JANUARY 2020
BxWP2020-01

BORDEAUX ECONOMICS WORKING PAPERS
CAHIERS D'ECONOMIE DE BORDEAUX

Coming from afar and picking a man's job: Women immigrant inventors in the United States

Edoardo FERRUCCI
LUISS Business School
eferrucci@luiss.it

Francesco LISSONI
GREThA, CNRS, UMR 5113, Université de Bordeaux
ernest.miguelez@u-bordeaux.fr

Ernest MIGUELEZ
GREThA, CNRS, UMR 5113, Université de Bordeaux
ernest.miguelez@u-bordeaux.fr

GREThA UMR CNRS 5113
Université de Bordeaux
Avenue Léon Duguit
33608 Pessac – France
Tel : +33 (0)5.56.84.25.75
http://gretha.u-bordeaux.fr/

LAREFI
Université de Bordeaux
Avenue Léon Duguit
33608 Pessac – France
Tel : +33 (0)5.56.84.25.37
http://larefi.u-bordeaux.fr/

Abstract

Based on an original dataset spanning over 20 years of patenting at the United States Patent & Trademark Office (USPTO), we identify the gender, residence, and nationality of inventors, based on which we also identify migrants and natives in the United States, as well as stayers (non-migrants) in the migrants' countries of origin. We find that the share of women over the total number of US-resident inventors (or WIR: *Women Inventor Rate*) is generally higher for migrants than for US natives, so that the former have contributed significantly to the increase of WIR in the US over the past quarter century. At the same time, the WIR for migrants is higher than that of stayers, which suggests that migration to the US represents an opportunity for high-skilled women to undertake a career in R&D, notwithstanding the obstacles they may face, and irrespective of their country of origin. This intuition is reinforced by an analysis of women inventors' technological specialization, which reveals that female migrants are better represented than natives and stayers in men-dominated fields.

Keywords: STEM migrants, High-skilled migrants, Inventors, Gender

JEL: J16, F22, O15, O30

ACKNOWLEDGEMENTS: *The authors acknowledge financial support from the French National Research Agency (TKC project – reference: ANR-17-CE26-0016), as well as the United States Patent and Trademark Office (USPTO).*

To cite this paper: **FERRUCCI Edoardo, LISSONI Francesco, MIGUELEZ Ernest** (2020), Coming from afar and picking a man's job: Women immigrant inventors in the United States, Bordeaux Economics Working Papers, BxWP2020-01.

https://ideas.repec.org/p/grt/bdxewp/2020-01.html

1. Introduction

It was 1938 when Giuliana Cavaglieri, born into a Jewish family of Venice, was denied access to Italian universities, in accordance with the current Racial Laws recently imposed by the fascist regime. Fleeing through Switzerland, she eventually reached the United States, where she took a PhD in Organic Chemistry at Yale University. During a career that spanned over half a century, both as an industrial and an academic researcher, she would eventually file over 125 patents in textile processing and organic compounds, including the first flame-resistant fabrics (Wayne, 2011). A few years later, the Austrian-born Hedwig Eva Maria Kiesler was granted, joint with George Antheil, a patent for a radio communication system that would eventually make it into Bluetooth technology and for which she got an Electronic Frontier Foundation Pioneer Award, in 1997. During her lifetime, she filed other patents in the most disparate fields, while pursuing a brilliant Hollywood career under the name of Hedy Lamarr (Rhodes, 2012).

Filing patents was not a simple accomplishment for women in the 1940s, neither in the United States nor elsewhere; and the same holds true today. But Giuliana Cavaglieri and Hedy Lamarr were not just women inventors, they were migrants, too. Was their migrant status a further obstacle they had overtake in their careers as inventors? Or was it just revealing of their exceptional skills and determination, relative to other women, as per positive self-selection theories of migration (Borjas, 1991)? Would have they pursued the same careers had they remained in their countries of origin, or did their move abroad offer them a unique opportunity? Do their stories still resonate today, when high-skilled women have overtaken men in migratory flows, but they are reportedly more penalized than men by brain waste issues (Özden and Neagu, 2007b)?

We move from these questions to investigate the extent and characteristics of immigrant women's contribution to inventive in the United States, based on a dataset we recently produced for the United States Patent & Trademark Office (USPTO). The US is both the top destination country for migrant scientists and engineers from all over the world, many of whom are women.

According to our data, the female participation to inventive activities has been constantly rising over the past 30 years or so. In particular, the share of women over the total number of US-resident inventors (or WIR: *Women Inventor Rate*), has increased from around 4-5% in the 1980s to over 13% in 2016 (Toole et al., 2019). However, this is still well below the share of jobs held by women in Science, Engineering, Technology & Mathematics (STEM), which Noonan (2017), based on data from the American Community Survey, estimate at 24% in 2015; and it is even more distant from the women's share of STEM college graduates, which stands at 31%. This suggests that, when moving from STEM education to STEM jobs, and in particular to the inventor profession, the gender gap increases significantly, despite following a downward time trend.

On the other hand, the data also shows that the US does better than other patent-intensive economies. In 2016, its WIR was double than that of Japan, and slightly higher than that of Europe as whole, with individual countries such as Germany doing significantly worse (Toole et al., 2019).

Refining and explaining this evidence requires examining jointly the gender issue and the migration issue, for both a methodological and a substantive reason.

From the methodological viewpoint, our data, like many others, identify women inventors by attributing a gender to the inventors' names. For the attribution to be precise, one wishes first to identify each inventor's ethnic background. This is because, for some names, the gender varies with language. "Andrea" provides the typical example, being an Italian masculine name, but a feminine one in most other languages. Many authors simply identify the inventor's ethnicity by means of his/her country or region of residence, as contained in the address reported on the patent document. But for inventors in the US this is less and less a safe guess, due to the extent and continuous increase of STEM migration from all over the world. Recent estimates suggest that one in four inventors with a US address is a foreign national (Miguelez and Fink, 2017). When detecting their gender, and that of all second- or third-generation migrants, it is the country of origin that matters.

From the substantive viewpoint, the links between the gender and the migration perspectives are multiple, and can be organized around two research questions. The first one concerns the *effects of immigration* on women's participation to inventive activities in destination countries, and in particular the US; the second one with the *opportunity* that migration may offer to STEM women to become inventors.

The first question is motivated by a temporal link. The women's participation to inventive activities, as measured by WIR, has grown incessantly since the 1970s, with an acceleration at the end of the 1980s (Toole et al., 2019). The WIR gap between the US and Japan materializes at the same time when we observe the take-off of migrant inventors' activity in the US, both in absolute terms and relative to other countries (Kerr, 2008; Breschi *et al.*, 2017a). This coincidence begs the question of the relationship between the two trends. Did immigration contribute to the rise of women's participation to inventive activities?

Far from being entirely speculative, this question rests on the recent evidence concerning the increasing feminization of international migration, at all skill levels and especially in advanced destination countries such as the US (Dumont et al., 2007; Docquier et al., 2009; see also Arlsan et al., 2016); and with the observation that migration rates for highly skilled women tend to be higher than those of men (Faggian *et al.*, 2007; Docquier *et al.*, 2012).

Its answer depends on the dynamics of WIR by country of origin and social group (migrant vs natives). For the example, the available estimates of WIR for China (today's dominant country of origin of foreign STEM workers in the US) are higher than those for European countries, whose STEM emigration towards the US is no longer as important as it used to be. This suggests that the recent changes in inventors' immigration patterns may have strengthened the participation of women to inventive activities in the US. More generally, this forces us to study the composition effect that changes in the geography of immigration may have had on WIR: which countries of origin have contributed to sustain the rise of women's participation to inventive activities in the US? And which ones, on the contrary, may have hampered it?

The second question moves instead from the recent "brain gain" literature (Beine *et al.*, 2010), according to which a link exists at the individual choice level, between the decision to emigrate and that of getting a STEM degree. The sign of the relationship depends on the extent to which the destination country provides immigrant women with more or less opportunities than their countries of origin to undertake a career in science and technology (in our case, to become inventors). In order to answer this question we must compare the WIR estimates for the migrants' countries of origin to those for the inventors in the US, both migrants and natives.

In the remainder of the paper we first survey the relevant literature on women's patenting (section 2). We then present our dataset, with special emphasis on additions to the original data we produced for the USPTO (section 3), followed by our evidence on both the aggregate effects of immigration and the hypothesis of emigration as an opportunity (section 4). Section 5 concludes.

2. Literature review

In what follows, we examine two strands of literature. First, we summarize the methodological literature for the analysis of trends and cross-country differences in women's participation to inventive activities, which is based on large patent datasets and name analysis. We stress the importance, for methodological reasons, to integrate the gender analysis of inventors with the analysis of their migrant versus native status. Second, we focus on studies on the extent and sources of gender bias in patenting.

2.1 Women’s patenting: measurement issues and international evidence

In recent years, the number of large-scale gender studies of inventive activities and patenting has multiplied. The vast majority of such studies attribute a gender to inventors by classifying their names as either masculine or feminine. Most of them, however, do not consider the inventors’ migrant or native status, like we do, which limit the extent of their analysis and, in particular, it prevents them from calculating the migrants’ WIR in any meaningful way. In most cases, they also use non-disambiguated inventor data, which prevent them from accurately calculating the inventors’ individual productivity (number of patents per inventor), conditional on their gender and migrant status.[1]

Naldi et al. (2004) collected 8,291 different names from different sources such as dictionaries, calendars, books and internet sites, and phone books, which compared to around 100,000 names of inventors with addresses in six European countries, and appearing in published European Patent Office (EPO) patents in 1998. Their match effort was successful in 97.2% of the cases. Based on their name database, Frietsch et al. (2009) extended the analysis to all EPO patents up to 2005, for 14 countries. They calculate the participation of women to inventive activities on the basis of “fractional counts” of patents due to female inventors and co-inventors.[2] Spain and France turn out on top of the ranking (12.3% and 10.2% of fractional counts, respectively), with Germany and Austria at the bottom. The US is in the upper-side of the ranking, with 8.3% factional count in 2003-2005. Differences across technology fields appear to be remarkable (ranging from the 21% of Pharmaceuticals to the 1.8% of Machine-tools), which suggests that composition effects may explain, at least in part, the observed country differences.

More recently, Sugimoto et al. (2015) have performed a similar analysis for USPTO patents (1976-2013). According to their estimates, women account for 8% of worldwide patent fractional counts for the whole period, up to 10.8% for 2013, with important variations across technology fields, as well as between academic and business patents (the former showing more women’s participation; see also Delgado and Murray, 2019).

Finally, Martinez et al. (2016) have compiled an extensive “worldwide gender-name dictionary” (WGND), which contains over 6 million names from 182 different countries, based on Social Security registers and National Statistical Offices of various countries, Wikipedia lists, and even manual checks by officials from the World Intellectual Property Organization (WIPO). Based on this, they attribute gender to all the inventors appearing on patent applications filed through the Patent Cooperation Treaty (PCT), all over the world (Miguelez and Fink, 2017). They find that, over time, the worldwide WIR has increased from 9.5% in 1995 to around 15% in 2015, which is more than what estimated by the rest of the literature. For the period 2011-2015, several East Asian countries exhibit values over 20%, while Austria and Germany stand at the opposite end, with 7-9%, with the United States in between (14%).[3]

As for our own report to the USPTO (Toole et al., 2019), we provide some details in section 3.

2.2 Gender bias in patenting versus self-selection of migrants

Despite its growth over time, the share of women inventors – in the United States as elsewhere - remains lower than that of STEM workers (including academics), which in turn is lower than that of STEM graduates. This is due to a combination of factors that we can summarize as follows:

[1] Inventor disambiguation consists in assigning to each inventor a unique identifier, by deciding whether two homonyms (or any pair of inventors with different, but similar names) are the same person or not. In the absence of disambiguation, and conditional on male inventors being more prolific than female ones, any estimate of WIR will be affected by negative bias (prolific men will be counted many times as different inventors). Hence, alternative measures must be used. Knowing the native versus migrant status (and the country of origin) of inventors may both help the disambiguation process and improve the precision of gender attribution (see below in section 3). Alternative approaches to name analysis for gender attribution include matching inventors’ records with Social Security or Tax registers (Jung and Ejermo, 2014; Bell et al., 2018) and questionnaire surveying (Hoisl and Mariani, 2016; Walsh and Nagaoka, 2009). The former are always limited to inventors residing in the same country, with no international comparisons; the latter may return more or less WIR estimates, depending on the sampling scheme.

[2] Given a patent p with n≥1 inventors, its fractional count is $1/n$. When splitting the n inventors between men and women ($n_w+n_m=n$), the women’s share will be $1/n_w$. For P patents in the dataset, the women’s overall share will be $s_w = \sum_1^P 1/n_{w,p}$.

[3] Another large-scale study that claims to make use of disambiguated data is UKIPO (2019), which is based on the Worldwide Patent Statistical Database (PatStat), produced by the European Patent Office. At a close look, however, it appears that the authors make use of the inventor identifiers as found in the raw data, which are unique for inventors with multiple addresses.

- *Specialization*: When it comes to STEM education, women are more likely to hold degrees and jobs in the life sciences, for which the propensity to patent is lower than in the engineering disciplines; within the latter, women are especially under-represented in the most patent-intensive ones, such as electric and electronical engineering. In addition, when getting a STEM-related job, women are less likely to be employed in development or design activities, where the propensity to patent is the highest (Etzkowitz and Ranga, 2011; Hunt *et al.*, 2013).
- *Attrition*: The share of STEM students that get lost at every educational transition (from secondary to tertiary and from graduate to postgraduate) is higher than that of men; and the same applies to career transitions, from subordinate to superior positions. This loss, often described as resulting from 'leaks' in the 'pipeline' connecting education to the research profession, generates an increasing under-representation of women the higher the positions in academic and industrial research one considers (EU, 2019; NSF, 2019).[4]
- *Access to commercialization opportunities*: Women researchers are more likely than men to be employed in academia than industry, which by itself explains their lower propensity to seek or obtain patent protection for their inventions (the patent/R&D ratio of business firms being generally higher than that of universities). But even within academia, female scientists patent less than men with the same publication records (Breschi *et al.*, 2005; Azoulay *et al.*, 2007; Whittington and Smith-Doerr, 2008). This may be explained by women having fewer connections to operators in the marketplace than men, which diminishes their opportunities to commercialize their research results or to cash in their reputation through consultancy or participation in high-tech companies (Ding *et al.*, 2006; Murray and Graham, 2007). Analysis of patent-publication pairs by Lissoni et al. (2013, 2020) also suggests that, facing fewer chances of a research career in industry or opportunities to commercialize their inventions, women scientists may be more reluctant than men to stand for their intellectual property rights (they are more likely not to appear as co-inventors of patents covering the same research results they have published as co-authors). Finally, some evidence has been found of discriminatory attitudes by (male) patent examiners, who would be more reluctant to grant patents to women than to men (Jensen *et al.*, 2018).

Intuitively, the Attrition and Access factors may affect STEM migrants, too, on top of any gender effect. This would result in STEM female migrants being penalized twice when attempting a career as inventors, thus contributing negatively to the overall WIR of the destination country. The Specialization factor may act instead in the opposite direction, with female migrants being both highly skilled and more likely to become inventors than female natives, conditional on succeeding to enter R&D-intensive destination countries such as the US. This is less intuitive, and requires some explanation.

The Access factor may come into play whenever natives would be more likely to be selected for science and technology jobs, for example due to language difficulties or difficulties in getting recognition for their educational qualifications. Evidence in this respect is mixed and varies considerably across countries of origin of migrants, due to many confounding factors such as migration costs and motives (Özden, 2007). In addition, language issues may be more relevant for jobs outside science and technology, or for managerial roles in large corporations, witness the success of many migrant entrepreneurs in several hi-tech clusters of the US (Wadhwa *et al.*, 2007a; Wadhwa *et al.*, 2007b).

As for the Attrition and Specialization phenomena, these can be generated jointly by selective immigration policies. These policies target specific skills, especially STEM-related ones, which are more likely held by men than by women. Among STEM graduates and professionals, the most favored field is information and communication technologies, which further puts women at disadvantage. Even in the absence of explicitly selective policies such as those based on point systems, employers in R&D-intensive countries such as the US are more likely to support the visa applications of STEM workers than those by graduates in different disciplines or simply unskilled (see the case of H1B visas, which mostly go to ITC professionals; Hanson and Liu, 2018). As a result, many women with higher education, but in the "wrong" fields, may be refused access to the destination countries, or forced to enter with different visas than the work ones. They may also end up getting jobs that are unrelated to their skills, or in which their skills are under-utilized (Özden and Neagu, 2007a; Kofman, 2014).

[4] The fortune of the "leaky pipeline" metaphor dates back to the late 1980s, when it was popularized by, among others, the first US governmental report on "Women, Minorities, and the Handicapped in Science and Technology" (OSTP, 1989; Hughes, 1991; Alper and Gibbons, 1993).

At the same time, though, STEM-based selectivity increases the probability of migrants, both men and women, to hold a STEM degree and, in particular, a degree in patent-intensive fields. Ultimately, this results in a higher patenting propensity of migrants versus natives, regardless of gender, as found by Hunt (2011, 2015) and Hunt and Gauthier-Loiselle (2010), for a large sample of immigrant and native graduates in the US. Descriptive evidence by Stephan and Levin (2001) and No and Walsh (2010) also shows that migrants are not only over-represented among inventors in general, but especially so among the most productive ones.

At the very least, this implies a higher probability of high-skilled migrant women to become inventors, relative to native ones. But it may also lead to a higher WIR for migrants than natives to the extent that an individual's decision to migrate precedes her/his educational choices, as suggested by the 'brain gain' literature. Under this hypothesis, and conditional on the decision to emigrate to the US, getting a STEM degree may help succeeding. Further conditioning on women to be more likely to migrate than men, as suggested by the literature we reviewed in section 2.1, this may increase the share of STEM-educated and patent-oriented women in the migrant population, relative both to natives and non-migrants (home country's stayers).

A similar element also playing in favor of the Specialization argument having a positive impact on migrants' WIR is skill-based self-selection. According to the classic model by Borjas (1991), highly skilled individuals are expected to move from countries with lower skill premia to those with higher ones. For STEM-educated women in countries with worse science and technology gender bias than the US, this means a higher migration propensity than men, and, ultimately a higher WIR for migrants than for natives.

3. Data

Our main data source is *PatentsView* (http://www.patentsview.org/), a data repository recently made available by the USPTO, which provides disambiguated data on inventors of USPTO granted patents from 1975 onwards. It contains over 6 million patent documents and 3.5 million unique inventors' IDs (on average, each inventor is listed on 1.8 patent documents). For all such inventors we have information on the country of residence at the time of each recorded patent filing.

For gender attribution, we exploit two sources of information, respectively:

1) The *Global Name Recognition* system, a name search technology produced by IBM (from now on, IBM-GNR) that relies on information collected by the US immigration authorities in the first half of the 1990s. The database contains around 750,000 full names, plus country-sensitive orthographic and abbreviation rules (Breschi et al., 2017a,b). Each first name and surname is associated to several, potential countries of origin (c_i, with $i=1\ldots n$), along with information on the cross-country and within-country frequency of such name or surname. First names are also associated to gender, again in probabilistic terms (probability p to be feminine and $1\text{-}p$ of being masculine), irrespective of c_i.
2) Martínez et al.'s (2016) WGND, as made available by WIPO, which also allows conditioning the name-gender association on the inventor's country of origin c_i.

Using these two sources of information, we proceeded first to apply an "adjusted baseline method", consisting of three steps (more details in Toole et al., 2019).

Step 1 - Based on the IBM-GNR and to the exclusion of rare names, we classified as women all inventors whose name's p is equal to or greater than 97%; and as men all inventors whose name's $(1\text{-}p)$ is equal to or greater than 98%. The different threshold values for men and women were decided upon visual inspection of the distribution of shares. In this way, we genderized around 73% of inventors (around 2.5 million cases).

Step 2 - For the remaining ~900k inventors, we relied on WGND. We first considered the inventor's surname, and selected as c_i the country with the highest frequency of US immigrants bearing such surname, according to IBM-GNR. We then assigned to the inventor the gender suggested by the WGND country-gender association.

After steps 1 and 2, we obtained a worldwide gender attribution rate (percentage of genderized inventors over total inventors with patents filed in a given year) of around 92%. This means that gender remains unknown for 8% of our inventors (275,700 individuals). This is not much, but unfortunately it is concentrated in a few patent-intensive countries in East Asia, namely Japan (with over one quarter of non-attributions), China and South Korea (each one with around one eighth of non-attributions). These figures suggest that our algorithm, as many others in the literature, perform less well with Asian names. These same names are also responsible for the high share of non-genderized inventors in the United States (when compared to other Western countries), which is at the same time the country with the most inventors and the most immigrant inventors, especially from Asia.

As a remedy, we added a Step 3 to our procedure, which consists in relaxing our gender attribution criteria for inventors whose country of origin c_i is China, Singapore, Taiwan, Macao, Hong Kong, Korea or India. This raises the gender attribution to (93.2% of total). Despite this remedy, the growth of inventive activities in East Asia, along with the growth of inventors' migration from such countries to the United States, result in an increase of non-attribution figures over time, from less than 4% in the 1970s to over 8% after 2015.

We remain with 3,244,813 inventors with patents filed at the USPTO in between 1976 and 2016. Our descriptive analysis in section 4.1 is based on these figures.

Of these, 1,645,434 have resided at least once in the United States (accounting for 3,361,097 patents), while the remaining ones result from inventive activities entirely conducted in other countries.

Finally, in a last step, we infer the native versus migration status of inventors from the latter's nationality, compared to their residence, as reported on a subset of USPTO patents included in the WIPO-PCT dataset (Miguelez and Fink, 2017), also used by Martinez et al. (2016). The PCT procedure has been in place since the early 1990s and, until 2011, most applications first filed at or extended to the USPTO according to such procedure were required to report not only the address of the inventors, but also their nationality. Thus, for our empirical analysis (sections 4.2 and 4.3), we retain all the patents filed in between 1995 and 2011, and after matching them to those in *PatentsView* with gender information, we remain with ~442k patent documents, ~60k of which with at least one inventor residing in the United States.

4. Evidence

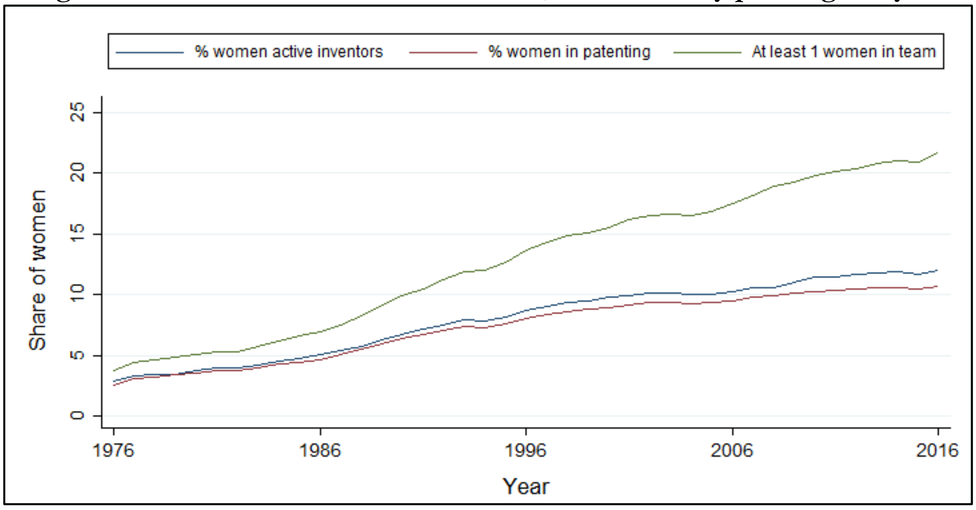
We first present some general evidence on women's participation to inventive activities worldwide and their specialization. We then analyse how immigration affects such participation in the US (impact of immigration). Finally we discuss to what extent migration affects women inventors' specialization and productivity (migration as an opportunity)

4.1 Women's patenting activity: worldwide trends and specialization patterns

Figure 1 shows yearly figures for three indicators of women's participation to inventive activities worldwide:

(1) the women's share of active inventors (women's inventor rate, or WIR)
(2) the women's share of patents (with fractional counts in case of multiple-inventor patents);
(3) the share of patents including at least one woman among the team of inventors

Figure 1: Women inventor rate worldwide, 1976-2016 - by patent grant year



We notice that the WIR index has increased over time, from less than 5% during the 1970s and the 1980s, to more than 12% at the end of the period. The women's share of patents has followed a similar path, but at systematically lower levels. This difference is due to the lower average number of patent per female inventor, with respect to males, which in turn may have two non-mutually exclusive explanations:

- First, women inventors may simply be, on average, less experienced and/or occupy less senior positions than men in R&D teams, which limits their patent production.
- Second, women inventors may be specialized in technological fields characterized by teamwork and possibly large inventor teams, which introduces a negative bias when measuring their productivity with fractional counting methods. This is confirmed by the third line in the figure, representing the share of inventor teams including at least one woman, which increases at a faster pace than the other indicators.

Large inventor teams are most common in science-based technologies such as Pharmaceuticals, Biotechnologies or Information & Communication technologies (ICT), as opposed to more production-based technologies such as Mechanical or Civil Engineering (Wuchty *et al.*, 2007). And it is precisely in science-based technologies where we find the highest WIR worldwide.

Table 1 breaks down data by technological fields and areas, as defined by Schmoch (2008). It shows that, for the entire period up to 2016 and all patents worldwide, the WIR indicator ranges between 4% for Mechanical Elements and 26% for Biotechnology.

Table 1: Women inventor rate across technological fields, all patents 1976-2016

TECHNOLOGICAL FIELD	AREA	Number of inventors	Nr of women inventors	WIR
Electrical machinery, apparatus, energy	Electrical engineering	328089	25333	8%
Audio-visual technology	Electrical engineering	248194	22086	9%
Telecommunications	Electrical engineering	196485	17354	9%
Digital communication	Electrical engineering	226083	22688	10%
Basic communication processes	Electrical engineering	92284	6169	7%
Computer technology	Electrical engineering	404499	44938	11%
IT methods for management	Electrical engineering	121965	16441	13%
Semiconductors	Electrical engineering	162170	19181	12%
Optics	Instruments	191695	19054	10%
Measurement	Instruments	332581	24870	7%
Analysis of biological materials	Instruments	71933	14368	20%
Control technology	Instruments	163113	13346	8%
Medical technology	Instruments	218549	28948	13%
Organic fine chemistry	Chemistry	182040	35622	20%
Biotechnology	Chemistry	148203	38941	26%
Pharmaceuticals	Chemistry	135277	32340	24%
Macromolecular chemistry, polymers	Chemistry	129188	18408	14%
Food chemistry	Chemistry	49568	8719	18%
Basic materials chemistry	Chemistry	169833	24359	14%
Materials, metallurgy	Chemistry	141221	12890	9%
Surface technology, coating	Chemistry	142693	13241	9%
Micro-structural and nano-technology	Chemistry	49117	6549	13%
Chemical engineering	Chemistry	204968	17928	9%
Environmental technology	Chemistry	97150	7400	8%
Handling	Mechanical eng.	155993	9545	6%
Machine tools	Mechanical eng.	165023	8265	5%
Engines, pumps, turbines	Mechanical eng.	157169	7724	5%
Textile and paper machines	Mechanical eng.	115332	10133	9%
Other special machines	Mechanical eng.	233313	18330	8%
Thermal processes and apparatus	Mechanical eng.	83533	4347	5%
Mechanical elements	Mechanical eng.	192769	8220	4%
Transport	Mechanical eng.	245268	14193	6%
Furniture, games	Others	138426	17054	12%
Other consumer goods	Others	126549	17769	14%
Civil engineering	Others	158347	8447	5%

At a more aggregate level, but with an eye on time trends, Figure 2 show that patents in Chemistry (which includes also Biotechnology and Pharmaceuticals) exhibit a way larger WIR than Mechanical Engineering (Machine tools, Engines, pumps, turbines, Mechanical elements, Transport, etc.), with all the other technologies in between. At the same time, the increase of WIR has been generalized across classes, so the women's inventor specialization pattern has not changed much in time.

Figure 3 breaks down patents by patent assignee categories, and it shows that women's technological specialization in Chemistry goes hand in hand with the prevalence of Universities & Hospitals as patent assignees for their inventions, followed by Public Research Organizations (PROs). Both types of organizations have patent portfolios mostly dedicated to pharmaceuticals and biotechnologies; they may also offer more equitable career chances to women, compared to the category where the latter are the least represented, namely Business firms. The WIR value for patents owned by individual inventors (physical persons, either alone or in association with others) stands in between the two extremes.

Figure 2: Women inventor rate across technological areas and over time, 1976-2016

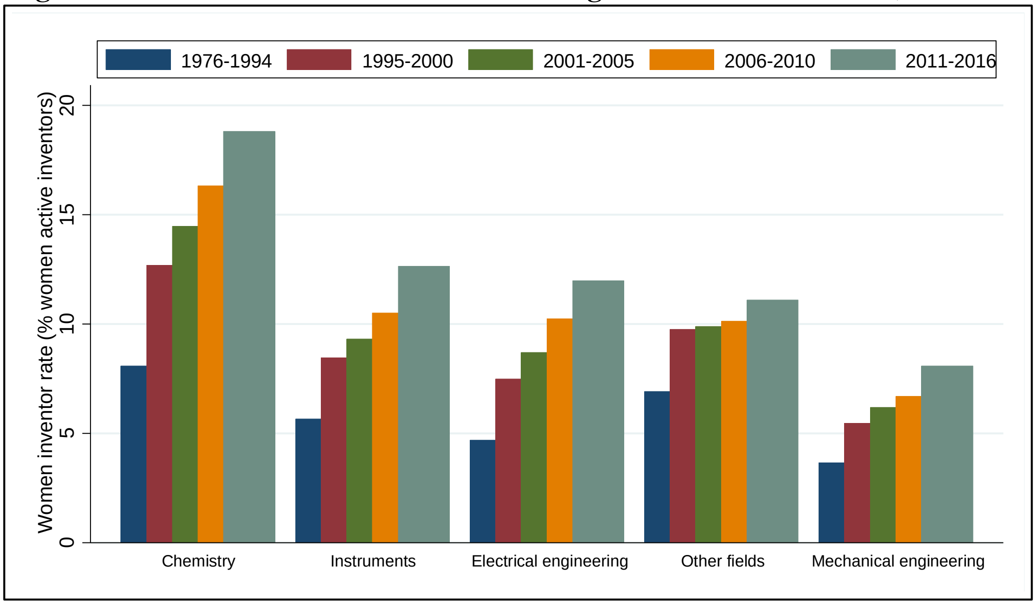
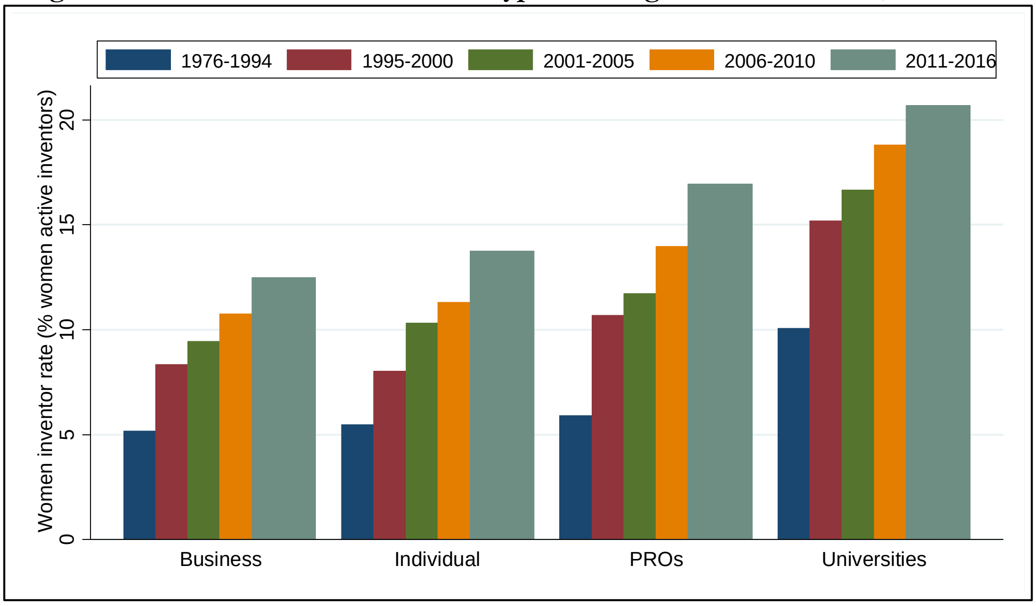


Figure 3: Women inventor rate across types of assignee and over time, 1976-2016

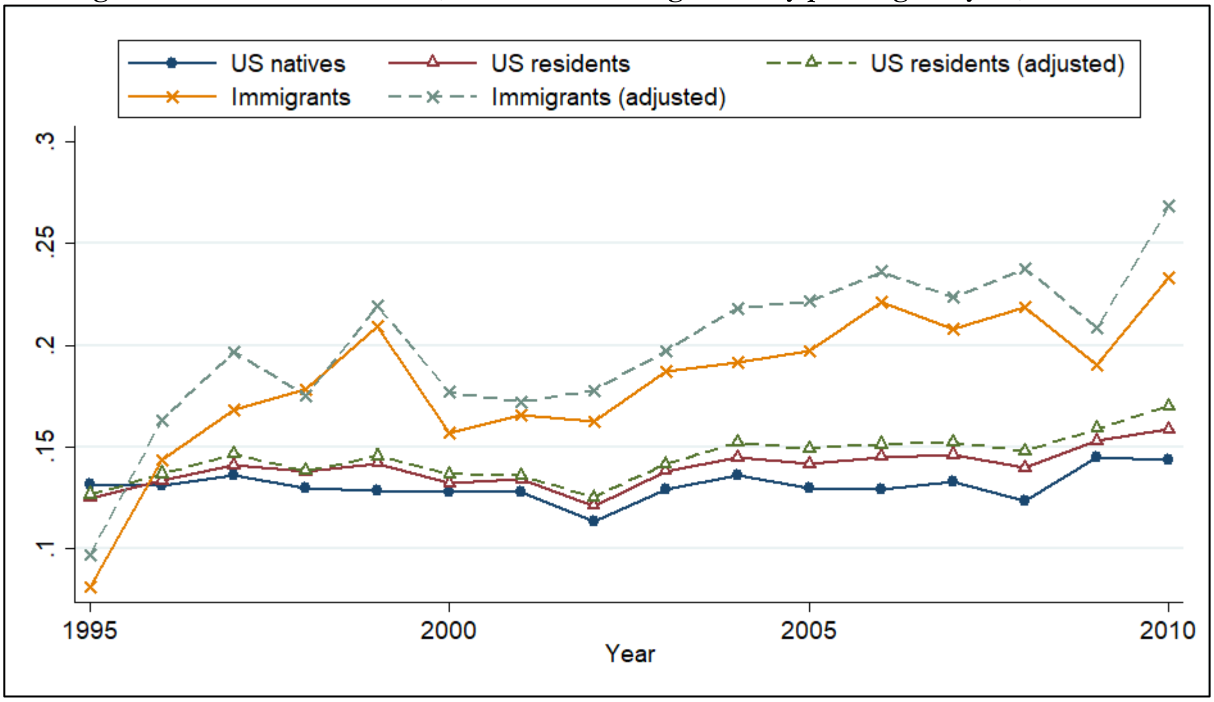


4.2 Women inventors in the US: the impact of immigration

Moving to the analysis of specific patterns for the US, the three continuous lines in figure 4 report WIR trends for, respectively, native inventors, migrant inventors, and the total of US-resident inventors (migrant plus natives), as measured on the sole basis of the genderized inventors. The time series runs only from 1995 to 2010, for which we have reliable inventor migration data.

We notice immediately that, with exception of the first year in the series, the WIR level for natives is always inferior to that of immigrants, and the trends diverge very quickly, with the WIR for immigrants increasing much more noticeably than that for natives. As a result, the overall WIR for US-resident inventors is higher than that of natives, with the difference between the two increasing slightly over time, due to the increasing weight of migrant inventors, as discussed in section 2.

Figure 4: WIR of US residents, natives and immigrants - by patent grant year, 1995-2010



Notes: See footnote 5 for formal definition of adjusted WIR estimates

The migrant-native WIR gap, and its growth over time, appear to be even larger when the WIR measurement for migrants and residents is extended to the non-genderized inventors, and adjusted accordingly (dashed lines). In a nutshell, this extension-cum-adjustment corrects for the fact that some ethnic groups of immigrants (such as the Chinese) exhibit at the same time a high WIR and a high number of non-genderized inventors. Hence, when excluding the latter from the computation of WIR, we then end up underestimating the number of women inventors among the overall immigrant inventor sample; when re-including them, we obtain a more correct estimate of immigrants' WIR, which we can also use to correct the WIR for residents.[5]

The patterns in figures 4 suggest a positive association between immigration and women's participation to inventive activities in the US. Figure 5 confirms it. We split the US-resident inventors (migrant+native) into two gender groups, and calculate the share of migrants for each of them. We notice immediately that the share is remarkably higher for women, with the lead over men increasing over time. This implies that the

[5] Formally, the baseline $WIR_{imm}$for immigrants we estimate on the sole basis of genderized inventors can be written as:

$$WIR_{imm} = \sum_{i=1}^{n} WIR_{imm-i}\gamma_{imm-i,g}$$

where WIR_{imm-i} is the WIR of each specific immigrant group i and $\gamma_{imm-i,g}$ is i's share of genderized immigrants. The adjusted $\widetilde{WIR}_{imm}$ is instead:

$$\widetilde{WIR}_{imm} = \sum_{i=1}^{n} WIR_{imm-i}\,\gamma_{imm-i,g+ng}$$

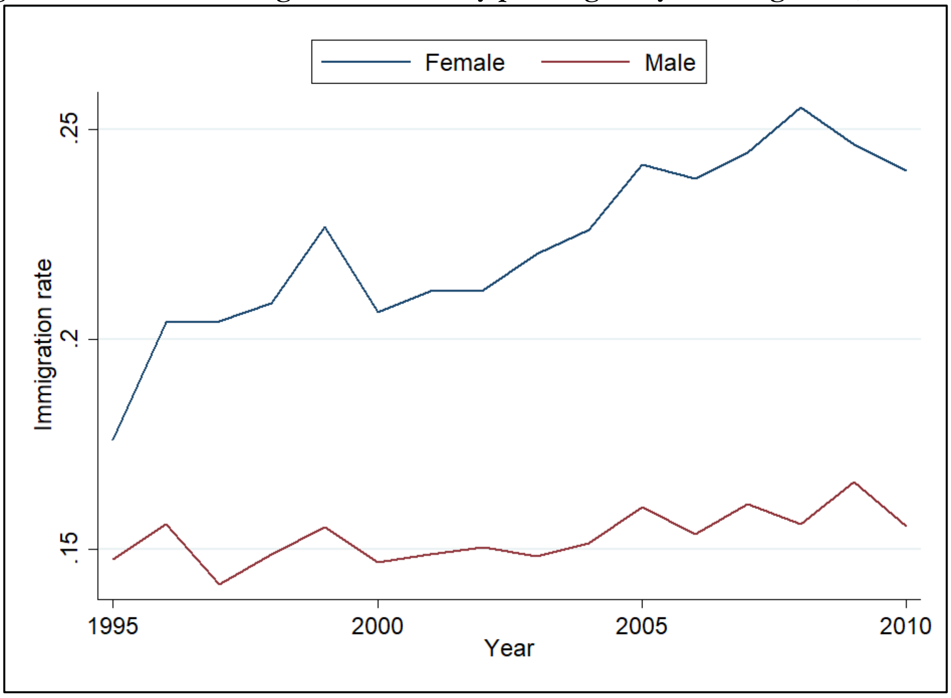
where $\gamma_{imm-i,g+ng}$ is i's share of the total immigrants (both genderized and non). It follows that:

$$\widetilde{WIR}_{imm} - WIR_{imm} = \sum_{i=1}^{k} WIR_{imm-i}\Delta\gamma_i + \sum_{i=k+1}^{n} WIR_{imm-i}\Delta\gamma_i$$

where $\Delta\gamma_i = \gamma_{imm-i,g+ng} - \gamma_{imm-i,g}$ and $\Delta\gamma_i > 0$ for $i = 1 \ldots k$ and $\Delta\gamma_i < 0$ for $i = k+1 \ldots n$. For $WIR_{imm-i(1\ldots k)}$ generally higher than and/or $|\Delta\gamma_{i(1\ldots k)}| > |\Delta\gamma_{i(k+1\ldots n)}|$, which is actually our case, we obtain $\widetilde{WIR}_{imm} > WIR_{imm}$. The same line of reasoning can be extended to the calculation of WIR for residents.

WIR for migrants is higher than that for natives, and confirms that immigration has sustained the increase of the overall US-resident WIR over time.

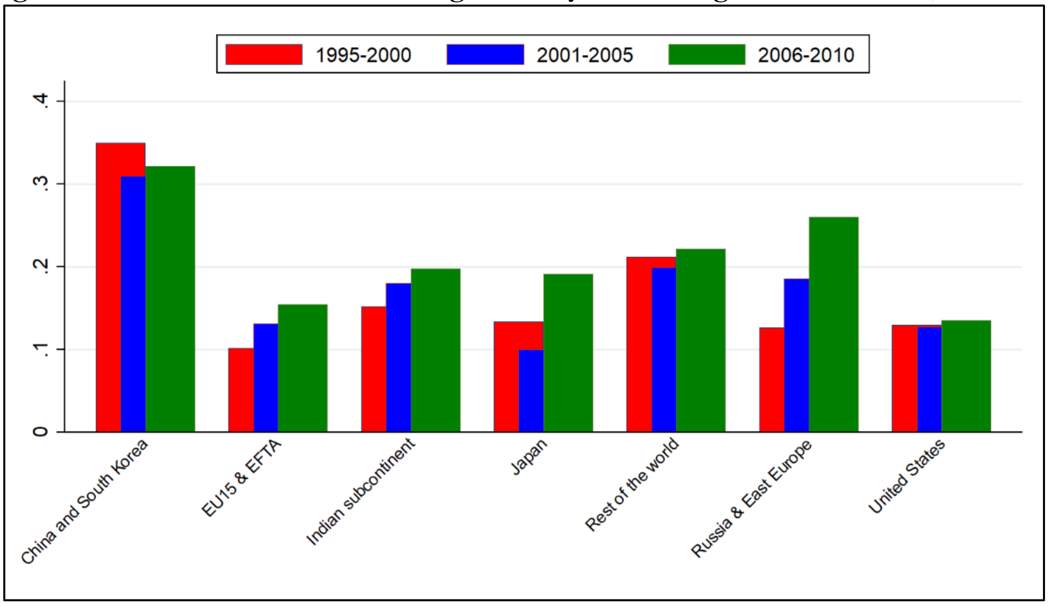
Figure 5 – Inventor immigration rates – by patent grant year and gender, 1995-2010



The superior level of WIR for immigrants may have two, non-mutually exclusive causes. First, it may reflect a higher WIR in the migrants' country of origin than in the US, provided that highly skilled women with STEM qualifications have at least the same propensity to migrate than comparable men. Second, it may result from these migrant women having more opportunities to become inventors in the US than they have in their countries of origin.

As a first step towards telling the two causes apart, figure 6 compares the WIR levels of US native and migrant inventors from various macro-areas of origin (collections of countries), for three sub-periods. Already in 1995-2000, migrants from all areas of origin exhibited a higher WIR than US natives, with the exception of Western European countries (EU15 and EFTA members). Later on, either the high WIR of migrants remained stable and much higher than that of US natives (as with migrants from China and Korea or the Rest of the World) or it increased fast, leaving that of US natives behind (as we can see for migrants from EU15 and EFTA, the Indian subcontinent, and, above all, Russia and Eastern Europe). We can conclude that all migrants, irrespective of the country of origin, ultimately contribute to increase the WIR of the US, albeit with different intensity.

Figure 6 - WIR of US natives vs immigrants - by area of origin and over time, 1995-2010



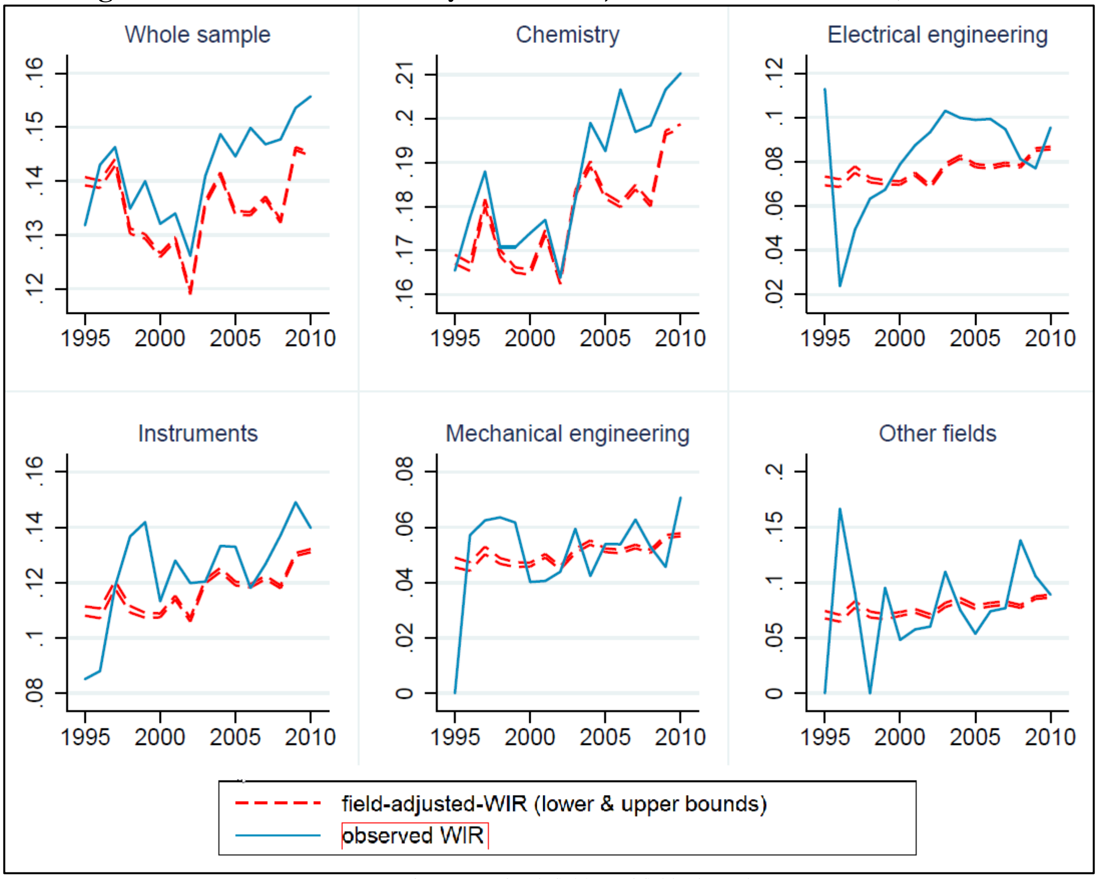
Notes: EU15-EFTA: European Union members and European Free Trade Area members, as of 1998 - *full list in Appendix*

Such higher WIR for migrants, relative to US natives, may depend on a composition effect, due to different technological specializations of immigrant and native inventors. Namely, the former could be more specialized than the latter in fields with high women's participation, such as Chemistry, as opposed to fields with low participation such as Mechanical Engineering.

In order to take into account this possibility we run a simulation exercise, as follows. First, we estimate a "field-adjusted-WIR", namely the counterfactual WIR we would have got if all inventors were US natives or, to put it in other words, in the absence of immigration. Second, we test whether the observed WIR – in different technological fields - is higher than the field-adjusted one, which would suggest a positive contribution of immigration to WIR, regardless of the immigrants' specialization. This is precisely what we find in figure 7 where the field-adjusted-WIR is represented by two red lines (respectively its upper- and lower-bound estimates, with a 95% confidence interval), while the line for the observed WIR is blue. The blue line is higher than both red ones for most of the years, especially for the technological fields with high female participation and for the most recent years. [6]

[6] In short, the field-adjusted-WIR is estimated as follows (more details in the Appendix). First, we consider only the US native inventors and regress a dummy variable coded 1 if inventor is female, 0 if he is male onto a set of dummies for the filing years and for 35 technological fields of their corresponding patents. Based on the estimated coefficients of such dummies, we then predict the upper- and lower- bound probabilities for each inventor to be a woman, at 95% level of confidence, based on the years and fields of his/her patents. Using such predicted probabilities as the key parameter of as many binomial distributions we then re-assign randomly a gender to all US-resident inventors, including migrants, and use it to calculate an upper- and lower-bound adjusted WIR. Whenever the observed WIR stands higher than the upper-bound field-adjusted-WIR, we can conclude that the migrants' contribution to the observed WIR, conditional on their distribution across technological fields, is positive with a 95% level of confidence. Were we observe the opposite, namely that the observed WIR stands lower than the lower-bound field-adjusted-WIR, we would conclude that migration detracts to the destination country's WIR. For an observed WIR in between the upper- and lower-bound field-adjusted WIR, we conclude that the migrants' contribution is null.

Figure 7 – Counterfactual analysis: field-adjusted vs observed WIR, 1995-2010



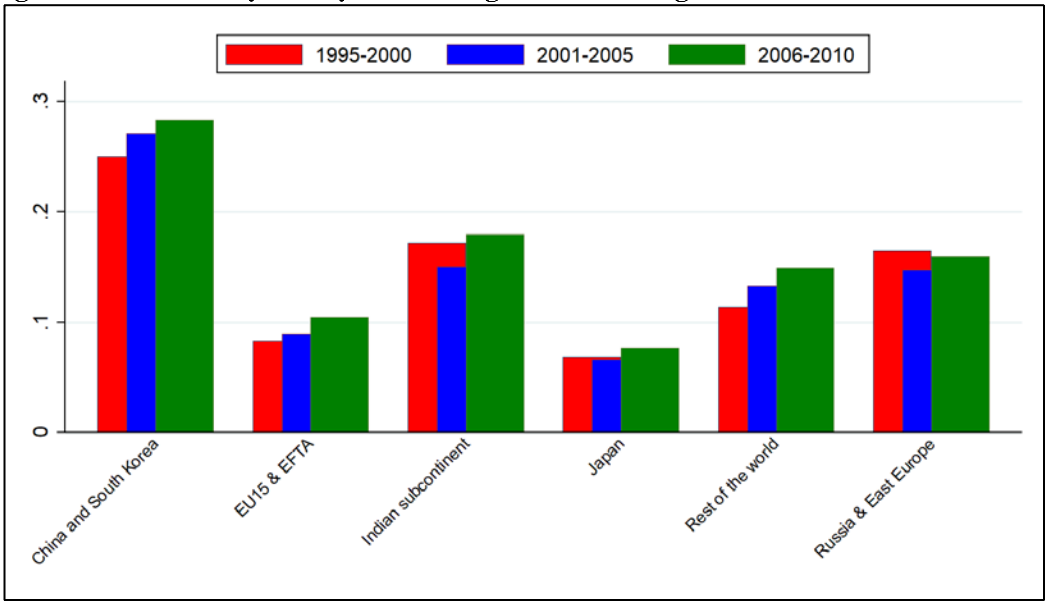
Notes: See footnote 6 for definition of field-adjusted WIR

4.3 Emigration as opportunity

Figure 8 reports the WIR levels, per subperiod, of stayers of the same areas of migrants' origin listed in figure 6 (where by stayer we mean a native of country *c*, who did not migrate). At a glance, we notice some positive correlation between the levels of WIR for migrants and stayers. For example, the WIR levels of both migrants (figure 6) and stayers (figure 8) of China and South Korea are higher than those of Western European countries. However, China and South Korea are the only countries whose stayers' WIR levels are clearly higher than those of US natives (in figure 6). This suggests that, in all other cases, the high WIR of migrants to US does not mirror an equivalent WIR in their countries of origin, but it is specific to migrants themselves.

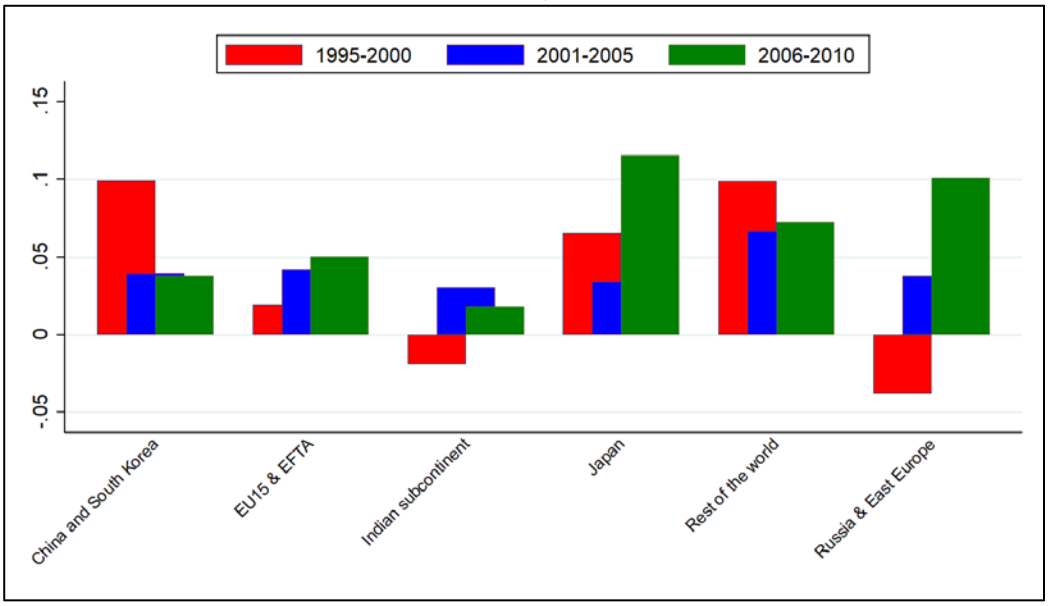
Figure 9 provides evidence in this direction. It reports, for each area of origin, the difference between the WIR of migrants and stayers, that is the difference between the values in figures 6 and 8, by subperiod. We notice immediately that, with a couple of exceptions in 1995-2000, the difference is always positive. This suggests that migration to the US may provide women with a STEM degree with better opportunities to become inventors than pursuing a career at home (opportunity effect), even when they come from countries of origin whose WIR is higher than that of the US. In the following figures we provide some further, circumstantial evidence in favor of this hypothesis.

Figure 8 - WIR of stayers - by area of origin of US immigrants and over time, 1995-2010



Notes: EU15-EFTA: European Union members and European Free Trade Area members, as of 1998 - *full list in Appendix*

Figure 9 - WIR difference between US immigrants and stayers - by area of origin of US immigrants and over time, 1995-2010



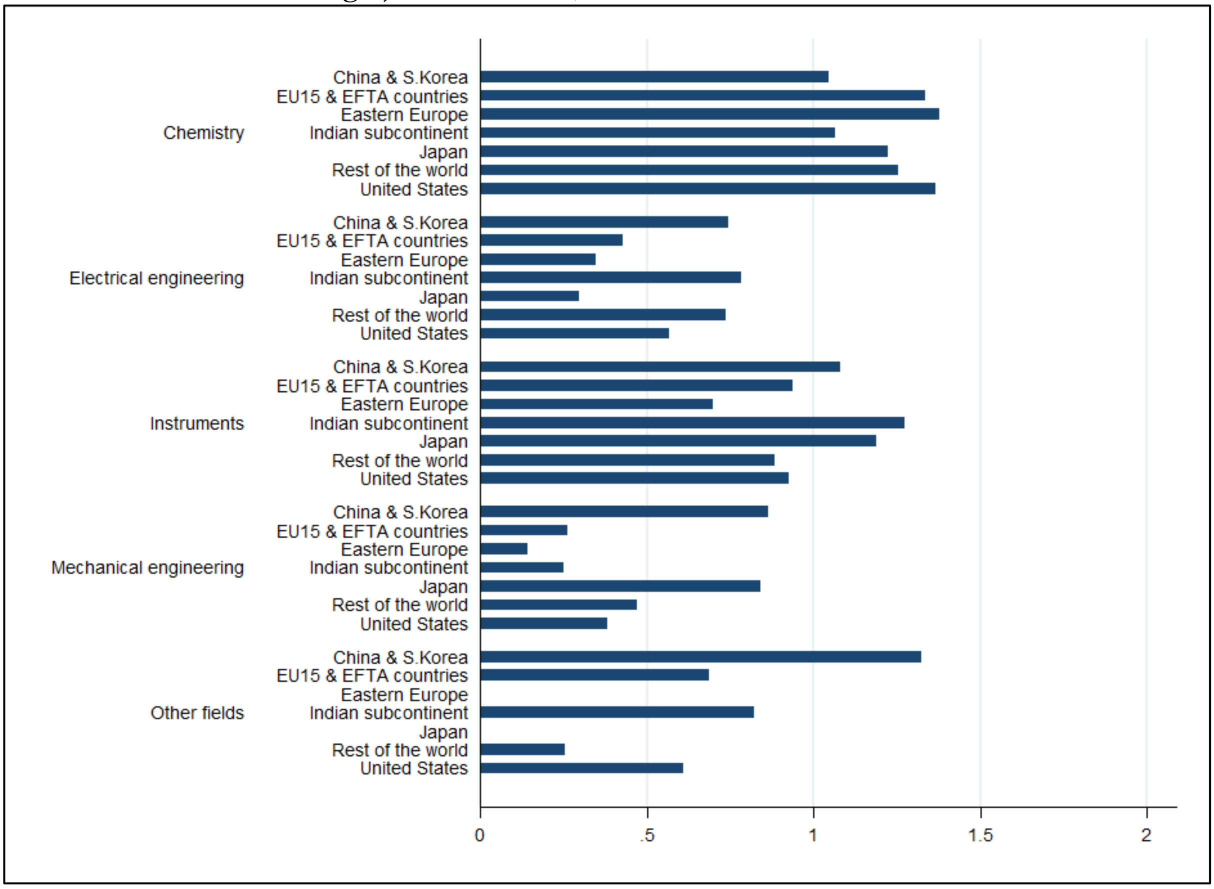
Notes: EU15-EFTA: European Union members and European Free Trade Area members, as of 1998 - *full list in Appendix*

Figure 10 reports the values of a specialization index of female inventors, by technological area, for:

- immigrant inventors in the US, by macro-areas of origin of the immigrant (top six bars for each technology)
- US natives (bottom bar).

The specialization indicator is calculated as $S_{w(i,j)}/S_{w(i)}$, where $S_{w(i,j)}$ is the share of female inventors from country (area) i in technology j and $S_{w(i)}$ is the share of female inventors from country (area) i across all technologies. Values greater than one indicate women's specialization, that is over-representation of women in technology j relative to the all-technologies average, while values lower than one indicate under-representation.

Figure 10 - Specialization of female inventors in the US, by technological area: migrants (by area of origin) versus natives, mean values for 1995-2010



Although correlated, the specialization of female immigrant and native inventors do not coincide. In particular, female inventors from the Indian subcontinent, Japan and China/Korea, tend to be less specialized (index's value closer to one from above) than their US-native homologues in Chemistry, but more specialized in Instruments (index's value higher than one) as well as in Mechanical Engineering and/or Other fields. Their de-specialization in Electrical Engineering looks also less pronounced (index's value closer to one from below). At the same time, though, these migrants versus natives differences in specialization do not merely reflect the specialization patterns of women inventors in the home countries (stayers). These are reported in Figure 11, while figure 12 reports the differences in values from figure 10 (migrants' specialization – stayers' specialization). We notice immediately that female migrant inventors to the US are less specialized than their non-migrant homologues in both Chemistry and Electrical Engineering, wherever they come from; while they are more specialized in Instruments. As for Mechanical Engineering and Other fields, the patterns is more confused, but differences prevail over similarities. We interpret these results as indicative of migration offering to women with STEM degrees or jobs the opportunity to engage in fields less open to them in their home countries. These fields, however, are not the same as those in which US-native female migrant inventors specialize.

At the same time, though, these migrants-versus-natives differences in specialization do not merely reflect the specialization patterns of women inventors in the home countries (stayers). These are reported in Figure 11, while figure 12 reports the differences in values from figure 10 (migrants' specialization – stayers' specialization). We notice immediately that female migrant inventors to the US are less specialized than their non-migrant homologues in both Chemistry and Electrical Engineering, wherever they come from; while they are more specialized in Instruments. As for Mechanical Engineering and Other fields, the patterns are more confused, but differences prevail over similarities. We interpret these results as indicative of migration offering to women with STEM degrees or jobs the opportunity to engage in fields less open to them in their home countries. These fields, however, are not the same as those in which US-native female migrant inventors specialize, which in turn suggests that the opportunities arise from a fine-grained job matching between individual skills and job offers.

Figure 11 - Specialization of non-migrant female inventors (stayers) - by technological area and area of origin of US immigrants, mean values for 1995-2010

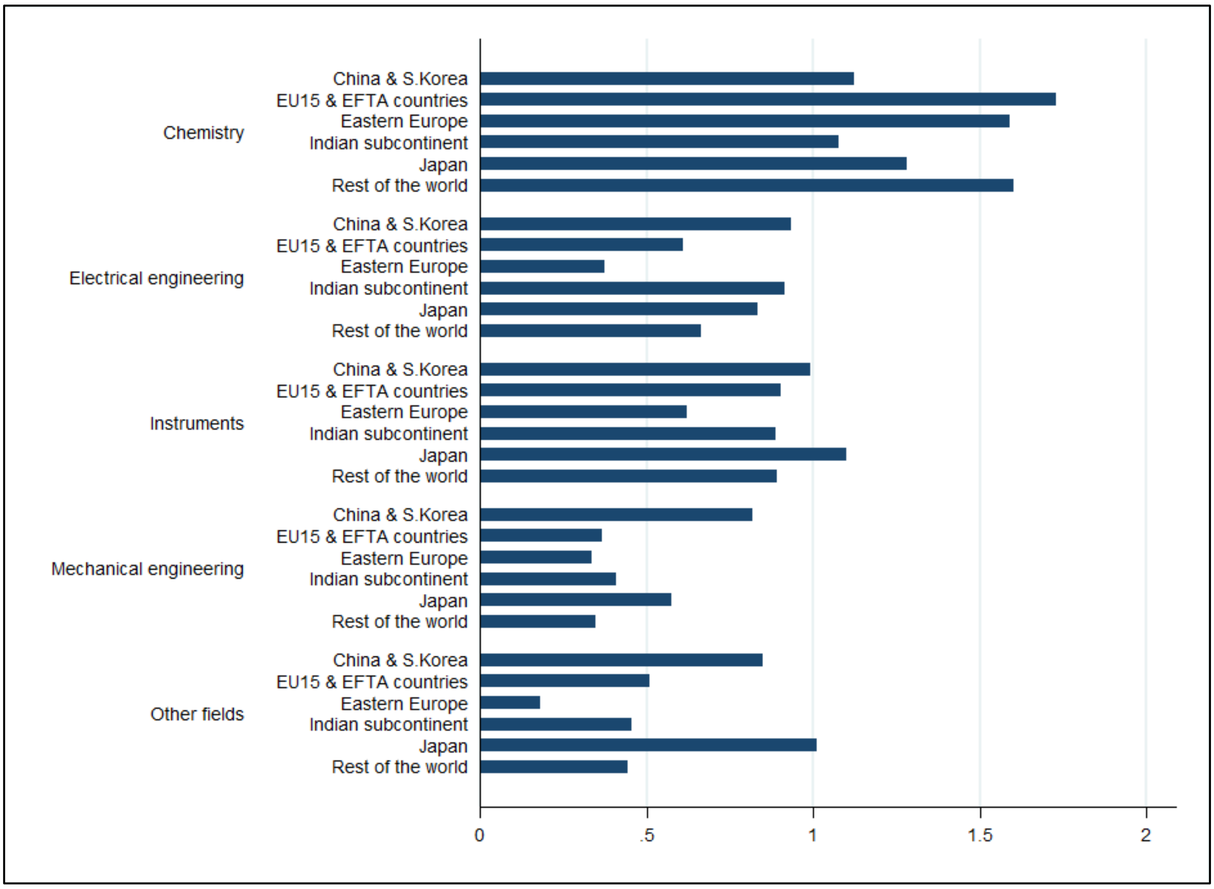
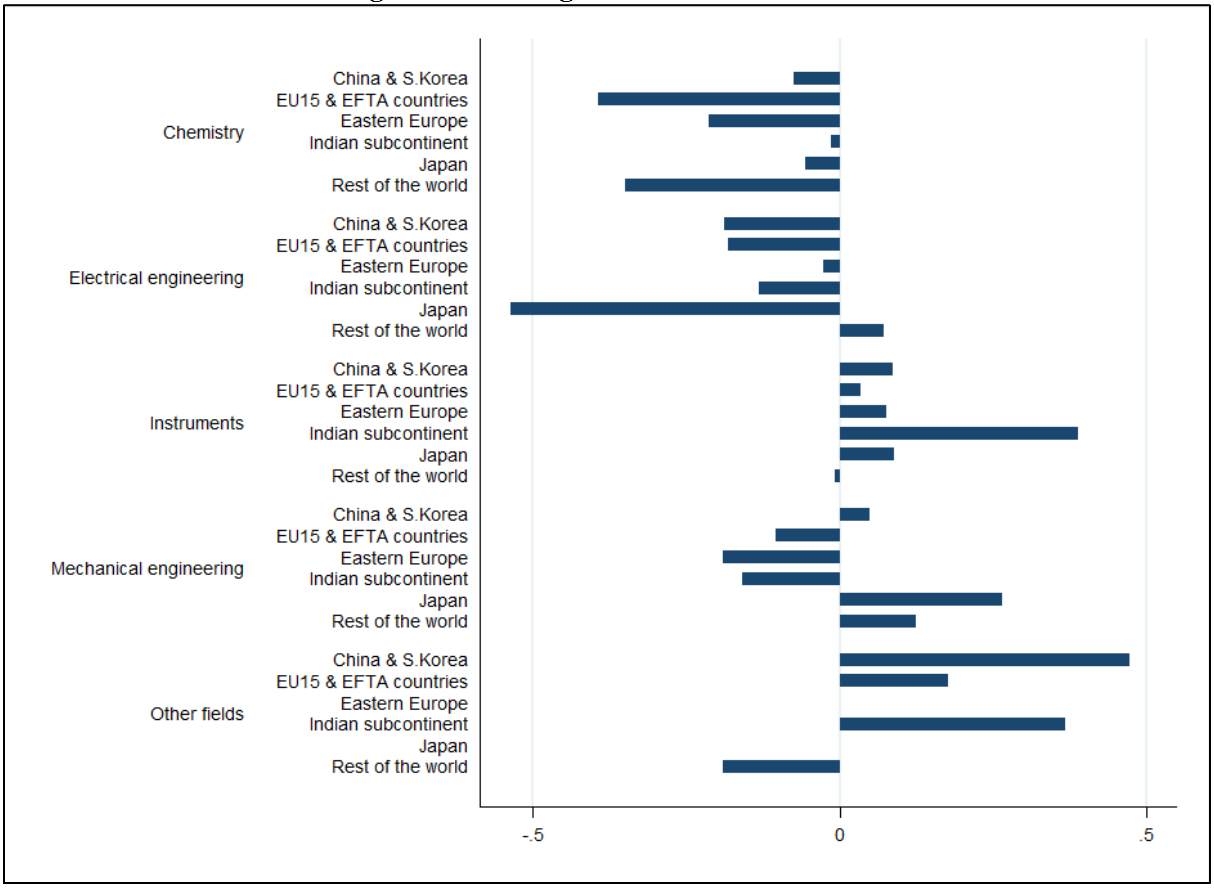


Figure 12 - Specialization difference between US immigrants and stayers - by technological area and area of origin of US immigrants, mean values for 1995-2010



5. Conclusions

Although exploratory and preliminary, the evidence we produced in this paper suggests that female immigration may affect significantly the gender balance of inventive activities in the United States. First, it has contributed to the growth of the US WIR (Women Inventor Rate) over the past quarter century, both in absolute terms and relative to other patent-intensive economies such as Japan and Europe. The WIR of immigrants is generally higher than that of natives, not only because some migrants' countries of origin exhibit higher WIRs than the US, but also and more generally because, for all the countries of origin, the migrants' WIR is generally higher than the WIR of stayers (non-migrants).

Policy-wise, this implies that it is migration *per se* that, on average, increases the participation of women to inventive activities, and not the specific gender conditions of either the home or destination countries. This is in line with the view of migration as a powerful mechanism for re-allocating human resources wherever they can be best matched, especially for highly-skilled individuals (Docquier *et al.*, 2014).

Second, the specialization patterns of migrant women inventors differ from both those of their US-native homologues and those of women inventors in the home countries. This is compatible with migration offering to women with STEM degrees either more opportunities to become inventors or to invent in technological fields in which female participation is otherwise particularly feeble.

In this respect, our work contributes to the emerging evidence on the positive gains from migration for both the destination countries, the migrants themselves, and possibly their home countries, too (Clemens, 2011). It builds on the literature's suggestion that migration is a powerful force for improving the match of skills and jobs worldwide; and it suggests that less restrictive or pro-active policies for high-skilled migration may help redressing the gender balance in STEM-related professions of the host country, even when women's participation to such professions in the migrants' home countries is not higher than at destination.

What we could not assess, based solely on the inventor data at our disposal, is the amount of brain waste that come along with the patterns and trends we observe, due to the underlying conditions and policies that determine the migration of STEM-educated women to the United States. This is because we only observe the women (and men) who finally managed to become inventors and the patents they have actually filed, while we have no data on potential inventors (including STEM graduates who tried but failed a research career). Nor we observe the full potential women's inventors, in terms of the number and quality of patents they could or could have filed under different working conditions, but only their factual output.

In this respect, our present work is silent on the potentially negative effects of gender-blind selective immigration policies or of the human resource practices of large multinationals or international organization, which tend to favor high-skilled migration of men rather than women (Kofman, 2000; Purkayastha, 2005; Kofman, 2014). But it has the merit of defining high-skilled migrant women neither with reference to the visa they first obtained when reaching their destination country, nor to their education level, but on the basis of their job experience, as measured by their patenting activity. In this respect, we pulled them out of the "invisibility" to which they could be otherwise relegated.

Besides, our data will allow us to pursue, in a near future, some more policy-oriented work, such as assessing the impact on WIR of immigration policy changes in the United States and/or other, R&D-intensive attractors of high-skilled migrants; and/or extending our analysis on the careers of women migrant inventors, relative to both men and natives, as measured by the number and quality of patents filed, as well as their mobility across companies and other patent-filing organizations.

One final limitation of our work consists in its neglect of the effects of women inventors' migration on their home countries, neither in terms of knowledge remittances (Kerr, 2008; Breschi *et al.*, 2017a), nor in terms of encouragement for women to get a STEM education (along the lines of the more general literature on the education effects of migration; Stark and Wang, 2002; Stark, 2004). We plan to fill some this research gap in the near future. In particular, we will focus on the dynamics of WIR in the migrants' home countries, and whether this may depend on the migration opportunities presented to STEM-educated women in the United States and other knowledge-intensive destination countries.

We also plan to fill some this research gap in the near future. In particular, we plan to study both the dynamics of WIR in the migrants' home countries, and whether this may depend on the migration opportunities presented to STEM-educated women in the United States and other destination countries.

References

Alper, J. and Gibbons, A. (1993) 'The pipeline is leaking women all the way along', *Science*, 260(5106), pp. 409-412.

Arslan, C., Dumont, J.-C., Kone, Z. L., Özden, Ç., Parsons, C. R. and Xenogiani, T. (2016) 'International Migration to the OECD in the 21st Century', *KNOMAD Working Paper 16, World Bank*.

Azoulay, P., Ding, W. and Stuart, T. (2007) 'The determinants of faculty patenting behavior: Demographics or opportunities?', *Journal of Economic Behavior & Organization*, 63(4), pp. 599-623.

Beine, M., Docquier, F. and Rapoport, H. (2010) 'On the robustness of brain gain estimates', *Annals of Economics and Statistics/Annales d'Économie et de Statistique*, pp. 143-165.

Borjas, G. J. (1991) 'Immigration and self-selection', in *Immigration, trade, and the labor market*. University of Chicago Press, pp. 29-76.

Breschi, S., Lissoni, F. and Miguelez, E. (2017a) 'Foreign-origin inventors in the US: Testing for Diaspora and Brain Gain Effects', *Journal of Economic Geography*, 17(5), pp. 1009–1038.

Breschi, S., Lissoni, F. and Montobbio, F. (2005) 'From Publishing to Patenting: Do Productive Scientists Turn into Academic Inventors?', *Revue d'économie industrielle*, 110, pp. 75-102.

Breschi, S., Lissoni, F. and Tarasconi, G. (2017b) 'Inventor Data for Research on Migration & Innovation: The Ethnic-Inv Pilot Database', in Fink, C. and Miguelez, E. (eds.) *The International Mobility of Talent and Innovation: New Evidence and Policy Implications*. Cambridge University Press.

Clemens, M. A. (2011) 'Economics and emigration: Trillion-dollar bills on the sidewalk?', *Journal of Economic perspectives*, 25(3), pp. 83-106.

Delgado, M. and Murray, F. (2019) 'Catalysts for Gender Inclusion in Innovation: The Role of Universities and their Top Inventors ', mimeo.

Ding, W. W., Murray, F. and Stuart, T. E. (2006) 'Gender differences in patenting in the academic life sciences', *Science*, 313(5787), pp. 665-667.

Docquier, F., Lowell, B. L. and Marfouk, A. (2009) 'A gendered assessment of highly skilled emigration', *Population and Development Review*, 35(2), pp. 297-321.

Docquier, F., Marfouk, A., Salomone, S. and Sekkat, K. (2012) 'Are skilled women more migratory than skilled men?', *World development*, 40(2), pp. 251-265.

Docquier, F., Peri, G. and Ruyssen, I. (2014) 'The cross-country determinants of potential and actual migration', *International Migration Review*, 48(1_suppl), pp. 37-99.

Dumont, J.-C., Martin, J. P. and Spielvogel, G. (2007) 'Women on the move: the neglected gender dimension of the brain drain'.

Etzkowitz, H. and Ranga, M. (2011) 'Gender dynamics in science and technology: From the "leaky pipeline"to the "vanish box"', *Brussels economic review*, 54(2/3), pp. 131-147.

EU (2019) *She Figures*. Brussels: Publication Office of the European Commission Brussels (https://ec.europa.eu/info/publications/she-figures-2018_en; last visited in 2019).

Faggian, A., McCann, P. and Sheppard, S. (2007) 'Some evidence that women are more mobile than men: Gender differences in UK graduate migration behavior', *Journal of Regional Science*, 47(3), pp. 517-539.

Frietsch, R., Haller, I., Funken-Vrohlings, M. and Grupp, H. (2009) 'Gender-specific patterns in patenting and publishing', *Research policy*, 38(4), pp. 590-599.

Hanson, G. H. and Liu, C. (2018) 'High-Skilled Immigration and the Comparative Advantage of Foreign-Born Workers across US Occupations', in Hanson, G. H., Kerr, W. R. and Turner, S. (eds.) *High-skilled Migration to the United States and Its Economic Consequences*. University of Chicago Press.

Hughes, D. M. (1991) 'Transforming Science and Technology: Has the Elephant Yet Flicked Its Trunk?', *NWSA Journal*, 3(3), pp. 382-401.

Hunt, J. (2011) 'Which Immigrants Are Most Innovative and Entrepreneurial? Distinctions by Entry Visa', *Journal of Labor Economics*, 29, pp. 417-457.

Hunt, J. (2015) 'Are Immigrants the Most Skilled US Computer and Engineering Workers?', *Journal of Labor Economics*, 33(S1 Part 2), pp. S39-S77.

Hunt, J., Garant, J.-P., Herman, H. and Munroe, D. J. (2013) 'Why are women underrepresented amongst patentees?', *Research Policy*, 42(4), pp. 831-843.

Hunt, J. and Gauthier-Loiselle, M. (2010) 'How Much Does Immigration Boost Innovation?', *American Economic Journal: Macroeconomics*, 2(2), pp. 31-56.

Jensen, K., Kovács, B. and Sorenson, O. (2018) 'Gender differences in obtaining and maintaining patent rights', *Nature biotechnology*, 36(4), p. 307.

Kerr, W. R. (2008) 'Ethnic Scientific Communities and International Technology Diffusion', *Review of Economics and Statistics*, 90(3), pp. 518-537.
Kofman, E. (2000) 'The invisibility of skilled female migrants and gender relations in studies of skilled migration in Europe', *International Journal of Population Geography*, 6(1), pp. 45-59.
Kofman, E. (2014) 'Towards a gendered evaluation of (highly) skilled immigration policies in Europe', *International Migration*, 52(3), pp. 116-128.
Lissoni, F., Montobbio, F. and Zirulia, L. (2013) 'Inventorship and authorship as attribution rights: An enquiry into the economics of scientific credit', *Journal of Economic Behavior & Organization*, 95(0), pp. 49-69.
Lissoni, F., Montobbio, F. and Zirulia, L. (2020) 'Don't leave me this way: Misallocation of scientific credit in patent-publication pairs', *Industrial and Corporate Change*, (forthcoming).
Martínez, G. L., Raffo, J. and Saito, K. (2016) *Identifying the Gender of PCT inventors*.
Miguelez, E. and Fink, C. (2017) 'Measuring the International Mobility of Inventors: A New Database', in Fink, C. and Miguelez, E. (eds.) *The International Mobility of Talent and Innovation: New Evidence and Policy Implications*. Cambridge University Press.
Murray, F. and Graham, L. (2007) 'Buying science and selling science: gender differences in the market for commercial science', *Industrial and Corporate Change*, 16(4), pp. 657-689.
Naldi, F., Luzi, D., Valente, A. and Parenti, I. V. (2004) 'Scientific and technological performance by gender', in *Handbook of quantitative science and technology research*. Springer, pp. 299-314.
No, Y. and Walsh, J. P. (2010) 'The importance of foreign-born talent for US innovation', *Nature biotechnology*, 28(3), pp. 289-291.
NSF (2019) *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Alexandria VA: National Science Foundation (https://ncses.nsf.gov/pubs/nsf19304/; last visited in 2019)
OSTP (1989) *Changing America: The New Face of Science and Engineering - Final Report*. Washington DC: Office of Science and Technology Policy: Task Force on Women, Minorities, and the Handicapped in Science and Technology.
Purkayastha, B. (2005) 'Skilled migration and cumulative disadvantage: the case of highly qualified Asian Indian immigrant women in the US', *Geoforum*, 36(2), pp. 181-196.
Rhodes, R. (2012) *Hedy's Folly: The life and breakthrough inventions of Hedy Lamarr, the most beautiful woman in the world*. Vintage.
Schmoch, U. (2008) 'Concept of a technology classification for country comparisons', *Final Report to the World Intellectial Property Office (WIPO), Karslruhe: Fraunhofer ISI*.
Stark, O. (2004) 'Rethinking the brain drain', *World Development*, 32(1), pp. 15-22.
Stark, O. and Wang, Y. (2002) 'Inducing human capital formation: migration as a substitute for subsidies', *Journal of Public Economics*, 86(1), pp. 29-46.
Stephan, P. E. and Levin, S. G. (2001) 'Exceptional contributions to US science by the foreign-born and foreign-educated', *Population Research and Policy Review*, 20(1), pp. 59-79.
Sugimoto, C. R., Ni, C., West, J. D. and Lariviére, V. (2015) 'The academic advantage: Gender disparities in patenting', *PloS one*, 10(5), p. e0128000.
UKIPO (2019) *Gender Profiles in Worldwide Patenting: An analysis of female inventorship*. UK Intellectual Property Office: Newport UK.
Wadhwa, V., Rissing, B., Saxenian, A. and Gereffi, G. (2007a) *Education, Entrepreneurship and Immigration: America's New Immigrant Entrepreneurs, Part II*.
Wadhwa, V., Saxenian, A., Rissing, B. and Gereffi, G. (2007b) 'America's new Immigrant entrepreneurs: Part I', *Duke Science, Technology & Innovation Paper*, (23).
Wayne, T. K. (2011) *American women of science since 1900*. Greenwood:
Santa Barbara CA.
Whittington, K. B. and Smith-Doerr, L. (2008) 'Women inventors in context: Disparities in patenting across academia and industry', *Gender & Society*.
Wuchty, S., Jones, B. F. and Uzzi, B. (2007) 'The increasing dominance of teams in production of knowledge', *Science*, 316(5827), pp. 1036-1039.
Özden, Ç. and Neagu, I. C. (2007a) 'Immigrant Women's Participation and Performance in the US Labor Market', in Morrison, A. R., Schiff, M. and Sjöblom, M. (eds.) *The International Migration of Women*. New York: World Bank Publications.
Özden, Ç. and Neagu, I. C. (2007b) 'Immigrant Women's Participation and Performance in the US Labor Market', in Morrison, A. R., Schiff, M. and Sjöblom, M. (eds.) *The International Migration of Women*. New York: World Bank Publications, p. pp. 153.

Appendix

We report here more details on the simulation exercise whose results we comment in section 4.2 of the main text. The exercise was designed to quantify the potential contribution of migration to the Women Inventor Rate (WIR) in the United States. The basic idea is to generate an artificial population of US-resident inventors whose gender is determined on the basis of the WIR exhibited by US natives, and to compare with the observed WIR in the real population.

In order to do so we firs computed a series of probability estimates for US-inventors to be female. We first run a logit regression in which:

- the observations are all patent*inventor pairs, for all the US native inventors;
- the dependent variable is the probability for the inventor in the pair to be a woman (GENDER=1; =0 otherwise)
- and the dependent variables consist of a set of dummies indicating the filing year of the patent and its technological fields (both WIPO Sectors and IPC technological codes).

Model specification:

$$GENDER_{ijt} = a_0 + a_1\ WIPO\_sector_i + IPC\_tech_i + year_t + e_i$$

The results of the regression are reported in Table A1.

Based on the estimated parameters, we then computed the predicted probability *p* to be female, for a generic inventor active in a given year and technological field. The probability *p* enters then as the key parameter of a binomial distribution for the GENDER variable, conditional both the year and the technological sector activity of the inventor. For each observation we drew a total of 10k GENDER outcomes. This process will result in set of *n*10k* matrices, where *n* is the number of active inventors in a specific year-sector. Each iteration within the same year-sector combination is used to compute a theoretical WIR, resulting in 10k theoretical WIR values. Figure A1 presents the lower and upper bounds of confidence intervals.

Table A1

	GENDER
WIPO Sectors	
Electrical engineering	0.266
	(0.209)
Instruments	1.557***
	(0.158)
Mechanical engineerig	-0.157
	(0.196)
Other fields	0.846***
	(0.234)
IPC Technological fields	
Audio-visual technology	-0.372**
	(0.185)
Basic communication processes	-0.199
	(0.332)
Basic materials chemistry	1.133***
	(0.161)
Biotechnology	1.742***
	(0.153)
Chemical engineering	0.152
	(0.188)
Civil engineering	-1.105***
	(0.239)
Computer technology	0.221
	(0.170)
Control	-1.466***
	(0.127)
Digital communication	-0.0878
	(0.194)
Electrical machinery, apparatus, energy	-0.0906
	(0.164)
Engines, pumps, turbines	-0.492**
	(0.236)
Environmental technology	-0.173
	(0.243)
Food chemistry	1.374***
	(0.194)
Furniture, games	-0.254
	(0.245)
Handling	0.207
	(0.186)
IT methods for management	1.046***
	(0.212)
Machine tools	-0.0484
	(0.225)
Macromolecular chemistry, polymers	0.902***
	(0.161)
Materials, metallurgy	0.401**
	(0.187)

Measurement	-1.260***
	(0.0783)
Mechanical elements	-0.180
	(0.212)
Medical technology	-0.883***
	(0.0671)
Micro-structural and nano-technology	0.679***
	(0.248)
Optics	-1.220***
	(0.138)
Organic fine chemistry	1.214***
	(0.152)
Other special machines	-0.00499
	(0.192)
Pharmaceuticals	1.404***
	(0.158)
Semiconductors	-0.157
	(0.236)
Textile and paper machines	0.316
	(0.203)
Thermal processes and apparatus	-0.335
	(0.346)
Constant	-2.790**
	(1.120)
Year dummies	Yes
N	58851
r2_p	0.0551
ll	-21677.8
chi2	2529.3

GREThA UMR CNRS 5113
Université de Bordeaux
Avenue Léon Duguit
33608 Pessac – France
Tel : +33 (0)5.56.84.25.75
http://gretha.u-bordeaux.fr/

LAREFI
Université de Bordeaux
Avenue Léon Duguit
33608 Pessac – France
Tel : +33 (0)5.56.84.25.37
http://larefi.u-bordeaux.fr/

Derniers numéros – Last issues

Ion LAPTEACRU and Ernest MIGUELEZ are the scientific coordinators of the Bordeaux Economics Working Papers. The layout and distribution are provided by Cyril MESMER and Julie VISSAGUET.