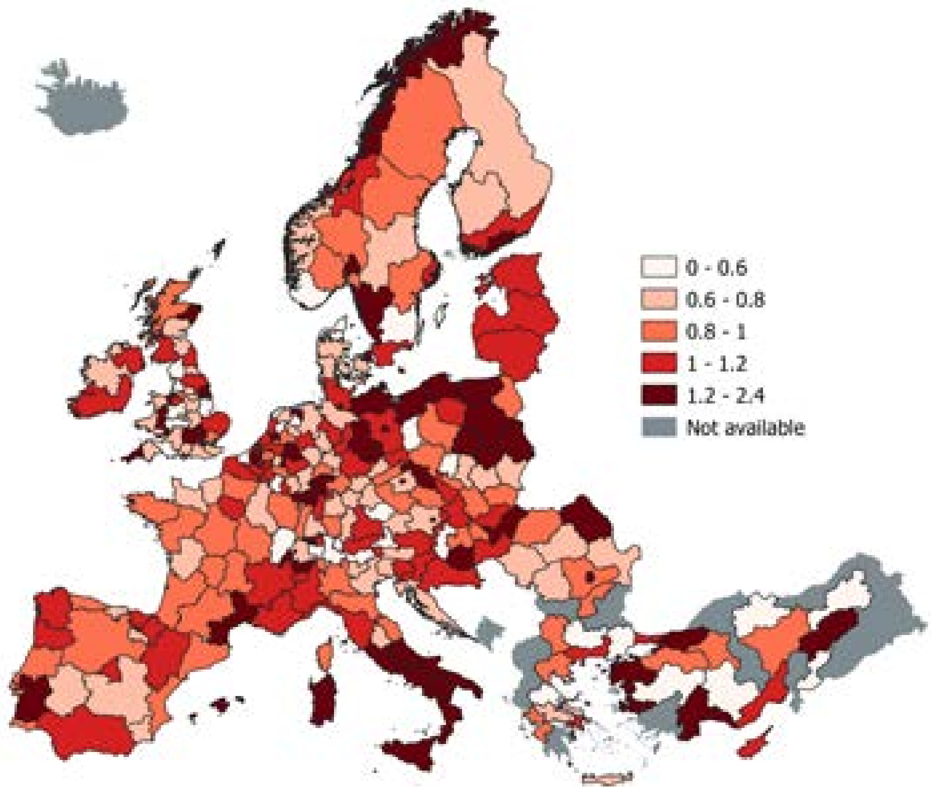
Source: author's calculations

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.

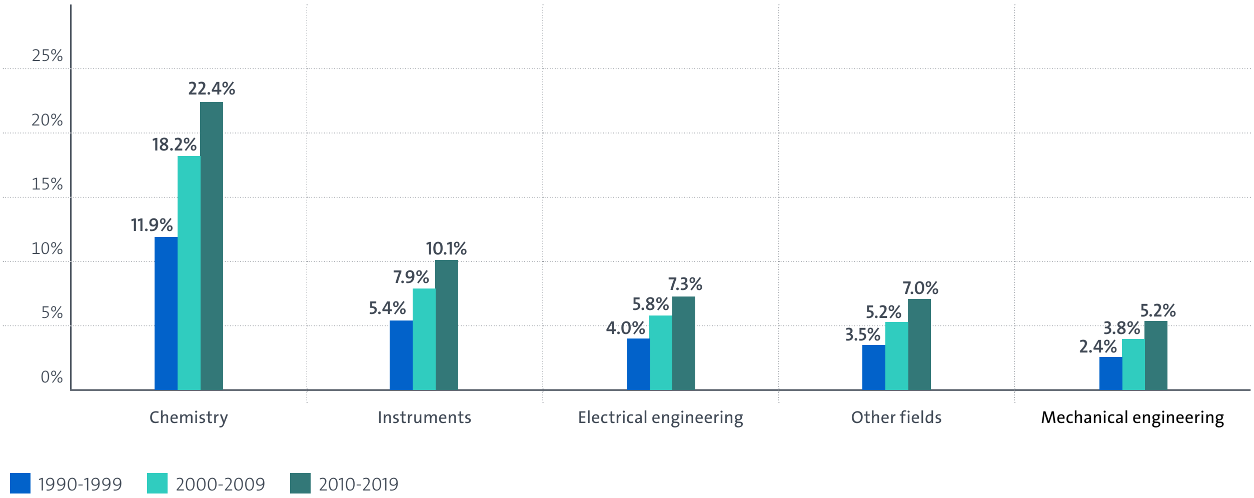
4. Composition effects: technology and applicant type

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



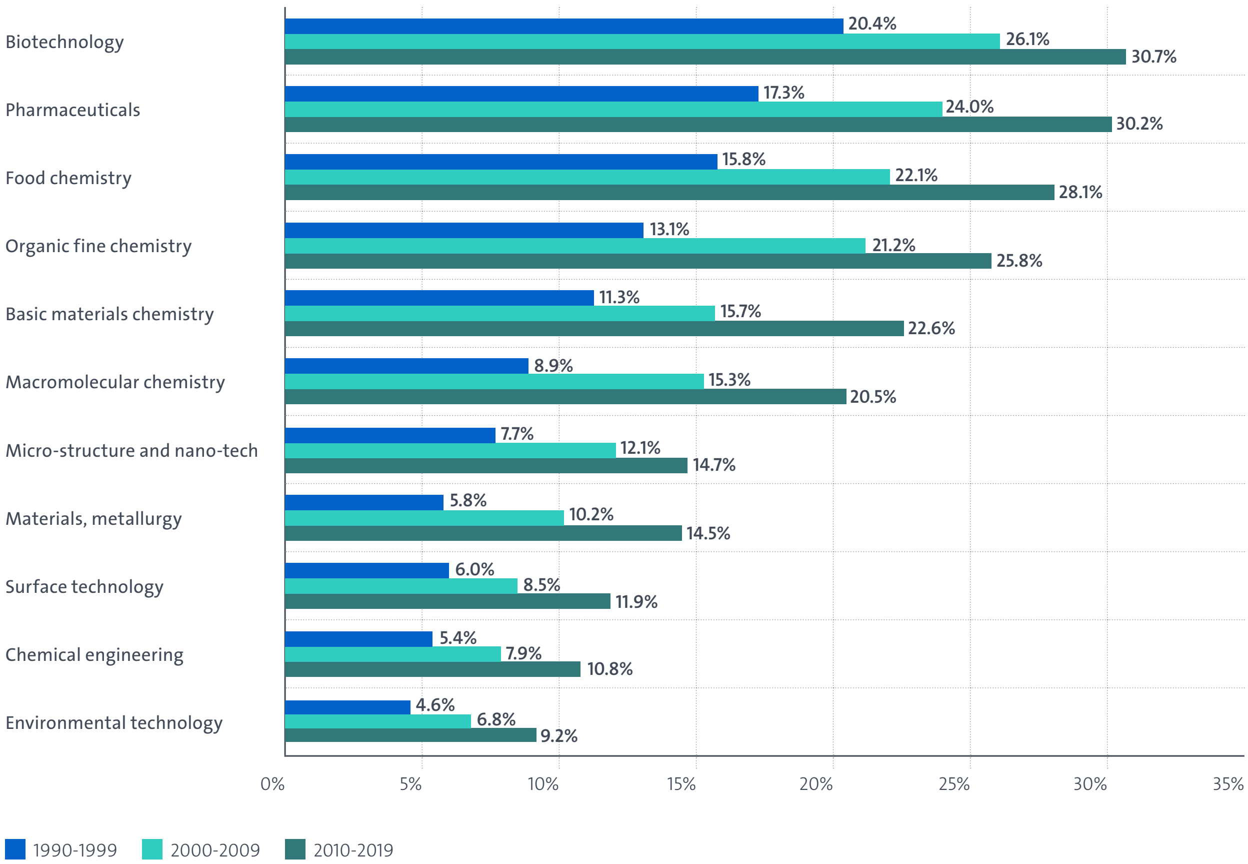
Notes: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

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



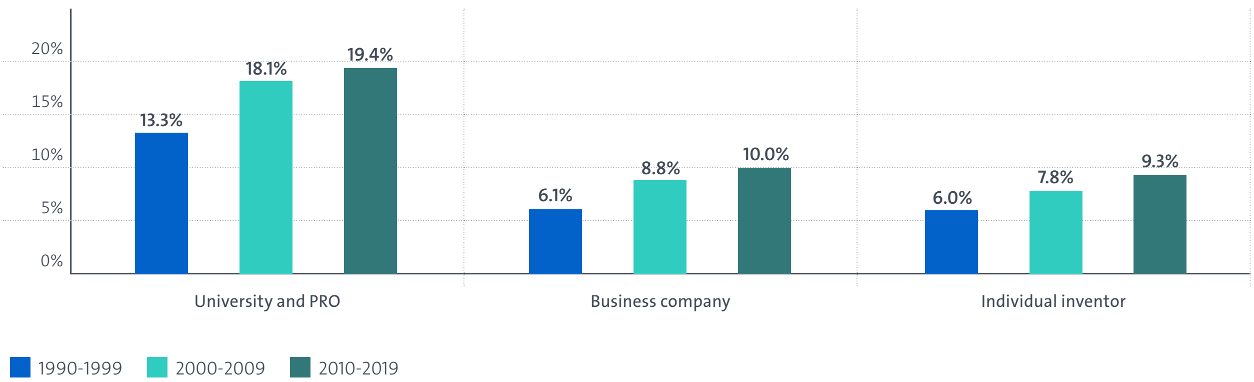
Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

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***

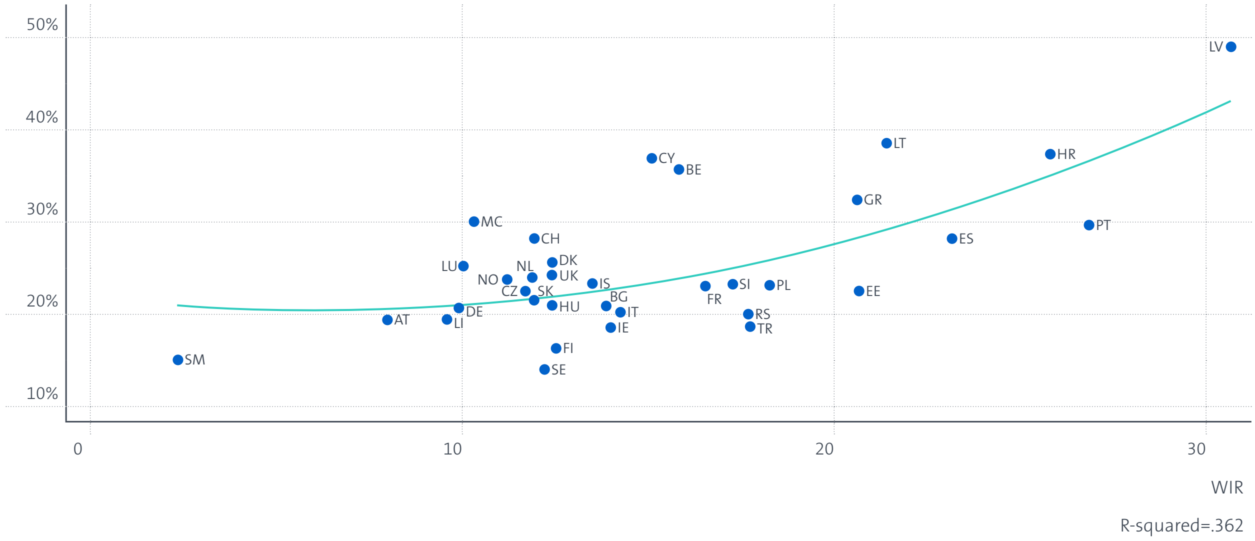
Econometric analysis confirms that both the technology specialisation of a country and the contribution of universities and PROs to its patenting activity determine that country's WIR. Figure 10 relates the WIR values of a country to its patent specialisation in Chemistry (Figure 10 a)) and to its share 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

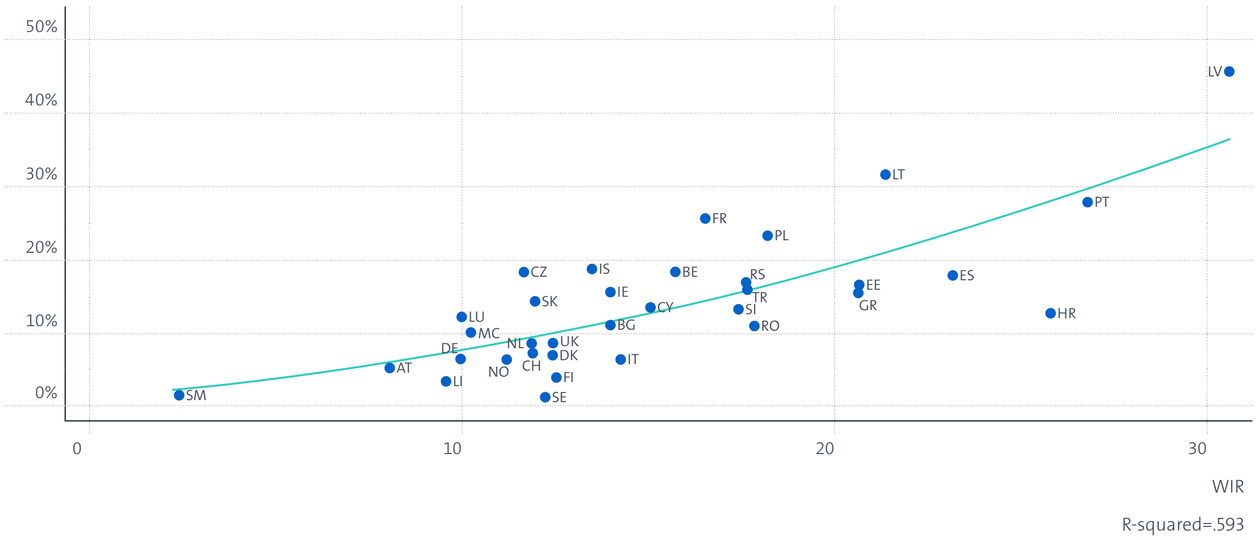
a) WIR vs specialisation in Chemistry, 2010–2019

Share of patent applications in Chemistry



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

Share of patent applications from universities and PROs



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.

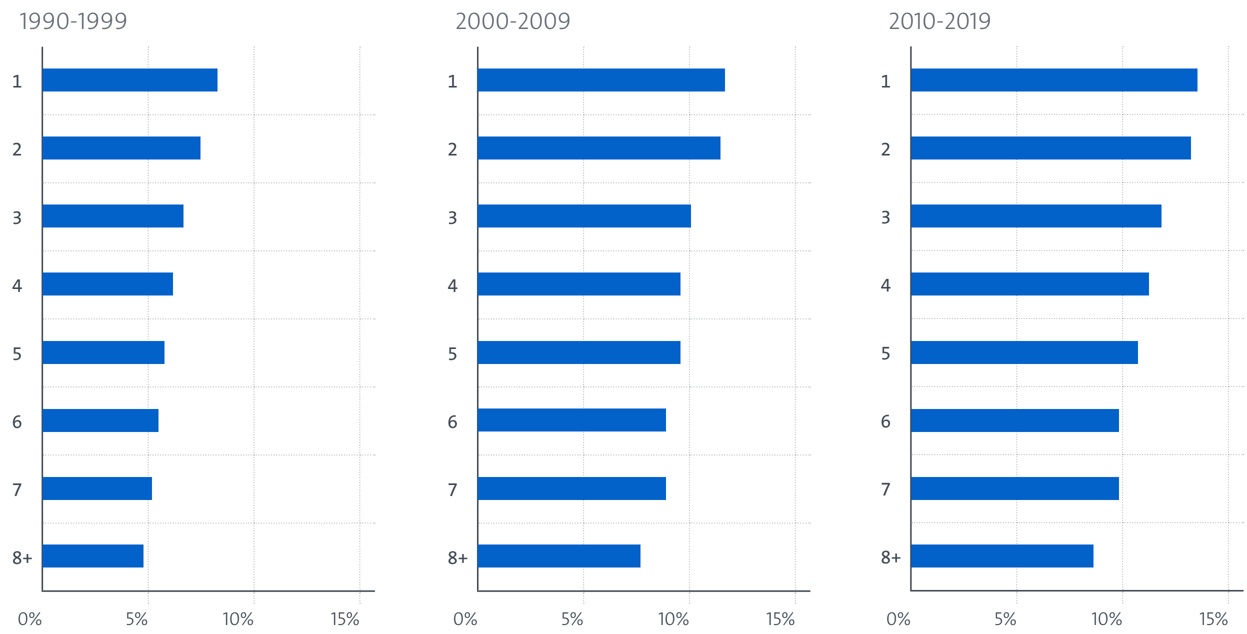
5.1 Productivity and impact

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



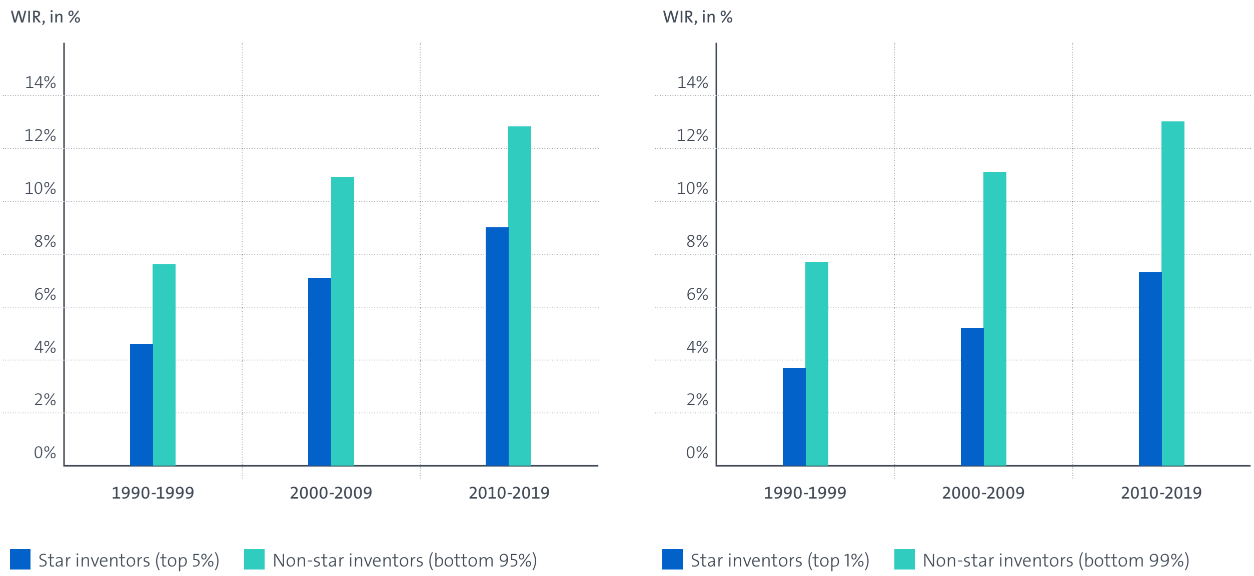
Note: Data used in the Figure correspond to patent applications whose inventors reside in one (or more) of the 38 EPO countries.

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.

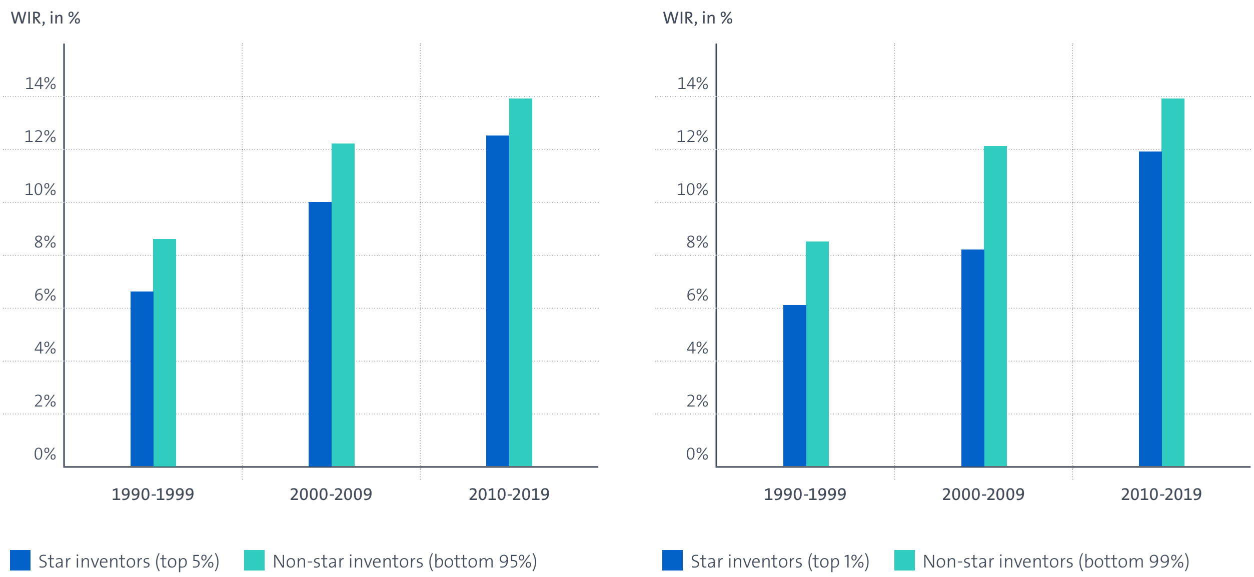
Source: author's calculations

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)

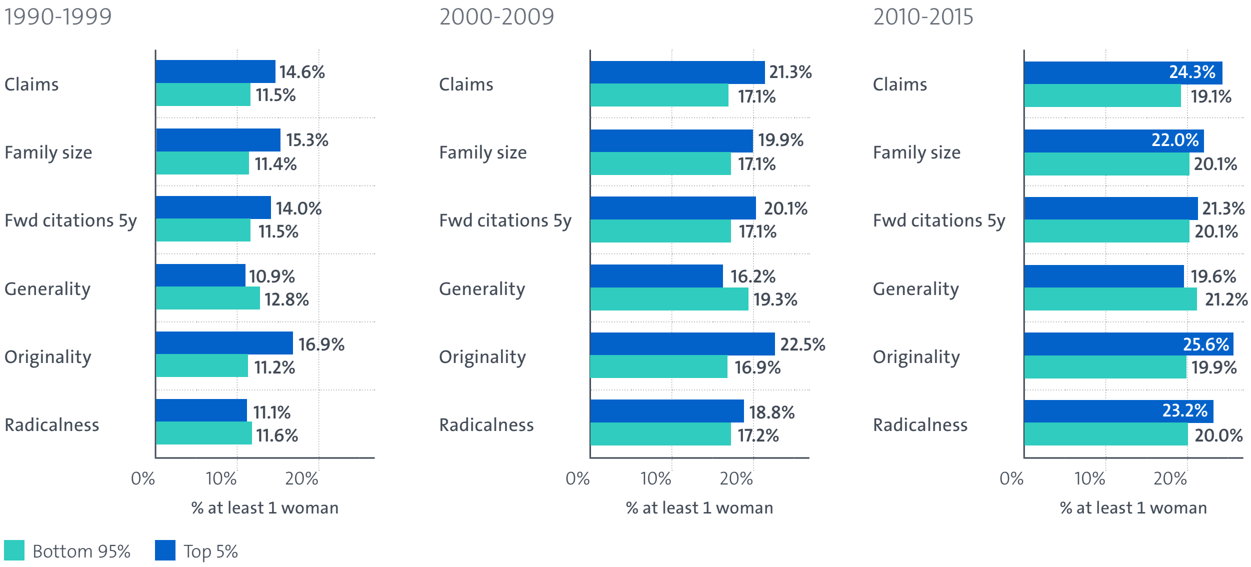
— the patent's originality, which – broadly speaking – captures the extent to which a patent recombines previously unrelated pieces of knowledge, as measured by the distribution of its citations of the prior art across all the technological sectors (the more concentrated in a technological sector the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

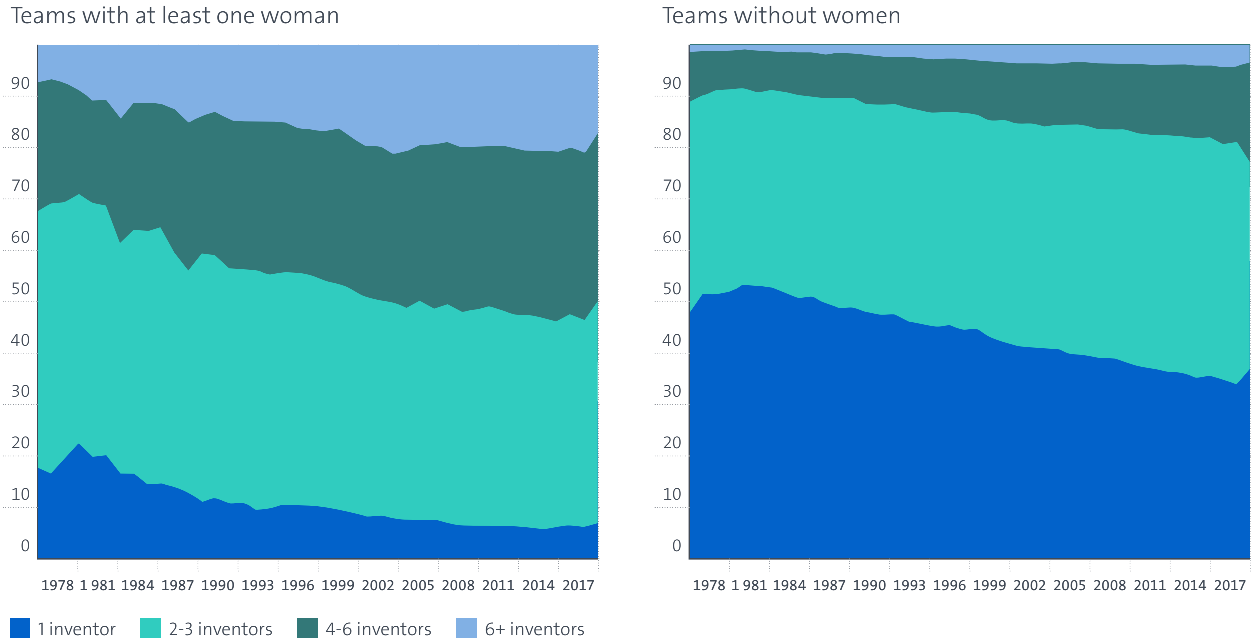
From this it can be inferred that over-representation of women on university and pharma/biotech patents translates into their over-representation on patents listing more than one inventor. This is clearly illustrated by Figure 15. Patent applications listing at least one woman among their inventors are 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).

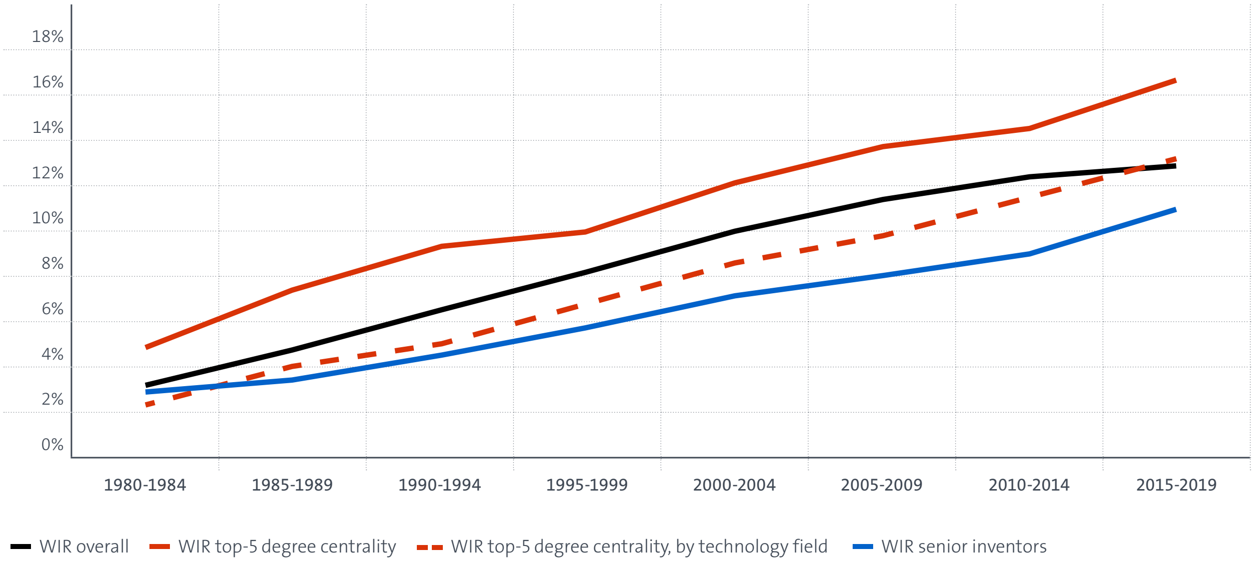
Figure 16 presents WIR values calculated for all inventors, for five-year time windows, and compares them with the WIR of: (1) the top 5% most central inventors in the network, (2) the top 5% most central inventors (with the top 5% computed also per technology field) and (3) the subset of inventors comprising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

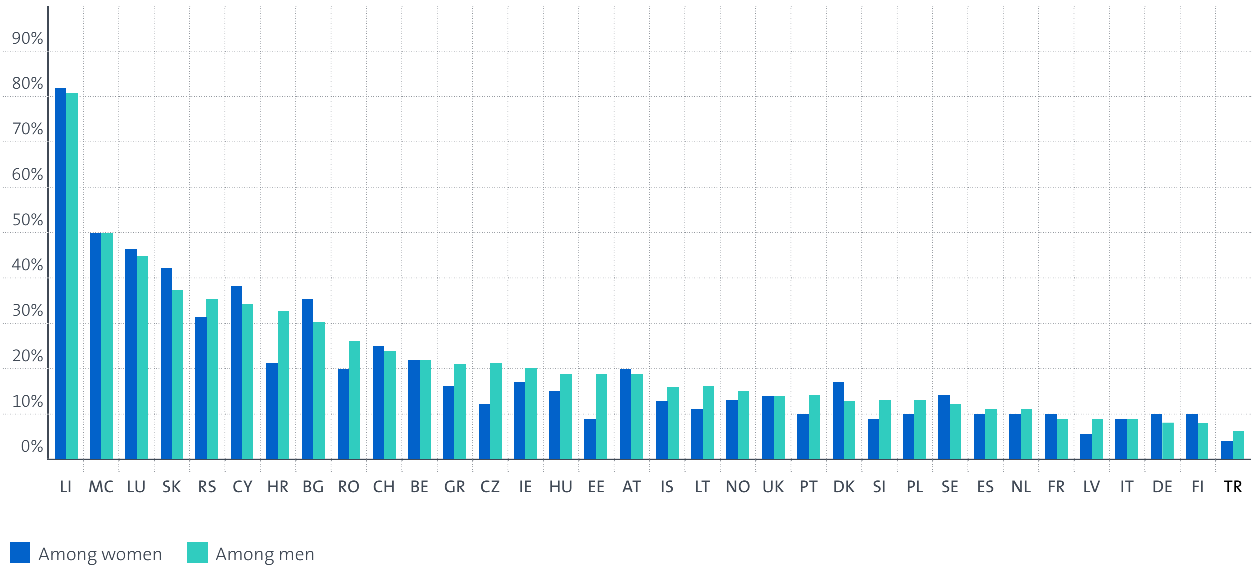
5.3 Internationalisation

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.

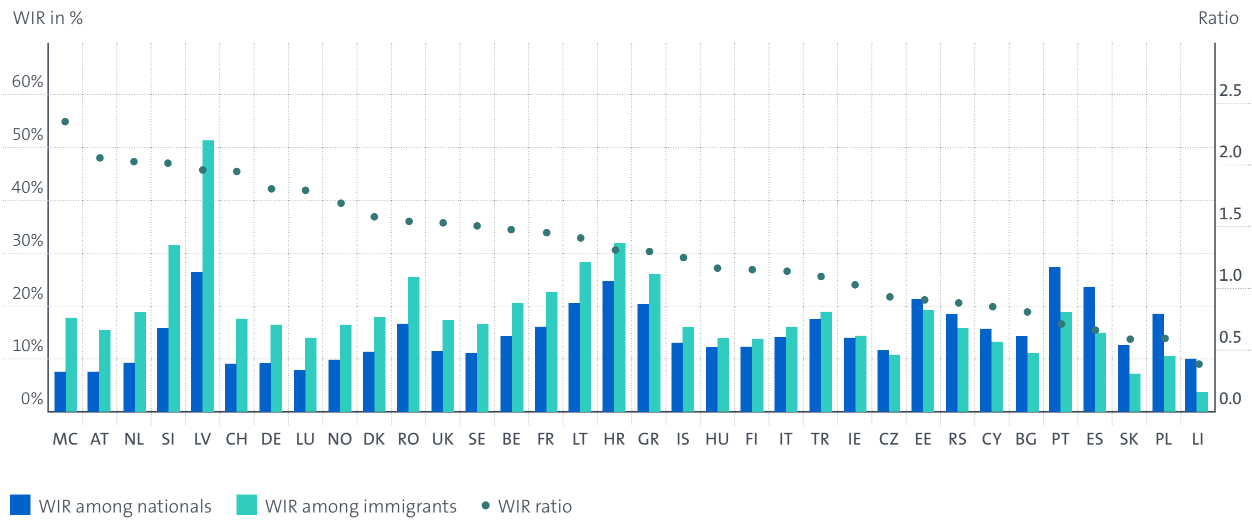
Source: author's calculations

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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ENGAGING MORE WOMEN IN ACADEMIC INNOVATION: FINDINGS AND RECOMMENDATIONS

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Diversity is a key driver of innovation and a critical component of success on a global scale. Countries that deploy strategies to foster greater inclusion of all inventors in the innovation lifecycle will ultimately be best positioned to maximize their gross domestic product and ensure economic prosperity. The U.S. is losing ground because it is not fully engaging a significant portion of the inventive talent pool. According to a 2019 report from the U.S. Patent and Trademark Office, the share of women among all U.S. inventor-patentees is only 12.8%.

In an effort to understand factors that encouraged and discouraged academic women's participation in technology commercialization, a group of technology transfer professionals conducted a survey of academic women involved in innovation, invention and/or entrepreneurship. The 168 respondents were from public and private research institutions of varying sizes from all regions of the U.S. This paper outlines the key findings from the qualitative and quantitative data around the themes that emerged. It also puts forth a set of recommendations based on the survey feedback, follow-up interviews, and the collective experience of technology transfer professionals who work daily with academic innovators. It is our hope that these recommendations will provide valuable insights into concrete actions that can be taken to ensure systemic changes that foster greater engagement of academic women and other under-represented populations in all stages of the innovation lifecycle.

Key words: Innovation; Inclusion; Women; Academia; Engagement

BACKGROUND

Diversity is a key driver of innovation and a critical component of success on a global scale (1). Countries that deploy strategies to foster greater inclusion of all inventors in the innovation lifecycle will ultimately be best positioned to maximize their gross domestic product (GDP) and ensure economic prosperity. The Equality of Opportunity Project analyzed the lives of over a million inventors in the U.S. and found that innovation in the U.S. would quadruple if women,

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people of color, and people from low-income families invented at the same rate of groups who are not held back by discrimination and structural barriers (2). The U.S. is losing ground because it is not fully engaging a significant portion of the inventive talent pool.

The 2019 U.S. Patent and Trademark Office (USPTO) *Progress and Potential* findings reported the women inventor rate (WIR) (that is, the share of women among all U.S. inventor-patentees) grew from 12.1% in 2016 to 12.8% by 2019 (3). While this was an improvement, it is a far cry from parity considering that women make up nearly half the workforce (4).

A recent report by the Institute for Women's Policy Research (IWPR) (5) notes that in 2019 only 21.9% of patents had at least one woman inventor. This is up only slightly from 2016 and at the current rate of progress, women will not reach parity in patenting during the 21st century.

According to AUTM's (the technology transfer professional association) 2020 survey data (6), participating U.S. universities and research institutions expended over $83 billion on research, received 27,112 invention disclosures, and filed 17,738 new U.S. patent applications. It is the role of technology transfer professionals associated with these institutions to manage the complex process of shepherding those ideas from the lab to the marketplace — from evaluating and protecting discoveries to commercializing the inventions through new and existing companies.

Recognizing the lack of women participating in the process, a group of senior technology transfer professionals came together at the 2013 AUTM annual meeting to discuss what they could to do address the disparity. Collectively, these professionals had hundreds of years of experience working with university innovators, companies of all sizes, and entrepreneurs starting new ventures. Because of the pivotal role that they and their colleagues in the technology transfer profession serve in technology commercialization, they recognized they were uniquely positioned to identify and implement actions that could be taken to foster greater inclusion in the process. The group coalesced as the AUTM Women Inventors Committee and is now known as the AUTM Women Inventors Special Interest Group (WISIG).

Since 2013, numerous entities around the world have recognized this gender disparity and research has been conducted that substantiates and quantifies the initial observations of the WISIG. The USPTO (7), the World Intellectual Property Organization (WIPO) (8), and the Institute For Women's Policy Research (IWPR) (5) have quantified the lack of representation of women in the patenting process. Research done at Osage University Partners (OUP) has quantified the lack of women founders in university-based startup companies and found that, of the more than 6,000 university startups in the OUP database, only 11% had a female founder or co-founder (9). Crunchbase has quantified the lack of venture capital funding invested in women-led startups and shows it actually declined in 2020 to 2.3% (10).

Awareness of the lack of inclusiveness in invention and entrepreneurship is now at an all-time high, and significantly more attention is being given to identifying and implementing approaches to address the problem. Recognizing the changing landscape and wanting to be intentional without being duplicative of existing resources, the WISIG decided in the spring of 2020 to conduct customer discovery to help guide their future efforts. The goal of the customer discovery was to understand factors that encouraged and discouraged academic women's participation in technology commercialization at their respective institutions. Additionally, they wanted to better understand the barriers that impede female participation so they could engage with the technology transfer community and other synergistic groups to further address and reduce those barriers.

Methodology

The WISIG formed a task force to develop the methodology for a survey of female academics who had participated in some level of innovation, invention, or entrepreneurship. The task force members were experienced technology transfer professionals giving them a unique ability to identify and reach out to women who fit this demographic. The members of the task force compiled a list of names they knew personally and augmented that by engaging AUTM members who served as directors of technology transfer offices (TTOs). The task force recognized that a request coming from within the innovator's own institution would be most likely to garner a response.

Female innovators from public and private research institutions of varying sizes from all regions of the U.S. were invited to complete the survey. The goal was to achieve representation from various levels of professorship and from different races and ethnicities. Developing a list that identified these variables proved challenging primarily because of lack of access to this data. It was decided to make this information an optional question on the survey and hope for diverse representation among respondents. A goal of fifty responses was established as realistic and sufficient to provide meaningful results.

The task force crafted a questionnaire that consisted of multiple-choice questions, ranking questions, and open-response questions. The survey also captured demographics with the intent of learning how respondents' experiences varied based on academic position and/or ethnicity and race.

The survey was launched the first week in November 2020 and participants were given a November 20th deadline to respond. The survey exceeded expectations, generating 168 responses. The task force evaluated responses to identify key takeaways and common themes.

The survey also asked the participants if they would be willing to speak with a member of the task force to discuss their experiences in a follow-up interview, and sixty-eight of the respondents volunteered. Additional questions were created to delve further into the common themes that were identified in the survey responses. Of the 68 women who originally volunteered, 16 were subsequently interviewed. Follow-up interviews reinforced many of the findings from the original survey and provided expanded insights for the recommendations put forth in this paper.

Demographics of Survey Participants

Survey participants included 166 academic women from across the U.S., and two outside the U.S., from public and private institutions of varying sizes. Respondents had varying levels of experience, ranging from undergraduates new to the process to tenured faculty with decades of innovation and patenting experience. While the initial plan was to only include faculty, we decided to include all participants to increase the types of experiences and hopefully expand our insights. Since the goal was to understand factors that encouraged and discouraged academic women's participation in technology commercialization, questions were framed around the respondents' experiences at the time of their first invention. The majority were at various levels of professorship (60%), with the remaining being post-doctoral research associates and graduate students (28%) and other (12%). The majority of respondents were Caucasian (73%) followed by Asian (18%), Hispanic/Latina (5%), and Black (2%). As a result of the lack of representation from non-Caucasian and non-Asian respondents, insights on the intersectionality of experiences and race were inconclusive.

Key Findings

The survey contained an open-response question to which 60 respondents shared additional feedback about their experiences. Those responses were analyzed and categorized into one or more of the following themes:

- Training, information, and resources
- Mentors, role models, and networking opportunities; people guiding them through the commercialization process
- Interactions with the Technology Transfer Office
- Lack of time and conflicting priorities
- Funding to conduct research and development
- Discrimination and bias

The following are the key findings from the qualitative and quantitative data around the themes that emerged. The quotes included throughout this document are taken from those responses.

Finding #1

Almost all respondents who participated in technology commercialization efforts were motivated to do so because they wanted to see their research applied in the real world. Other key drivers included compliance with university policies, the search for additional resources for research and development, and potential connections to outside collaborators and industry.

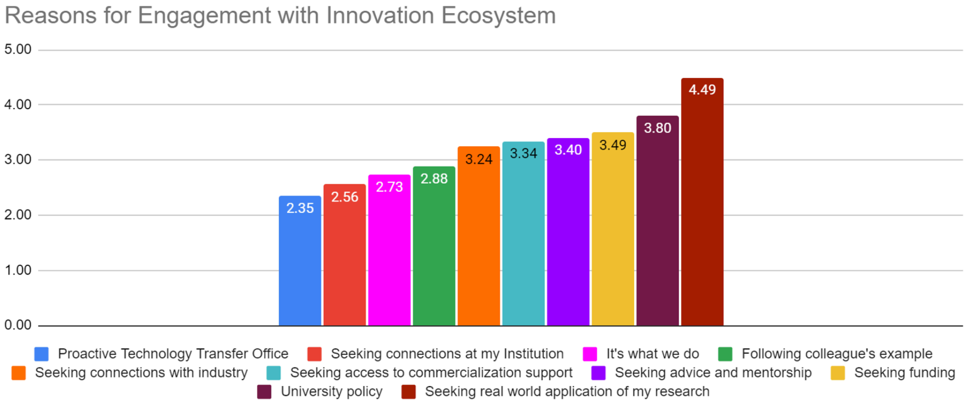

Figure 1. Responses to multiple choice question in survey asking participants why they chose to engage with their innovation ecosystem.

> "Getting a technology out into the world to save lives is really really rewarding."

A key component to engaging more women in the inventive process is to understand the motivations of women who have elected to participate. The survey explored this by asking participants to score (from 1 (least important) to 5 (most important)) the importance of a prescribed set of eleven reasons as to why they engaged with their university's innovation ecosystem (by disclosing their invention, taking an entrepreneurship class, etc.). Their responses provide keen insights into developing more effective outreach efforts.

The primary reason respondents engaged was their desire to see their research applied in the real world (Figure 1). This is consistent with research that suggests women are intrinsically more altruistic than their male counterparts (11).

A significant majority rated following university policies obligating them to disclose was an important factor. This correlates with research that demonstrates women have a significantly higher tendency than their male counterparts to follow the rules (12). It is also worth noting that any potentially patentable research discovery generated from federal funding requires disclosure per the terms of the funding agency.

Over half of the participants indicated they were motivated to participate to explore additional resources for research and development funding. Without funding, it is difficult to conduct the research that generates patentable new discoveries. Funding is also typically a consideration in tenure and promotion for both male and female faculty, providing an added incentive to seek it out.

> "Initial funding was the biggest gap then, and it's the biggest gap now."

Respondent comments about difficulties in accessing funding for research and development, patent prosecution, and lack of access to investors were relatively evenly distributed among full professors, assistant professors, postdoctoral associates, and graduate students.

Approximately half of the respondents were motivated to participate to find industry connections and potential outside collaborators.

Less than half of the respondents participated because someone encouraged them or because they were following the advice or example of colleagues. The ranking of importance on this question could be construed in several ways. One could interpret this as simply not an important factor motivating respondents to participate. Alternatively, it could be interpreted that they didn't have the benefit of a mentor encouraging them. Because many of the open response questions referenced the desire for and importance of mentors, the latter is arguably the more likely interpretation.

Similarly, proactive outreach by the TTO was not seen as a motivating factor. It is unclear if this was not relevant to their decision to engage, if it didn't happen, or if they simply weren't aware of outreach. The question also did not differentiate between outreach by the TTO directly to the female faculty or outreach regarding educational programs being offered to all faculty.

The remaining choices that did not seem to be important motivators included university culture supporting innovation and connections to collaborators and expertise within their institution.

It is worth noting that the all-female task force, although well-informed about royalty streams from licensed inventions and the value of equity in startups, inadvertently did not include personal monetary benefits as a reason to engage on this survey question. Therefore, we cannot conclude whether the potential for monetary benefits was a motivation for respondents to participate. During the review process, it was a male colleague who brought this to light.

Factors mentioned in the open response questions that were a deterrent to participation in innovation included time constraints and conflicting priorities.

> "Time is the biggest issue holding me back. This is especially true as I try to combine this with getting tenure and having/raising kids (oh, and now a pandemic)."

Responsibilities such as teaching, administration, publications, and the need to successfully attain grant funding to get tenure and promotion take priority over commercialization activities. These constraints exist for male and female academics but are more pronounced for women because of their typically larger proportion of time spent on household responsibilities. Assistant professors (44%) and postdoctoral associates and graduate students collectively (38%) represented the majority of comments related to time, motivation, and conflicting priorities.

Finding #2

Approximately two-thirds of respondents were aware of technology commercialization training programs at their institution, and three-quarters of those who were aware participated. Slightly fewer were aware of entrepreneurship training at their institutions; however, considerably fewer (only approximately half) of those aware participated. Respondents who participated in both types of training programs considered the training to be helpful.

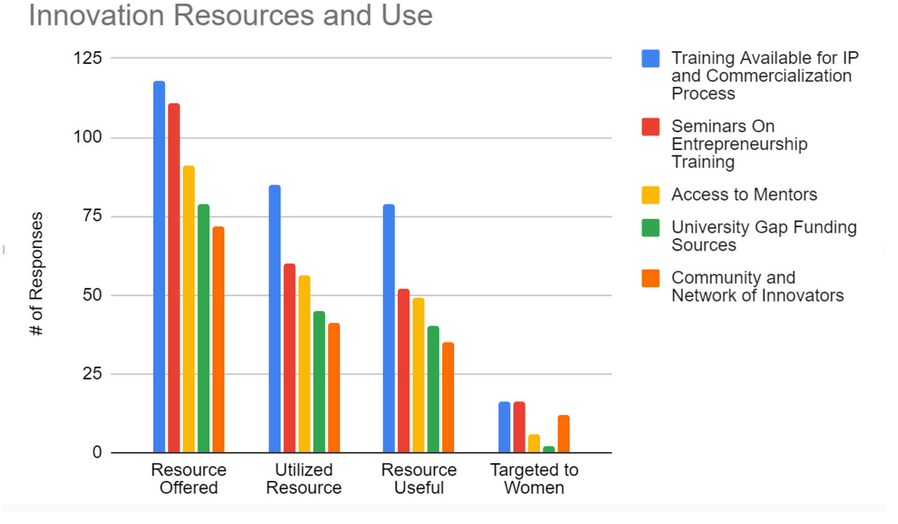

Figure 2. Survey results depicting the knowledge and use of resources typically offered by commercialization offices at institutions.

> "I think learning about the commercialization process as a graduate student demystified it for me early on and enabled me to file additional IP, acquire more licenses, and found a company later."

> "The various trainings that I have attended have been invaluable, but again, I think that somehow these need to "reach" more faculty, grad students, and postdocs, particularly women who might not see themselves as entrepreneurs or innovators."

Collectively, the most frequently referenced topic in the open response questions was the need for training on commercialization, intellectual property, and entrepreneurship-related topics. These comments were cited most often by those early in their academic careers at the assistant professor level (26%), followed by postdoctoral associates and graduate students, collectively, at (42%).

Specifically, a key barrier to respondents' participation in innovation was their lack of knowledge of intellectual property and the commercialization process. Associate professors and staff scientists made the most comments related to intellectual property policies (33% from each for a total of 66%), followed by assistant professors and post-doctoral associates at 17% each.

It is important to note that all survey respondents had been involved with innovation, invention, or entrepreneurship within their respective institutions. It is reasonable to assume, therefore, that they are more aware than other female faculty members of the technology commercialization and entrepreneurship training programs available to them and have a greater incentive to participate (Figure 2). Therefore, it was no surprise to the task force that 70% (118) of respondents were aware of training on technology commercialization and that 50% (85) participated in that training. Similarly, 66% (111) were aware of entrepreneurial training; however, only 36% (60) participated in that training.

It is interesting that fewer respondents were aware of or participated in entrepreneurial training programs. This could be due to the lack of entrepreneurial training programs being offered by their institutions, the lack of awareness of such training programs, or the unconscious biases held by women wherein they don't typically self-associate as entrepreneurs and therefore disregard these programs as training not intended for them. Women tend to be more risk averse than their male colleagues, and entrepreneurial activities are seen as a high-risk activity (18).

Another possible explanation is that women were participating in technology commercialization activities at their institutions for the altruistic motivation of seeing their research applied to help people. Conversely, among academics, participating in entrepreneurial endeavors has historically been seen as "going to the dark side" or "selling your soul" (19).

> "I think building a dedicated career stream for basic science academics to venture into the innovation and commercialization space would be great."

Those who had received some level of training believed it was very helpful and frequently credited it for much of their success. The National Science Foundation's (NSF) Innovation Corps (I-Corps) training was referenced multiple times and was considered extremely beneficial as were several programs targeted specifically at women in innovation (20).

Finding #3

Academics look to their TTOs for training on technology commercialization.

> "I don't really know a lot about what resources are available or how to access them"
>
> "My institution doesn't advertise these programs very well if they exist."
>
> "Even if resources are available, they are hard to find. Also, even if you find them, it is hard to attend them as a full-time faculty."

Again, since the participants surveyed had all been involved with innovation, invention, or entrepreneurship within their respective institutions, it is reasonable to assume they would have a much greater awareness than most female faculty of their TTO and the training programs and resources offered. For this reason, it is not surprising that the majority of respondents would look to the TTO to provide that training.

However, there were numerous comments made by respondents who were not aware of training programs at their institutions (if they existed) or how to find resources to help them through the process, demonstrating a need for better outreach and potentially more resources.

Finding #4

The majority of respondents felt they had a reasonably good understanding of the commercialization process.

More than half (57.8%) of the survey respondents indicated that they had a good understanding of the commercialization process because of access to resources and training provided by their institution. This is in direct contrast to findings from the 2021 *Tackling the Gender and Racial Patenting Gap to Drive Innovation* report (5) by the IWPR, which stated:

- Women reported not understanding what constituted an invention.
- Women reported a lack knowledge about where to go for information on patenting.
- Women said they were often confused about the basics of the patenting process.

A possible explanation for the difference in these findings is that the criteria for participating in the WISIG survey was to be an academic woman with some level of involvement in innovation, invention, or entrepreneurship. Therefore, with involvement comes knowledge of the process. Additionally, since, 60% of participants were at various levels of professorship, the majority of respondents were well-established in their career path, making it more likely that they had above average participation in the commercialization process and thus above average understanding of it.

From our follow-up discussions, many women reported an initial inability to find the knowledge and support they needed and, therefore, had to self-educate at the start of their innovation journies. This finding reinforced our earlier assumption that experience resulted in expanded knowledge of the process and emphasizes the importance of early exposure and experience for female innovators.

Finding #5

Fewer than 10% of respondents were aware of any training, mentoring programs, or other resources specifically targeted at assisting women in the commercialization process.

> "Looking back, our advisor/partner at the university Innovations office is a woman supporting our all-woman entrepreneur team. I think our shared gender, and her confidence in our ability to try a LOT of new things, has been central to our moving forward with trademarking, launching our business, getting good industry advice, etc."

Fewer than 10% of respondents were aware of training programs or resources geared specifically for assisting female academics with technology commercialization activities. Programs and resources designed for women foster greater participation by providing a more welcoming and inclusive environment and are not hampered by the gender specific socio-dynamics that typically take place in mixed-gender environments. Examples include men typically leading a group, while women typically assume the role of note taker or secretary.

The most frequently cited topics that would be helpful with respondents' innovation endeavors were related to training and mentoring, with a few comments that specifically referenced gender-specific training. Numerous comments were made about the desire for a female mentor.

Finding #6

Mentorship was referenced repeatedly in the open-response questions as something respondents wished they had access to and felt would be helpful in engaging in commercialization activities.

Mentorship was the second most frequently

> "The availability of mentors, I believe, was the most meaningful thing (colleges, institutes, and start-ups) have done to help."
>
> "A member of our faculty was my mentor and that example was key."
>
> "It was helpful to have a woman as a mentor or in the meeting as often, I am the only woman with older white males except the assistant."

referenced topic in the open-response questions. The majority of assistant professors, postdoctoral associates, and graduate students mentioned mentorship (53%) followed by full professors (23%). Respondents expressed significant interest in mentors and role models with a subset of respondents specifically interested in those of the same gender and ethnicity. Those respondents who had been fortunate enough to have mentors reported that their mentors were invaluable in encouraging them and helping them in their innovation journies and often credited mentors as key to their success.

There were numerous references made about the lack of representation of women in the innovation ecosystem not only as mentors but as the people performing the training and those tasked with assisting faculty through the invention disclosure and patenting process.

Finding #7

Experiences with their TTOs were mixed. Some viewed the TTO as very helpful, while others felt a lack of assistance or, in a few cases, discriminated against.

The TTO is the designated office within an institution tasked with reviewing invention disclosures submitted by researchers. The staff of the TTO have finite budgets and are tasked with making decisions about which invention disclosures to submit for patenting. Based on AUTM statistics, historically, approximately 50% to 60% of invention disclosures submitted at academic institutions are put forward for patenting. When a patent application is rejected or claims are denied, the TTO staff further decides whether or not to continue to pursue the patent or fight for those claims. Additionally, the TTO staff decides which of the patents that do get issued will be maintained by paying the maintenance fees throughout the life of the patent.

Comments made by survey respondents about their TTOs were evenly split as to the helpfulness of the TTO staff. Approximately half of the comments were made about the "exceptional" assistance respondents received from the TTO staff. Many stated that without the TTO's assistance they would not have been able to navigate the process. It is worth noting that respondents who commented positively about the assistance they received from the TTO frequently mentioned that person was a woman.

> "I would never have taken any of these steps without their (TTO) help. The person assigned was amazing. It did make a difference that she is a woman."

The other half of the comments indicated they felt their TTOs were less than helpful, and some went so far as to say they felt the TTO "undermined" their efforts. Specific comments were made about the lack of diversity in the TTO and the office's proclivity to work with established faculty who tended to be Caucasian males rather than ensuring that all inventors are included and heard regardless of their positions. Other comments stated that frequent turnover at the TTO was frustrating and created more work bringing the new TTO officer up to speed.

> "When disclosures are filed, the TTO considers male-filed disclosures more seriously than mine."

Comments related to concerns about discrimination, gender bias, racial bias, or combinations thereof during the innovation and patenting process were mostly from assistant professors (29%) and then distributed evenly among all other academic levels.

Most Frequently Cited Barriers to Participation

Barriers to participation were referenced throughout the survey responses and during the follow-up interviews. The following are the most frequently cited barriers to participation from the qualitative and quantitative data.

Funding

Funding is a challenge for both male and female academics; however, it appears particularly daunting for women. An analysis of National Institutes of Health (NIH) funding over a ten-year period found female applicants across all grant types apply for fewer grants, ask for less money, and received an average of $40,000 less on first-time research awards compared to their male counterparts (13). It also found that female submission rates were significantly lower at the entry-level faculty rank. Women's average academic rank also emerged as a critical issue in unequal access to grant funding.

Across all Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) programs, which provide federal funding for early stage, high-risk research and development, the proportion of Phase I applications and awards to women-owned small businesses has remained consistent from 2011 to 2018, hovering between 13% to 15% (14). Awards were consistent with the number of proposals submitted by women-owned small businesses. Further analysis needs to be done to understand why women apply for such a small percentage of these awards.

Total venture funding invested into women-led startups has actually declined from 2.8% in 2019 to 2.3% in 2020 (10). This is despite the fact that the number of women-owned firms has grown at five times the national average, with 1,072 new women-owned firms starting every day (15). The dominance of men (95%) in the venture capital industry and the findings that male entrepreneurs are 60% more likely to be awarded venture funding than female entrepreneurs make funding for female entrepreneurs a major challenge (16).

Time Constraints

Time constraints exist for male and female academics but tend to be more pronounced for women. Women spend an average of 5.7 hours on daily household and family care work compared to their male counterparts, who average 3.6 hours. As a result, they have little time for what is seen as extra-curricular activity, including participation in invention and commercialization activities (17) . These differences have been exacerbated even further by the COVID-19 pandemic.

Lack of Knowledge

A key barrier to respondents' participation in innovation was their lack of knowledge of intellectual property and the commercialization process. The most frequently referenced topic in the open response questions was the need for training on commercialization, intellectual property, and entrepreneurship-related topics. While such training programs continue to increase in popularity, they are often not marketed in a manner that effectively engages female academics or are not offered at a time and place conducive to their participation. Many survey respondents have subsequently garnered that knowledge as a result of their participation in invention and commercialization and therefore have an above average knowledge of such programs.

Discrimination and Gender Bias

Most references to discrimination in the survey open response questions revolved around interactions during the invention disclosure and patenting processes with male scientific colleagues, patent attorneys, and TTO staff. Respondents felt there was a very clear propensity for TTOs to work with established faculty, who were most frequently Caucasian males. They frequently cited being left out of the discussions about patenting and licensing decisions. Furthermore, if they were the sole inventor, they were often not given the same level of consideration as their male counterparts. Follow-up interviews emphasized this feeling of bias and also a higher level of satisfaction when respondents worked with female TTO staff.

Recommendations

There are many important initiatives geared at the longer-term pipeline challenge of diversity in science, technology, engineering, and math (STEM) education and initiatives to assist women already involved in business. There are far fewer initiatives focused on engaging the current STEM-educated female workforce, many of whom work in academic

> "Training is key. Scientists are not trained in how to protect their work. I was lucky that my institution provided the support for doing it."

institutions, to foster their participation in innovation and entrepreneurship. U.S. innovators tend to be experienced and highly educated and most hold advanced degrees in the fields of science and technology. Focusing efforts to engage STEM-educated women, who have an above average ability to contribute to the innovation ecosystem, has significant potential for both short-term and long-term impact.

Based on the quantitative and qualitative data obtained from 168 female academic survey respondents, and the decades of collective technology transfer experience of the group, the WISIG recommends to policy makers and organizations that support technology transfer the following actions to increase the engagement of academic women in all stages of the innovation lifecycle.

1. The technology commercialization pathway is viewed as complex and daunting. There are programs that exist across the country to specifically engage female innovators in the process. Unfortunately, most of these programs are available only in the specific institutions where they were created and championed. Identifying the most successful of these programs and creating turnkey templates to scale them on a national level would increase their accessibility and their impact.

Training was the most frequently mentioned topic in all the open response questions and cited as one of the most important things universities can do to assist faculty in the innovation journey. A subset of those responses commented on the male-centric nature of the training they attended and referenced the need for female-inclusive training. It is important to develop programs specific to women, as they face unique barriers and challenges and do not typically participate in generalized commercialization training at the same rate as their male colleagues. Female-specific training has met with resistance at some academic institutions. Male-dominated academic administrators understand the need for training on the inventive process but often fail to recognize the gender-specific hurdles facing women in innovation. For example, research has found that venture capitalists prefer pitches by men, even when the same content is delivered by men and women (21). Similarly, investors have been found to ask male investors and female investors different and gender-biased questions. Training on investor presentation techniques is common in entrepreneurial training programs offered to faculty. Female-specific training provides additional knowledge about the biases held by venture capitalists and provides participants with techniques for overcoming those biases to increase their likelihood of garnering funding. Similarly, other gender-specific training topics should focus on recognizing challenges encountered by women innovators and provide techniques for addressing them.

Another reason for apprehension about female-specific training is the concern about whether federal laws make it illegal for a training program to discriminate based on gender. These concerns have been overcome at dozens of institutions by ensuring similar training is available for all academics so that participants can opt in for the generalized training or for the more female-centric training.

The IWPR conducted research in 2018 identifying 55 programs nationally that had some component of fostering greater engagement of women in innovation (4). They reviewed these programs to identify those that met the following criteria:

- Being actively focused on addressing the gender gap in patenting and/or innovation among U.S. adults
- Being in operation at the time of study
- Having received recognition from others as doing something innovative or exemplary to address the gender gap in patenting and innovation
- Having data on the program's outcomes or a way to measure or assess its impact (desired, not required)
- Having been in existence for more than a year (desired, not required)

The IWPR then did in-depth analysis of seven programs representing a range of instructional models that met the above-referenced criteria (Figure 3). A common theme across these programs was limited funding and the lack of sufficient staffing. Because of

Programs Fostering Greater Engagement of Women in Innovation	Location
Accelerating Women and under-Represented Entrepreneurs (AWARE)	University of Illinois Urbana-Champaign
Bioscience & Entrepreneurship Inclusion Initiative	BioSTL, St. Louis, Missouri
*Empowering Women in Technology Startups (Ewits©)	University of Florida
MyStartupXX	University of California San Diego
REACH for Commercialization™	Ohio State University
SBIR/STTR Phase 0 Assistance Program	U.S. Department of Energy
*STEM to Market	Association of Women in Science, Washington, D.C.; Chicago, IL; and the San Francisco Bay Area, CA
***Programs no longer offered.**	

Figure 3. Seven programs analyzed by the IWPR.

these limitations, the programs existed only within the institutions where they were created or within confined geographies and were unable to scale for broader impact. Two of the seven proven successful programs are no longer being offered due to lack of institutional support.

Rather than having individual institutions struggle to identify mechanisms to engage more women in their innovation ecosystems, it would be far more prudent to leverage existing female-centric programs that have proven track records. This could be done by working with established programs to develop turnkey templates that could be customized and implemented by interested institutions across the country. An alternative approach could be to provide already established programs, such as those referenced above, with the funding required to enable them to scale on a national level. Both options would provide institutions that are interested in engaging more women in their innovation ecosystems with the knowledge and tools necessary to do so. Allocating seed funding for program implementation would incentivize institutions and increase the dissemination of these impactful programs. Following the example of the NSF Advance program, requiring institutions receiving grants to commit to long-term support of the program would ensure program longevity.

2. Even though many commercialization resources and training programs exist, there appears to be a lack of general awareness of these programs among female academics. Identifying "best practices" for outreach to these populations and making the outreach methodologies readily available to TTOs and other organizations offering training would ensure greater engagement in their programs.

Even though 66% of respondents were aware of technology commercialization and entrepreneurship training programs, numerous comments were made about the difficulty participants had in finding and accessing the training. This lack of awareness is due in part to how these programs are marketed. Descriptions of the programs often use terminology that is unfamiliar and unappealing to faculty, especially female faculty. Therefore, they don't see the training as being directed at them. A number of the survey respondents learned about the training by word of mouth from a colleague or their TTO—not from a written correspondence.

> "I'm not sure I felt a lot of the continuing education or opportunities offered have totally thrilled me, and I wonder if it is that similar language barrier. They seem very heavy on the business language and light on the social justice responsibility and helping the world, which is a strong motivator to me and I suspect other women in academia."

One respondent, who was very complimentary of the I-Corps training she received, shared that even after having participated in I-Corps and now having founded a company, she reads the correspondence advertising the training programs and workshops and still doesn't participate because she feels like she can't relate to it.

In addition to the terminology used in the outreach, the logistics of when and where these programs are offered often make it difficult for academic women to participate. Challenging logistics (for men and women) include locations off campus, time slots that conflict with other responsibilities, and the length of the programs. Based on comments made, women prefer shorter sessions that are spread out over time rather than lengthy intensive training.

The seven programs identified in Figure 3 are specifically directed at getting more women engaged in innovation and have proven best practices for outreach and logistics. These practices should be researched, documented, and widely distributed to organizations offering related training to increase participation.

Additionally, future surveys would be useful to elucidate the reason behind the lack of participation and to help TTOs craft outreach and engagement strategies that result in increased participation.

3. There is significant interest in role models and mentors and some specific interest in those of the same gender and ethnicity. We recommend establishing a virtual national mentoring network to assist women in all phases of the innovation journey. Alternatively, identify programs that have incorporated a strong mentorship component and develop methodologies to replicate and/or scale those programs.

Mentors are seen as an extremely important component to the success of individuals in all facets of life, and the same is true for innovation and entrepreneurship. Because of the larger share of household and family responsibilities held by women, they tend to have less time for networking and in turn less exposure and access to mentors. This is further exacerbated by the fact that women are under-represented in innovation and entrepreneurship. Those actively participating are already stretched to find sufficient time to fulfill all their obligations.

> "The availability of mentors, I believe, was the most meaningful thing (colleges, institutes, and start-ups) have done to help."
>
> "People performing training are mostly male."

Many of the survey respondents credited their mentors as key to their engagement in innovation, and oftentimes the key to their success. Those who did not have the good fortune of having a mentor frequently referenced how helpful it would have been to have someone guide them through the process.

A number of comments were made about the lack of diversity among mentors and instructors in the various training programs. The lack of female role models in innovation tends to reinforce the concept that it is not something for women. It is also more difficult for the male mentors to relate to the many "quiet burdens" that can impede women's ability to fully participate in the training exercises. However, many women said having a mentor was very important regardless of whether they matched in demographics.

Consideration should be given to establishing a virtual national mentoring network aimed at engaging women in all phases of the innovation journey. Mentoring software platforms exist that enable mentees to identify a mentor on a given topic of interest and easily facilitate that engagement. The platform should have the ability to qualify mentors (both men and women) as knowledgeable on their selected topics and provide them with training on how to be a mentor. Efforts should also be made to engage the USPTO to encourage its 8,000-plus patent examiners and outreach educators to serve as mentors on this national platform. As an incentive, the platform should also offer a credential once that person is approved as a mentor. Having a national platform would also provide mentees with the ability to identify mentors with expertise who might not be readily available within their communities.

The platform could also provide resources and training on topics most useful to someone involved in invention, innovation, and entrepreneurship. Once created, the program should be widely publicized using terminology that would motivate women to participate both as mentors and as mentees. Outreach should also be directed at creating awareness throughout the technology transfer community.

Alternatively, research should be conducted at institutions with successful mentoring programs focused on innovation and entrepreneurship with special emphasis on engaging underserved populations. Consideration should then be given to doing one or more of the following:

- Identify best practices and disseminate this information to assist others in developing programs at their institutions.
- Work with one or more of these successful programs to develop a template for replicating the program.
- Work with one or more successful programs to scale them on a national level.

Providing access to mentors will be a key driver to fostering greater participation of women in all phases of the innovation lifecycle. It also has the potential to help institutions increase their retention of female academics, who have a greater propensity to leave academia than their male colleagues.

4. Tools, resources, and funding designed specifically to assist female academics are starting to become more readily available. There is currently proposed legislation that will make billions of dollars available to support research and development activities of under-represented populations. Outreach efforts should be increased to garner awareness among female faculty of these opportunities, and careful consideration should be given to the approach and the terminology utilized in the outreach.

There were numerous comments made about the terminology used to advertise training programs and in actual training for technology commercialization and entrepreneurship. This terminology affects both the level of participation and the impact of the training. Focusing outreach messages on previously identified motivators for female engagement in innovation will yield greater participation. Delivering training in a manner that helps women understand the connection between their participation in innovation and the ability to ensure their discoveries can have societal impact will promote ongoing engagement. Terminology focusing on profits and monetary rewards has historically been an anathema to academics, particularly to female academics.

> "The experiences we gained and challenges we encountered implementing this technology GREATLY enhanced my academic research and still do."

Rather than relying solely on general faculty communication channels, outreach efforts should identify organizations or groups within the university settings that are focused on the advancement of women. Meeting women where they are, and educating them on how their involvement in innovation can help them in countless ways throughout their careers, will produce better results. Additionally, sharing stories about successful women innovators and the societal impact of their discoveries can provide important role models that enable women to envision themselves in that role.

The USPTO currently has five regional offices across the country whose primary role is stakeholder engagement in the patent system. These offices should identify opportunities to work more closely with university TTOs in their regions to engage academic women and provide education about intellectual property and the resources available to assist them throughout the process.

5. Even though half of the doctorates (23) in the U.S. are earned by women and the largest employers (24) of women with doctorates in science, engineering and health are academic institutions, only 34% of all full professors are women (25). To ensure institutions of higher education have strategies in place to discourage discriminatory behavior, federal funding agencies should require evidence of a documented institutional diversity and inclusion (D&I) plan as a weighted criteria on all federal grant applications.

Women represent just over half (52.9%) of assistant professors and are near parity (46.4%) among associate professors, but they accounted for just over a third (34.3%) of professors in 2018 (25). Key achievements for tenure and promotion in academia are funding and publications. Studies show that among early career biomedical researchers, junior faculty women received significantly less start-up support from their institutions than men regardless of degree discipline (26). This, combined with the NIH disparities in funding referenced earlier, puts women at a fiscal disadvantage from the onset of their careers, limiting their ability to build a research program and enabling them to advance (13).

All federally-funded grant applications should include a weighted criterion based on evidence of a D&I plan at the applicant's institution. If federally funded institutions are required to show evidence of a plan as a pre-requisite to funding, it will become much more of a priority for those institutions and in turn for their faculty. Metric reporting requirements in the plan will ensure ongoing attention to it. This effort will also serve as a catalyst for conversation around the topics of diversity and inclusion amongst senior administration and faculty.

This type of action-oriented D&I plan can also be done to recruit and retain faculty. For example, The University of Michigan required all applicants applying for chair and dean positions to include an outline of how they would ensure their faculty was diverse and inclusive. Making that part of the process had a huge impact on raising awareness and thus fostering greater diversity among their faculty ranks.

6. TTOs are uniquely positioned in the innovation ecosystem to play a pivotal role in augmenting change that can help make technology commercialization and entrepreneurial activities more inclusive. TTOs should do the following:

a. Commit to tracking and reporting gender metrics on the AUTM survey

Data on participation rates by women in innovation are limited. Much of what has been reported used name recognition software. TTOs are uniquely positioned to capture and report this data without violating the law. AUTM tracks the gender of people submitting invention disclosures and filing patent applications in their annual Licensing Activity Survey. Unfortunately, this is an optional metric to report, and the majority of institutions that participate in the survey do not track or report this data consistently. Tracking these metrics is important to monitor progress. To further incentivize offices to track and report this data, AUTM should work with the USPTO and other offices engaged in intellectual property protection to create a recognition program for TTOs that report these metrics. An equivalent recognition program could also be created for industry.

b. Implement Gender Intelligence training for all TTO staff

The role of the TTO was referenced frequently by survey respondents as both a key to success as well as a barrier to their participation. A number of studies have offered explanations for the gender gap in academic patenting and licensing that are outside the control of technology licensing professionals. There is also research that indicates technology transfer professionals tend to favor invention disclosures from male faculty (27) members over female faculty inventors (5). In the present survey, some respondents shared having similar experiences.

Technology transfer officers influence which inventions are patented, licensed, and commercialized. Therefore, they play a gatekeeping role to technology commercialization for innovators at their institutions. Like all humans, these people subconsciously hold opinions based on upbringing and culture known as implicit or unconscious biases. There are many interesting studies that have addressed this including the Implicit Association Test developed at Harvard that showed academics of both sexes subconsciously associate science with masculine traits (28). While most people reject the notion that they are biased and would not consciously discriminate against anyone, the data from numerous studies suggests that because of our unconscious biases, we do in fact treat men and women differently.

Unfortunately, unconscious bias training alone has been found to be mostly ineffective at changing attitudes and, in many cases, only serves to reinforce those biases (29). However, implementing Gender Intelligence Training at TTOs would help TTO staff to understand, recognize, and value the differences between men and women and to identify how those differences are manifested in the innovation ecosystem (30). Having the tools to identify negative stereotypes and strategies to positively overcome them would ensure all faculty (men and women) are being given an equal opportunity to engage in innovation, invention, and entrepreneurship.

c. Adapt training programs and outreach to be more inclusive

TTOs are viewed as the primary source of training on technology commercialization. They should evaluate their programs to ensure:

- The outreach message about the training speaks to all faculty
- Outreach is sent to organizations whose members include under-represented populations in innovation
- Those providing the training represent the diversity of the faculty
- The timing and logistics are conducive to participation
- There are a number of programs tailored specifically for women that have demonstrated a high degree of success. TTO's with the resources should consider offering female-focused programs.

d. Create reward and recognition programs that would be given consideration as part of their institutions' faculty tenure and promotion package (Promotion and Tenure-Innovation and Entrepreneurship (PTIE) recommendations)

Lack of time and conflicting priorities were mentioned frequently by respondents as a barrier to participation in innovation, particularly the need to teach, publish, and get funding. These activities are recognized as primary components of a traditional tenure and promotion package. TTO's are encouraged to become familiar with the recommendations put forth by PTIE for recognizing scholarly impacts in less traditional area, such as innovation and entrepreneurship (31). TTO directors are ideally positioned to engage with their administrations in conversations about best practices for inclusively recognizing faculty innovation and entrepreneurial impact through university reward structures.

e. Review standard practices for communicating with faculty and identify mechanisms to ensure greater transparency around the invention disclosure, patenting, and licensing processes for all parties involved

Respondents frequently referenced 1) the lack of information and education on how the commercialization process works and 2) the lack of transparency about decisions that were made throughout their innovation journies. Making educational tools available for novice inventors to help them understand the process and establish realistic expectations enables more people to engage and have a positive experience. Numerous examples of these tools in the form of short videos, informative websites, guidebooks, and virtual training already exist. These tools need to be made available at every TTO. While only a fraction of inventions become products that make an impact, a positive first experience with a TTO makes it more likely for someone to be a return inventor.

With regard to transparency, electronic communications make it easy for TTOs to copy all inventors on communications related to their invention disclosure and patent. This creates good will, enables all inventors to share additional data, helps educate junior faculty on the process, and keeps inventors engaged with the TTO so that they are inclined to submit future disclosures. Engaging with all parties involved in the research also helps to ensure all inventors are included on the intellectual property, reducing the likelihood of future litigation or patent invalidation.

f. AUTM should adopt a D&I Pledge for TTOs

There are many versions of D&I pledges that exist across various disciplines and communities. They all have in common a goal to raise awareness and augment change toward a more diverse and inclusive environment.

As recognized earlier, technology transfer professionals play a gatekeeping role in who participates in academic innovation. Developing a pledge that includes a commitment to a set of standards that ensure inclusive innovation would help to raise awareness in the technology transfer community and provide a common set of practices for ensuring innovation inclusiveness. Because of AUTM's worldwide recognition, this pledge could be impactful around the globe.

7. Federal funding should be allocated to support TTOs and to advance the critically important profession of technology transfer

When the Bayh-Dole Act was implemented in 1980, it required universities to proactively protect and work to commercialize federally- funded research discoveries. Those responsibilities were assigned with limited guidance and with no allocation of funding to enable universities to perform these functions. The act was the genesis of the technology transfer profession and ultimately led to the creation of our professional association, AUTM. Over the past four decades, the profession and the association have evolved and continue to identify opportunities to improve the complex process of shepherding new ideas from the lab to the marketplace.

According to a 2017 report published by the Biotechnology Innovation Organization, these efforts have significantly impacted the American economy. From 1996 to 2017, academic technology transfer contributed:

- $1.7 trillion to U.S. gross industrial output
- $865 Billion to U.S. gross domestic product
- 5.9 million jobs supported
- 480,000+ inventions disclosed
- 117,000+ U.S. patents issued
- 5,000+ startups formed
- 200+ drugs and vaccines developed through public-private partnerships since Bayh-Dole Act was enacted in 1980

This impact could be significantly amplified if TTOs were able to better engage the entire inventive pool of their highly educated faculty and students. Many of the TTOs remain significantly underfunded and have limited patent budgets. We recommend that federal funding be allocated to enable these mostly under-resourced Technology Transfer Offices to implement the recommendations outlined in this paper.

Further consideration should be given to provide funding to AUTM to support TTOs in implementing these recommendations. Since AUTM was recently awarded the contract to operate the Federal Laboratory Consortium, it now has the additional potential to accelerate and transform the outputs of the 300+ federal labs that have historically been awarded similar amounts of research but have had magnitudes less economic impact. AUTM is uniquely positioned to leverage any funding it receives to magnify the outputs of all federal dollars invested in research and development.

Next Steps

The recommendations put forth are a combination of the survey responses and follow-up interviews from 168 academic women with firsthand experiences in innovation and entrepreneurship and the input of WISIG members who collectively have hundreds of years of experience in all aspects of technology transfer. It is our hope that these recommendations will provide valuable insights into concrete actions that can be taken to ensure systemic changes that foster greater engagement of academic women and other under-represented populations in all stages of the innovation lifecycle. Our next steps will be to engage with the policy makers, the technology transfer community, and other synergistic organizations interested in refining and implementing the recommendations set forth.

About WISIG

The WISIG coalesced in 2013 as the AUTM Women Inventors Committee and later transitioned to the AUTM WISIG. While the group acknowledged women were not the only under-represented population, they realized as volunteers with demanding careers:

1. They needed to leverage their core competencies and limited resources where they believed they could have the biggest impact;
2. While the data available on women was limited, even less was available on other under-represented groups;
3. Their efforts could ultimately prove beneficial for all under-represented groups; and
4. More focused efforts toward other groups could be developed over time.

Initially, the WISIG formed subcommittees to focus their efforts in three primary areas: metrics, barriers, and synergistic organizations. The metrics subcommittee was tasked with getting a baseline to assess the current state of female participation in technology commercialization. This would enable the WISIG to both better understand the extent of the problem and to be able to measure progress over time. The barriers subcommittee was tasked with understanding where there were disparities and what the contributing factors were causing those disparities. The synergistic organizations subcommittee was tasked with identifying other organizations that, because of their roles in the innovation lifecycle, were potential collaborators to address the disparities and coalesce around best practices.

Although the membership and the structure of the WISIG have changed over time, the one constant is the passion these volunteers share for their mission to be a catalyst for positive change to increase the participation of women in innovation, invention, and entrepreneurship. Much has been accomplished through their efforts, including:

- Working with the leading software platforms used by TTOs to incorporate the ability to track gender on invention disclosures
- Working with the AUTM Licensing Survey committee to add questions addressing gender and encouraging AUTM members to provide this data
- Developing a tool kit of best practices, tips, strategies, and programs appropriate for TTOs to implement to address greater inclusion in their innovation ecosystems (32)
- Building informal networks of like-minded organizations to share information, cross-promote, and collaborate on a number of awareness and advocacy efforts focused on inclusion and diversity. These efforts include but are not limited to webinars, white papers, and panel presentations at conferences and meetings

As a result of these accomplishments, members of the WISIG are routinely invited to share their knowledge by participating in various working groups and by presenting at meetings and conferences.

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