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Gender homophily and diversity in patenting: academic and corporate assignees in inventor's collaborations

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ABSTRACT

Understanding how gender dynamics shape inter-organizational collaboration is critical to addressing persistent inequalities in innovation systems. This study examines the gender composition of patenting teams and the organizational configuration of patent assignees across academic and corporate institutions. Drawing on over 100,000 U.S. patents (2000–2015), we explore how the share of women coinventors in a patent is associated with collaborations within a single academic organization or across multiple partners. Building on the literature on gender homophily, inequality in scientific teams, female participation in academia, and gender differences in professional networks, we test whether the share of female inventors relates to the likelihood that a patent involves multiple academic and corporate assignees. Our results show that modest increases in women's participation broaden academic collaboration, consistent with the benefits of heterophily, whereas teams with higher female representation tend to display narrower networks and less inter-organizational engagement. Additionally, higher shares of women inventors are consistently associated with a lower likelihood of including corporate partners. Nonetheless, in recent years the probability of producing collaborative patents has increased for both homogeneous (multiple universities) and heterogeneous (university-company) collaborations at all levels of female participation. These findings illustrate how gendered team structures shape organizational linkages in innovation.

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Patents; innovation; gender; inventor teams; homophily

1 Introduction

Despite gradual improvements in women's participation in science and technology, female scientists remain significantly underrepresented in patenting teams. To date, patented inventions are still predominantly produced by male inventors: in the two decades between 1999-2020, 96% of patents include at least one man as listed inventor, while only 23% of them included at least one woman, and only 4% of international patents were invented exclusively by women – either as a single inventor or as a team of women inventors (Aanstoos et al. 2023). This underrepresentation often reflects

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broader gender disparities in innovation systems and is symptomatic of structural barriers, including access to resources, mentorship, collaborations, and recognition (Avolio, Chávez, and Vílchez-Román 2020; Wang et al. 2020). This issue represents not only a social inequality challenge but can also have significant implications for innovation ecosystems. Persistent gender disparities in inventorship limit the pool of available talent and may skew innovation trajectories by excluding diverse perspectives, favoring the creation of patents in 'male-oriented' fields, and creating epistemic bubbles, with insular, homogeneous clusters that may reinforce existing disciplinary and social boundaries. Such distortions and siloed environments can constrain the cross-fertilization of both ideas and networks, which is essential for a dynamic innovation ecosystem.

Previous literature has highlighted that the biases against women in science can create compound disadvantages when female scientists work together in teams with two or more female inventors (Caviggioli, Colombelli, and Ravetti 2022; Lerchenmueller, Hoisl, and Schmallenbach 2019). One of the key issues is that female inventors typically face structural disadvantages in forming high-quality, diverse networks: women are less likely to be embedded in expansive and strategically valuable collaborative interactions, and more often form closed or academically bounded connections (Rua-Gomez, Carnabuci, and Goossen 2023). This pattern is consistent with well-documented tendencies toward gender *homophily* in professional and scientific networks, whereby social similarity and gendered norms shape collaboration choices (McPherson, Smith-Lovin, and Cook 2001; Yang, Chawla, and Uzzi 2019; Zeltzer 2020). Since knowledge networks are key for the transfer and recombination of information, ideas and competencies, collaborating with a broad and diverse group of scientists is crucial for scientific breakthroughs (Singh and Fleming 2010; Wuchty, Jones, and Uzzi 2007). However, research indicates that women tend to construct and utilize professional networks in distinct ways compared to men. Their networks are typically characterized by stronger interpersonal ties and greater relational cohesion, yet they tend to be less oriented toward instrumental gains and market-driven objectives. Moreover, female scientists on average have less access to international networks, with smaller, less prestigious collaborators and less favorable positions in each network compared to male scientists (Jadidi et al. 2018; Kwiek and Roszka 2021).

Additionally, the gender distribution of scientists across different types of organizations is not homogeneous: in most countries, a larger proportion of female inventors are affiliated with academia, a sector characterized by different innovation dynamics and incentives compared to the private sector (Abramo, D'Angelo, and Murgia 2013). While women inventors are more prevalent in academia than in the private sector, patent applications coming from academia represent only a minor share of the total (Aanstoos et al. 2023). Given that (i) patenting teams with high prevalence of female inventors remain exceedingly rare, (ii) female scientists are more concentrated in academic settings, and (iii) the networks formed by women inventors exhibit distinct structural characteristics, a comprehensive understanding of collaborative innovation dynamics based on gender must explicitly account for all these factors. Yet, to date, no empirical evidence has examined how different levels of gender homophily – defined as the tendency to collaborate with people of the same gender (McPherson, Smith-Lovin, and Cook 2001) – relates to the configuration of collaborative patents across universities and corporate boundaries, involving one or more institution in the academic and/or private sector. By addressing this gap, this study extends the literature on gender homophily from the interpersonal and team levels to the inter-organizational domain, offering new

insights into how gendered collaboration patterns could influence the structure and diversity of innovation networks.

In this context, this article examines the evidence for the emergence of collaborative patenting across different organizational networks, whereby more than one assignee is present for a given patent, depending on the prevalence of women in the patenting team. Based on the existing evidence of women's underrepresentation in patenting, concentration in academia, and their 'narrower' scientific networks, we hypothesize that a non-linear relationship could exist between the share of women in an inventors' team and the likelihood of producing a collaborative patent that involves a homogeneous network of multiple academic institutions, and possibly even a heterogeneous network which also includes other nonacademic (corporate) inventors. At low levels of female prevalence, increasing women's share in the patenting team should enhance diversity and collaboration, and thus, increasing gender heterophily is expected to play a valuable role in creating more collaborative inventions (Østergaard, Timmermans, and Kristinsson 2011), especially with academic institutions where women are more present. However, as the share of women increases, network closure, institutional homogeneity, and limited cross-sectoral engagement may reverse this trend, leading to a decrease in collaborative patents as female homophily[1] rises. In theory, we should expect a tipping point beyond which the advantages of inclusivity may be outweighed by structural constraints embedded in gendered innovation systems, where high female homophily is coupled with overall fewer and less diverse collaborations.

We investigate whether such a non-linear relationship between gender balance in patenting teams and their collaborative network exists. Our core research question is thus, 'How does an increase in female shares in patenting teams relate to the collaborative configuration of assignees of that patent?' We analyze this question considering two collaborative configurations, a homogeneous one of multiple assignees in different academic institutions, and a heterogeneous one with multiple assignees both in academic and private sector institutions; these two collaborative settings are contrasted to the case of minimal collaboration, namely having only one (academic) assignee. We consider how these collaborative configurations of patent assignees vary depending on the degree of male and female homophily at the extreme endpoints of female participation. Moreover, we consider how this relationship changed over time, confronting the early 2000s versus later years up to 2015. With a sample of more than 100'000 US patents, we observe that the dynamics at play are quite different between homogeneous academic collaborations, which indeed exhibit significant non-linearities, and heterogeneous university-company ones, and we confirm that they changed over the years.

The rest of the article is organized as follows. Section 2 positions our research questions within the literature and develops our theoretical expectations regarding gender and collaborations across multiple organizations. Section 3 illustrates the data and empirical methodology, followed by the results in Section 4. Finally, Section 5 discusses the interpretation of our main findings, and concludes.

2 Theoretical background

The concept of gender homophily has long been rooted in social sciences and network theory and, more recently, has gained traction within innovation studies. A rich

theoretical tradition has examined the mechanisms and implications of homophily within teams and networks across multiple levels of analysis – including individual, organizational, and societal dimensions (Baccara and Yariv 2013; Farè and Vismara 2025; Link 2025; Mele 2022; Zuckerman 2024). While this theoretical literature on homophily offers a robust conceptual foundation relevant to innovation ecosystems, entrepreneurship, and technological collaborations, empirical research has remained largely concentrated in specific domains, such as scientific coauthorship, entrepreneurial and managerial networks, and founding teams (Bednar, Gicheva, and Link 2021; Dohse, Goel, and Nelson 2019; Farè and Vismara 2025; Kwiek and Roszka 2021; Link 2025; Zhang et al. 2018), with only a few empirical contributions looking at homophily and patenting inventors (Subramani and Saksena 2024; Tahmooresnejad and Turkina 2022; Wang et al. 2020). Furthermore, there remains a need for analyses that bridge micro-level homophilic dynamics in teams with macro-level organizational structures. Therefore, this study contributes to the literature on homophily in innovation by examining how gender-based homophily among inventors is linked to inter-organizational collaboration, focusing specifically on the collaborative dynamics reflected in multi-assignee patenting.

This investigation draws on two primary streams of literature. First, we engage with research examining gender dynamics and the structural disadvantages faced by women within scientific teams, including patterns of collaboration, recognition, and innovation outcomes. Second, we build on scholarship analyzing the differences in female participation in academic and nonacademic organizations, along with broader evidence on gender differences in the formation and strategic use of professional networks. These two strands of literature inform our empirical investigation of how different levels of gender homophily within inventor teams should relate to the heterogeneity and openness of the organizational networks created through collaborative patenting.

2.1 Women in scientific collaborations and homophily in teams of inventors

A necessary first step toward examining the relationship between gender homophily in patenting teams and the organizations involved in the patenting process is, first of all, to map the most relevant gender disparities at play, which can then influence patterns of participation, collaboration structures, and innovation trajectories for men and women. In this section, we discuss how, according to existing evidence, homophily amongst women can present advantages and disadvantages for female scientists, starting from broader considerations about female disadvantages in innovation systems.

While women's participation in patenting activities has shown an encouraging upward trend, female inventors continue to be significantly underrepresented worldwide (Sugimoto et al. 2015; USPTO 2020). For example, at leading institutions such as the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO), women constitute only about 13–15% of inventors (Tahmooresnejad and Turkina 2022; USPTO 2020). Men represent the majority of scientists active in STEM fields (science, technology, engineering and mathematics), particularly within patent-intensive sectors, and persistent gender differences continue to characterize both productivity and career progression trajectories in technological ecosystems (Huang et al. 2020).[2]

This literature has extensively examined the roots of these gender differences, observing that these dynamics are multifaceted and embedded in broader gendered structures

within scientific professions in general (Avolio, Chávez, and Vílchez-Román 2020; Huang et al. 2020; Tomassini 2021). At the individual level, women's career trajectories are shaped by a combination of preferences, psychological traits, educational pathways, and family responsibilities, which are often different from those of their male colleagues (Ceci and Williams 2011; Fox, Whittington, and Linkova 2017). Moreover, studies have shown that individual factors operate within a systemic context of social norms, entrenched stereotypes, as well as explicit and implicit biases (van den Besselaar and Sandström 2016). Furthermore, the scarcity of women in scientific institutions can result in environments that are inadequately supportive, unwelcoming, or even hostile, to the point of being marked by episodes of discrimination and sexual harassment (Jagsi et al. 2016; National Academies of Sciences Engineering & Medicine 2018).

Unsurprisingly, empirical studies have shown that, in this context, female scientists often exhibit a preference for working with other women, in part to address these issues arising from being the minority. This pattern of gender-based homophily has been observed across various disciplines. For instance, research analyzing coauthorship networks has found that collaborations between same-gendered colleagues occur more frequently than would be expected by chance (Holman and Morandin 2019). Additionally, studies have shown that female scientists are more likely to form collaborations with other women, potentially as a strategy to navigate the challenges associated with being underrepresented in some fields (Wang et al. 2023).

While collaborating with other women may offer significant advantages – such as facilitating communication, fostering a sense of psychological safety, and enhancing mutual support – it can simultaneously reinforce some of the structural disadvantages and discriminatory barriers that female scientists already face. When women cluster into homophilous teams, they may remain marginalized from larger, more influential scientific networks, limiting their access to critical resources, prestigious collaborations, and broader visibility within the scientific community. As a result, gender homophily, although potentially beneficial at the interpersonal level, may inadvertently exacerbate the systemic inequities that constrain women's career advancement and recognition in scientific innovation (Caviggioli, Colombelli, and Ravetti 2022). It has been well documented that women in science experience a set of specific disadvantages in accessing tangible and intangible productive assets.[3] Women frequently have access to less funding (Bedi, Van Dam, and Munafo 2012; Oliveira et al. 2019), fewer citations (Maddi and Gingras 2021; Roper 2019) and, crucially for our study, smaller, less prestigious international networks of coauthors and coinventors, and tend to occupy peripheral rather than central positions within these professional structures (Jadidi et al. 2018; Kwiek and Roszka 2021).

As patenting increasingly evolves into a collaborative enterprise rather than a solo endeavor (Kerr and Kerr 2018), the structure of inventor teams – and the positional dynamics within them – has become a critical site for examining gendered inequalities. The disadvantages faced by individual female scientists do not dissipate within teams; rather, they may be magnified. The presence of female inventors within collaborative teams may expose the entire team to systemic biases operating in male-dominated environments, such as diminished access to influential networks, decreased visibility, and reduced access to key resources. Initial empirical evidence suggests that teams involving female inventors can experience slower career progression and reduced productivity

relative to all-male teams, as gendered disadvantages may extend to collaborative outcomes (Avin et al. 2015; Karimi et al. 2018; Meng 2016).

Thus, overall, two competing forces emerge in the literature. On one hand, female homophily may exacerbate existing disadvantages for women in science. Teams composed predominantly of women may collectively face more substantial challenges related to resource acquisition, network centrality, and external visibility, thereby amplifying structural inequalities (Reardon 2022). On the other hand, gender homophily may offer distinct advantages (Lawrence and Shah 2020).[4] Homophilous teams may benefit from enhanced internal cohesion, facilitated communication, and higher levels of trust and reciprocity among members (Kegen 2013). Such team environments may reduce interpersonal conflict and psychological stress, especially given that women tend to report lower levels of competitiveness and risk tolerance compared to men (Flory, Leibbrandt, and List 2015; Niederle and Vesterlund 2007).

Understanding the dual potential of gender homophily is thus critical. Team composition dynamics can offer possible adaptive strategies for mitigating some of the psychological and organizational stresses faced by women in scientific innovation, but simultaneously risk reinforcing structural inequalities. Building on the evidence in this literature, we expect that the dynamics of gender homophily in patenting teams may be non-linear. In fact, they may depend on the proportion of women scientists within the team: when women are a small minority, more female homophily may bring additional benefits from growing representation and additional diversity in male-dominated groups, while too much homophily in teams that are female-dominated could ultimately lead to an exacerbation of female disadvantages.

A key exemplification of this phenomenon should be evident in the types of organizational networks and cross-institutional collaborations formed by patenting teams with different degrees of female prevalence. For these gendered dynamics, it is essential to consider the collaborative networks and environments in which collaborations take place, and in particular, differences between academic and nonacademic settings are critical for homophilic dynamics. We discuss some of the evidence in this regard in the next section.

2.2 Gendered dynamics in organizations and professional networks

The second element underlying our analysis concerns the interaction between gender and institutional collaborations for innovation, both in terms of specific organizations and in social and professional networks. In particular, we discuss why women in science tend to be more present in academic contexts rather than in the private sector, and why they structure and exploit their collaborative networks differently. The distinction between academic and corporate organizational contexts in shaping collaboration dynamics has been well established in the literature (D'Este and Patel 2007; Goel, Göktepe-Hultén, and Grimpe 2017; Perkmann et al. 2013) and is particularly important for understanding how gendered patterns of participation may intersect with sectoral differences in innovation behavior.

The gender distribution of scientists across different types of organizations is not homogeneous and women inventors are more prevalent in academia than in the private sector (Aanstoos et al. 2023; Abramo, D'Angelo, and Murgia 2013). This is due

to a combination of historical, structural, and cultural factors. While both fields have made strides toward gender equality, disparities persist due to differing institutional dynamics and societal expectations. Claudia Goldin's extensive research on the historical role of women in the U.S. economy (Goldin 2006, 2023) has highlighted how women have historically been more integrated into the academic sector than the corporate world, due to earlier access to higher education and more structured career paths. In fact, higher education institutions were among the first to open their doors to women, albeit often in limited numbers. This early inclusion allowed women to establish careers in academia from an earlier date.

In contrast, corporate environments, especially in leadership roles, have been predominantly male-dominated, with women facing significant barriers to entry and advancement. Moreover, academic careers typically often offer more flexibility in terms of work hours and location, which can be advantageous for individuals balancing family responsibilities. In contrast, corporate roles, particularly in leadership positions, may demand longer hours and greater mobility for work, which can be challenging for those with caregiving duties. Studies have long shown that women, especially those with children, are more likely to experience slower career progression in environments that do not accommodate family responsibilities (Carr et al. 1998; Cech and Blair-Loy 2019; Williams, Blair-Loy, and Berdahl 2013). Societal expectations often place a disproportionate burden of domestic responsibilities on women, influencing their career choices. In academia, the emphasis on research and teaching can sometimes allow for more autonomy, whereas corporate environments may have more rigid structures and expectations. These cultural norms can steer women toward academia, where they might perceive a better alignment with their personal lives (Rafnsdóttir and Heijstra 2013).

Furthermore, beyond the concentration of female scientists in academia, there are significant gender differences in how women design, participate and leverage connections in their institutional networks (academic, corporate or involving other organizations). In general, previous studies have revealed that women on average have fewer networks compared to their male counterparts (Cromie and Birley 1992; Hanson and Blake 2009). Furthermore, women also spend less time networking since they face higher barriers in balancing family and work responsibilities compared to their male counterparts (Verheul, Uhlaner, and Thurik 2005). More specifically, women appear to form networks that are different from men and then exploit them differently (Mengel 2024; Yang, Chawla, and Uzzi 2019). We consider each of these two aspects in turn.

First, documented empirical findings show that men's and women's social networks differ in their design. Women tend to form networks that are more stable, path-dependent, and composed to a higher degree of strong rather than weak links. On the contrary, men are less selective and more opportunistic in their interpersonal behavior, which leads them to develop networks with more new links and consisting of weaker ties. The seminal work by (Granovetter 1973) distinguishes between strong links (i.e. close relationships) and weak links (i.e. more casual and opportunistic acquaintanceships) and shows that weak links are often more useful in contexts where acquaintances' greater ability to provide novel information outweighs their lower motivation to provide support and help. Women also tend to build more informal networks within their family and friend sphere (Brush 1992; Ibarra 1992; Munch, McPherson, and Smith-Lovin 1997; Verheul, Risseeuw, and Bartelse 2002), whereas, on the contrary, men rely on more formal networks

that could be relevant and useful sources of knowledge for business-related benefits. These differences may exert a substantial influence on both the structural typology and the degree of openness and heterogeneity characterizing the collaborative networks established by male and female scientists, potentially shaping patterns of knowledge exchange, resource access, and professional visibility within an academic context.

Second, extant literature reveals broad gender differences not only in the formation of professional networks but also in their exploitation (Friebel et al. 2017; Lalanne and Seabright 2011; Lindenlaub et al. 2014). This literature builds again on the notion of strong and weak links in network relationships (Granovetter 1973). It shows that women are more likely than men to rely upon strong links (i.e. in close relationships) rather than in opportunistic ones (Baumeister and Sommer 1997; Benenson 1993; Booth 1972; Moore 1990), but weak links favour better work-related outcomes, such as profitable exchanges, compared to strong links. Moreover, recent evidence supports the view that women and men leverage their networks differently (Beaman, Keleher, and Magruder 2018) and obtain different work-related benefits because of different network structures (Lindenlaub et al. 2014). Differences in men's and women's social networks may, therefore, be crucial in understanding gender differences in outcomes (Bertrand 2011). Based on this evidence, we argue that collaborative configurations should differ systematically by gender, with men more likely to cultivate broader, strategically oriented networks aimed at maximizing professional advancement and access to resources, and thus more contacts with industrial partners and the corporate ecosystems of innovation that are closer to the market; while women tend to form more intimate, trust-based ties that may offer emotional support but fewer instrumental benefits in competitive scientific environments.

3 Data and methodology

To investigate the relationship between different degrees of gender homophily and the collaborations developed across institutions in patenting activities, we collected data on granted patents from PatentsView, a repository that contains information from the United States Patent and Trademark Office (USPTO), and from Patstat, a comprehensive database provided by the European Patent Office (EPO) with bibliographical data.[5] PatentsView provides disambiguated assignees and inventors; the names of the latter are classified by gender through the application of a specific algorithm, which leads to the disambiguation of 93% of the patents; our investigation excludes those patents with some inventors whose gender has not been identified. Patstat provides a classification of the nature of the assignees: company, university, individual, and so on.

Our analysis focuses on patents filed in the period 2000-2015, allowing us to examine temporal patterns and potential changes in gender dynamics over time, and reporting a university among the assignees.[6] The final sample considers 116,383 patents: 75% have a single assignee; 9% have more than one assignee, all universities; and 16% have more than one assignee with at least one university and one company among them.

Our modeling approach operates at the level of an individual patent. To test our hypotheses regarding the (possibly non-linear) relationship between the share of women inventors and their network of co-assignees, we apply the following logit model to assess the likelihood that a patent displays specific networks of collaborations across institutions:

NETWORKj = β1 FEMALE SHAREj + β2 (FEMALE SHAREj)2 + θj + zj (1)where *j* is a given patent in a given year. The dependent variable is a dummy equal to one when we observe a cross-institutional collaboration, i.e. the patent reports more assignees with respect to the examined sample. A first sample focuses on patents owned by universities only and thus compares solo patents with those resulting from inter-universities collaborations. A second sample compares solo patents with those where the collaborating organizations are universities and companies.

The key explanatory variable is the share of female inventors in the patenting team. An increase in this share at low levels of female participation entails an increase in heterophily (predominantly male-dominated teams becoming more gender diverse), however, an increase of this share beyond a fifty-fifty ratio of males to females implies greater female homophily. We do not expect that these effects should necessarily be the same; therefore, we also include a quadratic term to account for non-linearity when moving from heterophily to female homophily.

The models include a set of controls (θ) for time, technological fields, and the number of inventors. The technological fields are identified according to the WIPO Concordance table that associates International Patent Classification codes to 35 groups.[7] Furthermore, universities are characterized by a dummy equal to one for U.S. organizations, and patent quality is controlled through the number of citations received (data from Patstat). The Appendix reports the correlation matrix and descriptive statistics for our data.

4 Results

Before turning to the multivariate analysis, we begin by examining the unconditional trends in team size and gender composition across the three network types. The selected sample of US patents granted to universities with teams of inventors is characterized by an increasing number of inventors in each type we have distinguished: patents with a single assignee ('university – solo assignee'), collaborative patents with multiple universities and no companies ('collab. among universities'), and collaborative patents with heterogeneous networks with at least one company among the assignees ('collab. univ and companies'). As expected, solo-assignee patents show a smaller average number of inventors (3.31 in the whole time frame) than those classified as collaborative among universities (4.35) and those including companies (4.66). Figure 1 and Figure 2 summarize the trend of number of inventors and female share among inventors for the three groups. While the modest increase in the team size is comparable for solo universities and collaborative networks (Figure 1), female participation is growing slightly for solo universities, more visibly for inter-universities collaboration, whereas collaborations involving companies display no clear upward trend (Figure 2).

Next, we move to the baseline model, which contrasts the two types of wider collaborations (homogeneous inter-university collaborations and heterogeneous university-company collaborations) relative to solo university patents. The results present the two possible combinations, with and without the quadratic term: first, looking at the probability that a patent is from multiple homogeneous university assignees compared to a single assignee from a university; second, considering the probability that a patent is from multiple heterogeneous assignees (university and company) compared to a single university. Results on the complete time frame 2000–2015 are reported in Table 1 below.

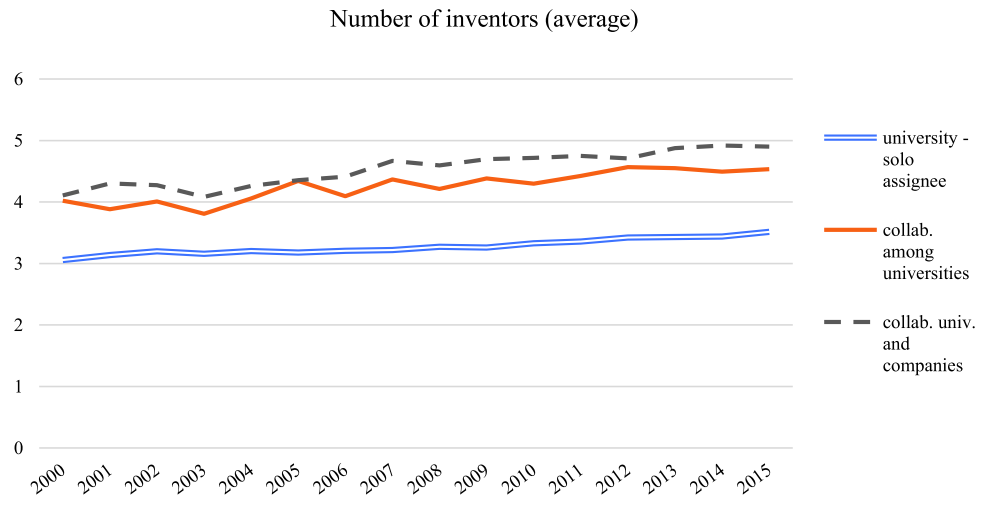


Figure 1. Average number of inventors per patent in each application year and distinguishing among patents owned by a single university, by multiple universities, and including at least one company among assignees.

Considering the linear models (1 and 2), we observe a significant negative relationship between the female share in the patenting team and the likelihood of the team to collaborate with other universities, as well as between universities and companies. The linear model, however, cannot distinguish differential effects taking place at low levels of female participation (when gender heterophily is increasing) versus higher levels of female participation (when female homophily is increasing). For this reason, we introduce a quadratic female share and observe some more nuanced effects. The validity of the quadratic relationship over the linear one is then tested following Lind and Mehlum (2010) and Haans, Pieters, and He (2016) (further details in the Appendix in Table 5).

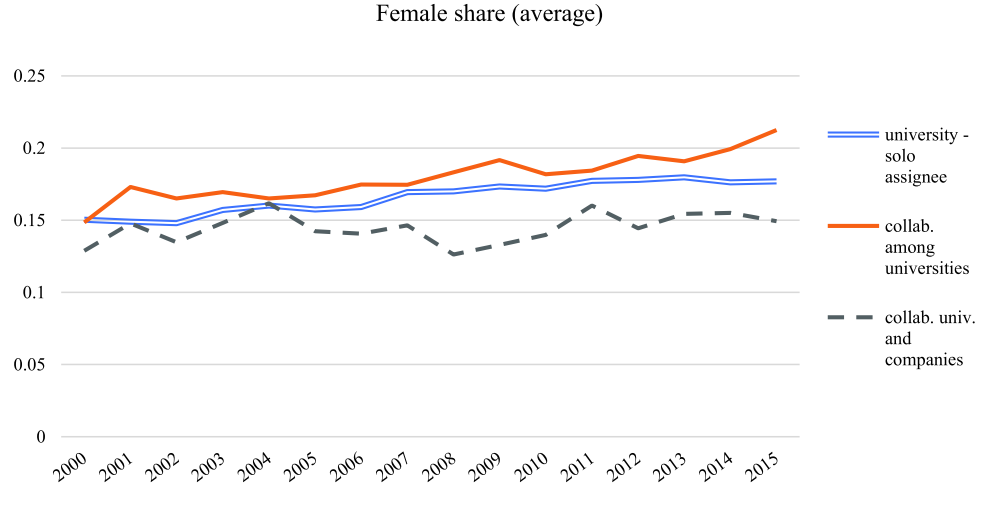


Figure 2. Average share of female inventors per patent in each application year and distinguishing among patents owned by a single university, by multiple universities, and including at least one company among assignees.

Table 1. Results of logit model where the dependent variable is the collaboration dummy. Full study period 2000–2015.

Sample	(1) Single univ. Vs multi univ.	(2) Single univ. vs univ. and companies	(3) Single univ. Vs multi univ.	(4) Single univ. vs univ. and companies
Female share	−0.1556***	−0.9292***	0.3447***	−0.3379***
	(0.0494)	(0.0451)	(0.1260)	(0.1170)
Fem. Share^2			−0.8259***	−1.0815***
			(0.1941)	(0.2010)
# of Inventors	0.2626***	0.3379***	0.2564***	0.3307***
	(0.0053)	(0.0046)	(0.0055)	(0.0047)
# of cit. received	0.0005***	0.0008***	0.0005***	0.0008***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
U.S. univ. dummy	−0.4764***	−1.0796***	−0.4754***	−1.0784***
	(0.0227)	(0.0187)	(0.0227)	(0.0187)
Controls for: Time and tech. fields	Yes	Yes	Yes	Yes
Constant	−2.8796***	−2.1716***	−2.8791***	−2.1659***
	(0.0468)	(0.0382)	(0.0468)	(0.0382)
Obs.	98048	106011	98048	106011
Log likelihood	−30731.6938	−42194.2284	−30722.2221	−42178.7744
chi-squared	4727.9559	13246.5502	4746.8992	13277.4581

Notes: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

The quadratic models indicate a varying role for different levels of female participation. In model (3), increasing female shares has initially a significant positive impact on the likelihood of multi-university collaborations, but this effect decreases at higher female shares, with a significant negative quadratic term. Indeed, following the tests suggested by Lind and Mehlum (2010) and Haans, Pieters, and He (2016), we confirm that model (3) displays a valid quadratic relationship. Instead, when companies are involved, the effect of higher shares of women is always significantly negative (model 4) and the tests show that the linear relationship is preferred to a quadratic one (see Table 5 in the Appendix).

To improve the understanding of these relationships, Figure 3 shows the predicted values for the likelihood of observing a collaborative patent for different values of female share (keeping other variables at their mean) from the four models of Table 1. In the case of inter-university collaboration, which presented a valid inverted U-shaped relationship, the most positive correlation occurs around a female share of 26.5% and then starts decreasing (right panel of Figure 3). Thus, when women are about one quarter of the patenting team, we expect the highest likelihood to observe a patent with multiple universities as joint assignees. Conversely, the highest chance of observing a collaboration that also involves companies is associated with a team of all male inventors, and any increase in female representation reduces linearly the probability of an open network with university and company assignees involved in the patent (left panel of Figure 3).

These results are in line with the theoretical expectations deriving from the higher prevalence of women in universities and the differences observed in men's and women's social networks. As women tend to build fewer, more stable, stronger and path-dependent networks, an increase in female representation and homophily in collaborative patents is associated with closer networks. High female homophily is indeed associated with the lowest probability that a patent is from multiple university assignees compared to a single assignee from a university, and the probability is even lower in the

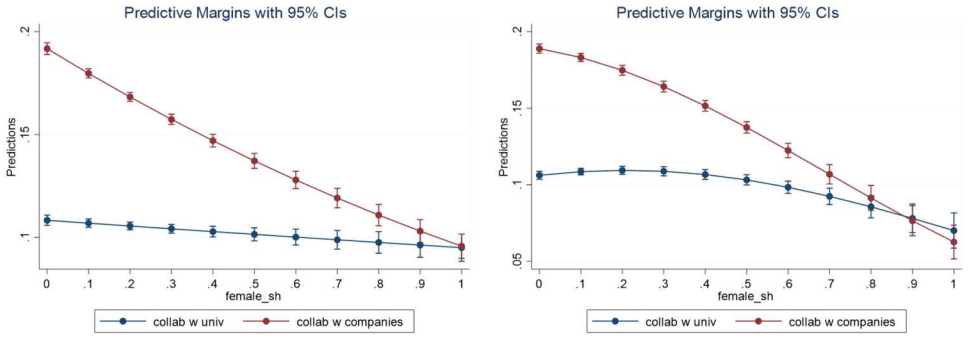


Figure 3. Relationship between female share and likelihood to observe a collaborative patent (multiple universities in blue; universities and companies in red). Predicted values when considering the other variables at their mean. Panel on the left considers the linear models 1 and 2 from Table 1; panel on the right, the quadratic models 3 and 4.

case that a patent is from multiple heterogeneous assignees (university and company) compared to that of a single university. On the contrary, as men tend to build weaker, more opportunistic, and business-oriented networks, male homophily is associated with the highest openness of the network when considering joint participation of university and private sector organizations in the network.

Next, we further explore the presence of dynamic changes throughout the period under consideration, considering the trend of increasing female participation over time. Table 2 and Table 3 report the results of the same models tested on two subsamples: at the beginning and at the end of our study period, respectively.

These results show that these gender effects did evolve in our sample of inventors over time. To interpret the results correctly, once again we test whether the linear or quadratic model is the most appropriate one according to Lind and Mehlum (2010) and Haans, Pieters, and He (2016). For the beginning of the examined period (2000-2005), in all cases linear modeling is a better approximation of the relationship between collaboration and female representation than the quadratic one. In the later period (2011-2015), the linear model is still the most appropriate for university-company collaborations, however we confirm the quadratic relationship of model (3), whereby female shares initially go hand in hand with an improvement in the chances of multi-university collaborations, but then decline, confirming the inverted U-shape specification. Figure 4 reports graphically these relationships, focusing only on the models confirmed by the quadratic tests: in the case of inter-university collaboration, the most positive correlation occurs around a null female share in the 2000–2005 period (linear model in the left panel of Figue 4), while this value increases to 30% in the 2011–2015 period (quadratic model, right panel of Figure 4). Also, the probability that a patent is from multiple homogeneous university assignees compared to a single assignee from a university in the case of full female homophily (teams composed only of women) increases between the two periods.

When companies are involved, the highest chance to observe a collaboration is instead always associated with a team of all male inventors (linear models in left and right panels of Figure 4), but the decrease in the likelihood to observe a collaboration with companies with more women in the inventor team becomes less marked over time. The probability that a

Table 2. Results of logit model where the dependent variable is the collaboration dummy. Examined sample: years 2000-2005.

Sample	(1) Single univ. Vs multi univ.	(2) Single univ. vs univ and companies	(3) Single univ. Vs multi univ.	(4) Single univ. vs univ and companies
Female share	−0.2458*	−0.2458*	0.0154	0.3454
	(0.1260)	(0.1260)	(0.3153)	(0.3074)
Fem. Sh.^2			−0.4386	−1.7005***
			(0.4896)	(0.5409)
# of Inventors	0.2588***	0.2588***	0.2555***	0.3108***
	(0.0142)	(0.0142)	(0.0147)	(0.0126)
# of cit. received	0.0004	0.0004	0.0004	0.0012***
	(0.0003)	(0.0003)	(0.0003)	(0.0002)
U.S. univ. dummy	−0.6593***	−0.6593***	−0.6586***	−0.6521***
	(0.0579)	(0.0579)	(0.0579)	(0.0490)
Controls for: Time and tech. fields	Yes	Yes	Yes	Yes
Constant	−3.0404***	−3.0404***	−3.0392***	−2.7142***
	(0.1073)	(0.1073)	(0.1074)	(0.0888)
Obs.	20992	20992	20992	21777
Log likelihood	−5318.9596	−5318.9596	−5318.5476	−6964.5192
chi-squared	728.9535	728.9535	729.7776	1165.3065

Notes: *p < 0.10, **p < 0.05, ***p < 0.01.

patent is from multiple heterogenous university-company assignees compared to a single assignee in the case of full female homophily almost doubles from the first to the second period analyzed. Overall, we see that at all levels of female participation, the chances of collaborative patents have increased over time , both for homogeneous collaborations (multiple universities) and heterogeneous ones (university-company collaborations).

Taken together, these results show that the role of women's presence in patenting teams has evolved as an increasingly meaningful correlate of collaboration patterns

Table 3. Results of logit model where the dependent variable is the collaboration dummy. Examined sample: years 2011–2015.

Sample	1 Single univ. Vs multi univ.	2 Single univ. vs univ and companies	3 Single univ. Vs multi univ.	4 Single univ. vs univ and companies
Female share	−0.0337	−0.8877***	0.4829***	−0.3450**
	(0.0685)	(0.0643)	(0.1748)	(0.1647)
Fem. Sh.^2			−0.8370***	−0.9829***
			(0.2641)	(0.2791)
# of Inventors	0.2528***	0.3224***	0.2465***	0.3158***
	(0.0072)	(0.0063)	(0.0074)	(0.0065)
# of cit. received	0.0004	0.0005**	0.0004	0.0005**
	(0.0003)	(0.0002)	(0.0003)	(0.0002)
U.S. univ. dummy	−0.3396***	−1.1154***	−0.3389***	−1.1142***
	(0.0318)	(0.0275)	(0.0318)	(0.0275)
Controls for: Time and tech. fields	Yes	Yes	Yes	Yes
Constant	−2.9016***	−2.1383***	−2.9034***	−2.1343***
	(0.0585)	(0.0477)	(0.0585)	(0.0477)
Obs.	43876	47708	43876	47708
Log likelihood	−15087.2973	−20127.7124	−15082.0544	−20121.1452
chi-squared	2138.7104	6315.8049	2149.1960	6328.9394

Notes: *p < 0.10, **p < 0.05, ***p < 0.01.

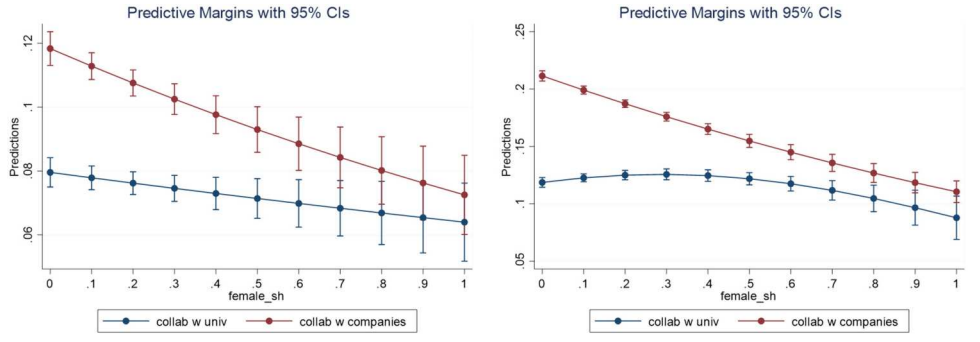


Figure 4. Relationship between female share and likelihood to observe a collaborative patent (multiple universities in blue; universities and companies in red). Predicted values when considering the other variables at their mean. Panel on the left considers earlier years (2000–2005) and plots the linear models 1 and 2 from Table 2. Panel on the right considers later years (2011–2015) and plot the quadratic model 3 and the linear model 2 from Table 3.

across organizational boundaries. In recent years, inter-university collaborations have exhibited a non-linear relationship with female participation, with higher collaborative propensity at intermediate levels of diversity. By contrast, university-industry collaborations consistently display a negative association with women's representation, although this penalty has attenuated over time.

5 Conclusion

Understanding gender disparities in scientific innovation is essential for addressing systemic inefficiencies in knowledge production and ensuring a more inclusive, collaborative, and effective technological ecosystem. Despite considerable policy attention and incremental improvements over the past decades, profound gender imbalances remain entrenched in science and technology sectors, especially in areas directly linked to patenting and commercialization activities.

Our present work contributes to a more nuances understanding of how gender dynamics unfold in collaborative innovation settings. We show that moderate increases in the female share of inventors contributing to a patent are associated with a higher likelihood of multi-university collaboration, suggesting that gender-diverse teams are more strongly positioned to engage across academic boundaries. However, when female homophily becomes dominant, this relationship reverses, reducing the probability of collaboration among universities. This quadratic relation has become prominent in recent years, while in the early 2000s, any increase in the share of women represented a disadvantage for implementing multi-university collaborations. For university-industry collaborations, the negative and linear pattern has instead remained consistent over time; teams with higher female representation are persistently less likely to engage with companies.

However, the evolution observed over time also suggests gradual improvements: the 'penalty' of higher female shares reduced between the early 2000s and the period 2010-2015, and collaborations have become more likely over time at all levels of female participation. This could reflect changing institutional norms, improved support structures, or broader shifts in the academic and corporate environments that facilitate female

inventors' engagement across sectors. Nevertheless, our findings underscore that simply increasing the number of women in innovation ecosystems is not sufficient to overcome structural barriers: the way networks remain gendered, the composition of teams and the contexts in which they operate remain crucial.

Several important questions remain open for future research. First, although our results reveal significant associations between gender composition and inter-organizational collaboration, the causal mechanisms underlying these patterns require further investigation. One limitation of our analysis is that it cannot disentangle to what extent institutional settings drive the emergence of homophilic collaboration patterns, or whether pre-existing preferences and structural constraints among female inventors lead them to form more institutionally homogeneous networks.

Second, future research should also consider the mediating role of state actors and policy frameworks, such as public funding bodies, government-sponsored innovation programs, or national strategies for gender equality in science and technology. These factors may not only influence the distribution of collaborative opportunities but also shape the overall systemic conditions under which gender homophily either constrains or facilitates inter-organizational collaboration. Furthermore, distinguishing between domestic and international collaborations could provide deeper insight into how national policy environments and cross-border dynamics affect the relationship between team composition and collaborative reach.

Finally, attention in future studies should also be directed toward organizational practices and internal structures – such as collaboration incentives, team formation mechanisms, evaluation criteria, mentoring opportunities, and leadership composition – which may either reinforce or mitigate gendered network patterns. Understanding how these organization-level dynamics interact with team composition can offer practical pathways for fostering more inclusive and structurally diverse innovation environments.

Notes

1. For the purposes of our empirical analysis, we define gender homophily as cases in which a majority of team members are of the same sex. Thus. peak heterophily occurs in teams that have a 50% representation of each gender. More sophisticated empirical definitions of gender homophily exist (Lawrence and Shah 2020), for example estimating how many gender pairings are observed above and beyond what should be expected given gender ratios in a given field. For the purposes of our analysis, it is sufficient to say that homophily increases at the two ends of the spectrum (all male and all female patenting teams) and conversely heterophily increases as we move towards a balanced gender representation.
2. While women are generally less likely than men to become entrepreneurs or innovators, it should be noted that the gender gap narrows in specific settings – for instance, in not-for-profit entrepreneurship (Zhang et al. 2025) and in innovative start-ups with a social orientation (Colombelli, D'Ambrosio, and Ravetti 2025).
3. A broad reading of the literature has shown that this issue applies not only to women in science. Indeed, in general, women have to face particular difficulties in accessing the same economic resources as men (Else 2019), even in times of economic growth (Bennett, Ravetti, and Wong 2021).
4. Homophilic behavior has been documented extensively not only on the basis of gender, but for any socially salient characteristics such as ethnicity, religion, and social class, and in many contexts can lead to social segregation (Ravetti et al. 2019; Reme et al. 2022).

5. Crosswalk between the two datasets was possible via the concordance table available here: https://rawpatentdata.blogspot.com/2018/04/patentsview-patstat-concordance.html.
6. We included in the category "University" the following types of Patstat: UNIVERSITY, GOV NON-PROFIT UNIVERSITY, COMPANY UNIVERSITY, COMPANY GOV NON-PROFIT UNIVERSITY. University hospitals are not included.
7. Further information here: https://www.wipo.int/en/web/ip-statistics (last access in April 2025).

Disclosure statement

No potential conflict of interest was reported by the authors.

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7. Appendix

Table 4. Descriptive statistics of main variables and corelation matrix.

Variable		Mean	Std. Dev.	Min	Max	Correlations				
#	Name					(1)	(2)	(3)	(4)	(5)
(1)	Collab. dummy	0.247	0.431	0	1	1.000				
(2)	# of inventors	3.617	1.833	2	32	0.292	1.000			
(3)	Female share	0.167	0.223	0	1	−0.015	0.045	1.000		
(4)	# of citations received	29.840	70.223	0	3331	0.007	0.058	−0.067	1.000	
(5)	U.S. univ. dummy	0.598	0.490	0	1	−0.206	−0.141	−0.067	0.135	1.0000

7.1 Quadratic relationship: validity test

To further validate the non-linear relationships observed in our analysis with the inverted the U-shaped effects associated with female representation in patenting teams, we draw on the methodological guidelines proposed by Lind and Mehlum (2010) and Haans, Pieters, and He (2016). Their framework outlines rigorous criteria for testing and interpreting U-shaped and inverted U-shaped relationships in empirical research, emphasizing the need to go beyond visual inspection or the mere significance of quadratic terms. Following their recommendations, we implement additional robustness checks, including slope difference tests and inflection point confidence intervals, to assess the reliability and interpretability of the observed curvilinear patterns. These supplementary tests reveal that, while some relationships remain consistent with a U-shaped form, others do not meet the necessary statistical conditions for a genuine quadratic effect, underscoring the importance of cautious interpretation of non-linear dynamics in this context.

Table 5. Test of quadratic shape based on based on Lind and Mehlum (2010) and Haans, Pieters, and He (2016).

Test	Table 1 Single univ. Vs multi univ. Full sample	Table 1 Single univ. vs univ and companies Full sample	Table 2 Single univ. Vs multi univ. 2000–05	Table 2 Single univ. vs univ and companies 2000–05	Table 3 Single univ. vs univ and companies 2011–15	Table 3 Single univ. vs univ and companies 2011–15
Test 1: $\beta 2$ needs to be significant and of the expected sign and the slope must be sufficiently steep at both ends of the data range.						
in x = 0	0.031*	−0.044**	0.001	0.033	0.048*	−0.049**
	(0.011)	(0.015)	(0.022)	(0.029)	(0.017)	(0.023)
in x = 1	−0.081***	−0.132***	−0.042	−0.099***	−0.091***	−0.146***
	(0.012)	(0.006)	(0.027)	(0.006)	(0.020)	(0.012)
Test 2: The turning point needs to be located within the data range (between 0 and 1).						
Turning point in:	0.265	−0.156	0.018	0.102	0.289	−0.176
(95% Confidence Interval)	(0.206 0.324)	(−0.316 0.004)	(−0.652 0.687)	(−0.020 0.223)	(0.206 0.371)	(−0.432 0.081)
Relationship	Quadratic	Linear	Linear	Linear	Quadratic	Linear