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Determinants of Female Participation in Patenting Activity in Brazil: The Role of Multinational Corporations

Determinantes de la participación feminina en las patentes en Brasil: el rol de las corporaciones multinacionales

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Abstract

This study examines female participation in patenting activity across various institutions and the role of multinationals (MN) in this context, exploring the origin of capital and the location of firms, by analyzing patents filed at INPI-Brazil from 2000 to 2019. Despite the increasing number of female inventors, women remain underrepresented in engineering fields, with greater participation in chemistry. MNs contribute to female participation through chemical patents, while national firms and MN subsidiaries focus on engineering, which shows lower female involvement. Public policies promoting women in high-tech sectors and digital entrepreneurship are recommended to address persistent gender disparities in innovation.

Keywords: Gender, Patents, Brazil, Multinationals.

Resumen

Este estudio analiza la participación femenina en patentes entre las instituciones y el papel de las Multinacionales (EM) en este contexto, explorando el origen del capital y la ubicación de las empresas, mediante el análisis de patentes presentadas en el INPI-Brasil entre 2000 y 2019. Hay una tendencia creciente de inventoras, aunque las mujeres siguen su representadas en ingeniería y se destacan en química. Las multinacionales contribuyen a participación femenina a través de las patentes químicas, mientras que las empresas nacionales y filiales se centran en ingeniería, donde la participación femenina es menor. Se recomiendan políticas públicas para promover la integración de mujeres en sectores tecnológicos avanzados y emprendimientos digitales, reduciendo disparidades de género.

Palabras clave: Género, Patentes, Brasil, Multinacionales.

JEL Classification/ Clasificación JEL: J16, L20, O31, O54.

1. Introduction

Gender equity in science, technology, and innovation (STI) remains a pressing global challenge. Addressing gender disparities has gained prominence within international development agendas, as evidenced by the inclusion of women's empowerment in the Sustainable Development Goals (SDGs) of the United Nations' 2030 Agenda (UN, 2015). Research highlights persistent underrepresentation of women in certain technical areas and leadership positions (Yáñez, 2016; ONU Mujeres, 2020), despite evidence showing that gender diversity enhances creativity, broadens perspectives, and improves problem-solving capabilities (Díaz-García et al. 2013). Moreover, while the knowledge and digital economy —heavily reliant on STEM fields—offers opportunities to advance gender equity, it also risks exacerbating existing inequalities if systemic biases are not addressed (Yáñez, 2016; Urraca-Ruiz, 2024).

As a consequence of the second wave of feminism in the 1960s and 1970s, women have gradually advanced in higher education and the labor market (Hayashi et al., 2007). Despite these advances, the literature identifies two phenomena related to women's careers: horizontal and vertical segregation. The former refers to the unequal distribution of women and men across various fields of knowledge and economic sectors, with women being particularly underrepresented in STEM and the industrial sector. The latter pertains to the decline in women's participation as they advance to higher levels of power and visibility (Yañez, 2016).

In Brazil, significant advancements have been made in women's education. In 2021, women represented 60% of all bachelor's degrees (INEP, 2023) but the percentage of women decreases when they advance to the degrees obtained at the master's and doctoral levels: 57% and 56%, respectively (CGEE, 2024). Additionally, women constituted half of the workforce in research groups under the National Council for Scientific and Technological Development (CNPq) in 2016 (MCTI, 2023). However, disparities persist across disciplines and are more pronounced in engineering (Schneegans et al. 2021). For instance, in 2021, women represented 35% of all doctoral degrees in engineering and just 23% of the engineers with doctoral degrees who were employed (CGEE, 2024).

Despite their growing qualifications and presence in higher education, women's representation in leadership positions remains disproportionately

low. In the scientific career, the reduction in women's representation is visible when contrasting the percentage of female researchers of CNPq groups with the percentage of female leaders (Machado et al, 2019). In the labor market in general, women held only 39% of managerial positions, 24% of general director roles (Feijó, 2023), and only 2% of presidencies among Brazil's largest firms (Goulart, 2017).

In this context, the need for patent indicators by gender has been claimed and different approaches have been developed to solve this problem. Naldi et al. (2004) were the first to use a file of names in different languages to associate the gender to each name. Following this, many studies were developed (Mauleón and Bordons, 2010; Sugimoto et al. 2015; Martinez; Raffo and Saito, 2016; Carvalho; Bares and Silva, 2020; Sifontes and Morales, 2020; Medina and Álvarez, 2022) and indicators were constructed by patent offices (UKIPO, 2016; USPTO, 2020; WIPO, 2024; INPI, 2024). The above-mentioned studies share conclusions about the relevance of patent-based indicators to monitor gender gaps and show important differences by countries, technological fields, and institutional sectors. Another line of studies has analyzed gender differences in patent productivity (Whittington and Smith-Doerr, 2008), impact of patents (Sugimoto et al. 2015), and firm performance (Ferrary and Déo, 2023). Teruel and Segarra-Blasco (2022) analyzed gender diversity in fostering the development of new, patent-protectable knowledge, but highlight that occupationally diversified R&D teams may be more important.

Given the vast evidence of a gender gap across sectors, industries, countries, and regions, its application to Brazil remains limited (Azevedo and Abrantes, 2021). While Sifontes and Morales (2020) aimed to explain the factors influencing women participation in patenting activities in Latin America, they relied on data from the USPTO, which represents a small sample of patenting activity in Brazil. This study contributes to existing literature in three ways: data, methodological analyses, and new focus. Using data from invention patents filed at the National Institute of Industrial Property (INPI) from 2000 to 2019 and focusing specifically on how the origin of capital and the location of companies relate to female participation within inventor teams, a probabilistic model is applied to estimate whether a patent has female participation or not.

The aim of this paper is to identify the factors influencing the evolution of women's participation in patenting activity, highlighting specificities among multinational patent-filing companies. The article contains five sections after this introduction. Section 2 presents a review of the literature. Section 3 presents the database and the challenges overpassed to identify the gender of inventors and the institutional sector of applicants in patents. Section 4 creates a frame of reference with the evolution of female participation in all patents applied at the INPI. Section 5 presents an econometric model to test the relation between the main determinants and female participation in patents filed by residents. The final section summarizes the conclusions.

2. Literature review

2.1. Horizontal and vertical segregation

Horizontal segregation refers to the unequal distribution of women and men across different areas of knowledge and economic sectors (Yañez, 2016). Empirical evidence shows that women tend to dominate disciplines related to medicine and health sciences, social sciences, and the humanities. In contrast, fields related to exact and natural sciences and engineering —including computer and information sciences— are predominantly male-dominated. Another manifestation of horizontal gender segregation is the extremely low representation of women in industrial research.

Vertical segregation describes the unequal positioning of women and men within occupational hierarchies in science and technology. Female researchers face challenges in advancing to the highest levels of the professional hierarchy and accessing positions of power (Yañez, 2016). This phenomenon is commonly referred to as the "glass ceiling", "leaky pipeline", or "scissor effect" (Naldi et al., 2004).

Despite the increasing number of women entering higher education and pursuing professional careers in knowledge-intensive fields and new technologies, horizontal and vertical gender segregation remains persistent in STI, particularly in engineering and technology.

This kind of segregation is closely tied to gender stereotypes, which often steer women towards certain activities based on societal perceptions of their skills and preferences (Medina and Álvarez, 2022). Cultural stereotypes often associate brilliance and aptitude with men rather than women in specific domains, thereby discouraging women's interest in these areas (Bian et al., 2018). Additionally, cultural stereotypes often associate women with care, biotechnology, pharmaceuticals, and chemistry (Naldi et al., 2004; Whittington and Smith-Doerr, 2008; Morales-Valera and Sifontes-Fernandez, 2014). In contrast, fields like mechanical and electrical engineering exhibit lower female participation (Carvalho et al., 2020).

However, this study focuses solely on analyzing horizontal segregation; vertical segregation, although very relevant, is not the central concern of this paper.

2.2. Diversity and co-invention

The second factor influencing female participation in patents is the diversity within the teams. Technological knowledge and innovation have become increasingly complex, requiring greater interaction across technological fields (Avanci and Urraca-Ruiz, 2017). This heightened complexity underscores the need for diversity and complementarity within inventor teams, which surpasses the efficacy of individual inventors working alone (Wuchty et al., 2007). While individuals have unique learning histories, teams combine diverse skills, competencies, and perspectives for problem-solving (Nelson

and Winter, 1982; Dosi, 1988). Moreover, interactions among team members tend to influence both the creation and decision-making processes (Lundvall, 1992). Furthermore, a diversity of knowledge, experiences, and skills allows firms to increase their available knowledge base and improve their capacity for generating new ideas and assimilating new knowledge (Cohen and Levinthal, 1990).

The existence of co-invention and the higher number of inventors in teams may promote female participation in patents. Given that women have to balance their professional lives with numerous tasks in their private lives, being part of a supportive team of co-inventors makes it easier for them to engage in research and achieve major goals (Sifontes and Morales, 2020). As women tend to develop smaller academic and commercial networks, they often participate in inventions as co-inventors, with less responsibility (Murray and Graham, 2007; Acosta, 2022). This fact is also consistent with the difficulty women face in gaining adequate visibility for their research work (De Negri, 2020).

Gender diversity has gained attention in the corporate world because teams and leadership structures with greater gender diversity have a positive impact on certain forms of innovation (Fernández, 2015) and on firms' competitiveness (Oberfield, 2014; Ferrary and Déo, 2023). Gender diversity within teams fosters heightened creativity and provides diverse perspectives on product needs and the consumer market. Additionally, diversity in leadership facilitates the attraction of talent from human resources and enhances dialogue with other institutions. However, despite the growing importance attributed to diversity, the integration of mixed-gender groups within corporations has progressed at a sluggish pace (Azmat and Boring, 2020).

2.3. Organizational and cultural characteristics

The existing literature indicates that cultural and organizational characteristics significantly impact female participation in scientific research (Whittington and Smith-Doerr, 2008; Marques, 2017; Sifontes and Morales, 2020; Azevedo and Abrantes, 2021). Academic environments may be more conducive to female patenting than business organizations. This difference can be attributed to the varying proportions of women in the workforce within these sectors and the less hierarchical structure of academic institutions, which often foster collaborative research networks. Additionally, greater job stability in universities and government research institutions, compared to the private sector, may positively influence female participation in patenting.

Empirical studies in the United States reveal that female participation tends to be more prevalent in universities than in firms or government institutions across all technological domains (Sugimoto et al., 2015). In Ibero-American countries, female participation was also higher in patents filed by government institutions and universities than in firms (Carvalho et al., 2020).

Cooperation between institutions serves as a viable solution for organizations that may lack the necessary resources for successful innovation, enabling them to navigate these challenges more effectively. When patents are filed collaboratively by different organizations, they often include agreements regarding the control of rights over the resulting innovations and the roles of the participating organizations and inventors. These arrangements provide a level of stability and protection for all participants, thereby promoting greater inclusion of women in the innovation process (Sifontes and Morales, 2020).

Moreover, as knowledge production and diffusion become increasingly globalized, multinationals (MNs) play a critical role in shaping gender equity in the countries where they operate (OECD, 2022). However, Ferner et al. (2005) argue that the transfer of diversity practices across borders depends on different conceptions of diversity in national and foreign contexts.

Fernández (2015) highlights that transfer of HR policies across borders is contingent upon three key factors. First, the role of the subsidiary within the multinational network determines its level of autonomy and strategic focus. Since foreign subsidiaries generally prioritize technological adaptation to the local market and provide technical support to offshore units, they tend to engage in incremental innovation, whereas gender diversity is more closely associated with radical innovations. This reduces the relevance of such policies for subsidiaries that do not play a central role in generating new technologies.

Second, the nature of the knowledge involved directly affects the ease of disseminating these practices. Gender diversity management relies on cultural norms, social interactions, and behavioral changes, making it predominantly tacit knowledge. The lack of codified guidelines hinders its standardization and effective implementation in subsidiaries located in different cultural contexts.

Third, the strategic importance of HR policies for international competitive advantage influences the priority given to their transfer. Since gender diversity is not universally recognized as a key competitive differentiator, parent companies may not invest in disseminating these practices. Moreover, institutional differences between countries create barriers to the acceptance of these policies, as they may conflict with local norms and impact the subsidiary's relationships within the host country's institutional environment. Thus, these three combined factors limit the effectiveness of gender diversity policy transfer within multinational networks.

However, Yáñez (2016) points out that time and mobility limitations associated with family responsibilities may have a more significant impact on women in science and technology careers in Latin America. Although geographical mobility is very important in academic careers, in business, and especially in multinationals, the availability for regular travels is an essential requirement for career promotion, since it shows commitment to the company. As such, women may face greater challenges working in MN subsidiaries.

Considering the findings in these three subsections, this study supports the hypothesis that female participation in patents is more likely when patents are related to chemistry and life sciences, involve larger inventor teams, and

are filed by universities, research institutions and government agencies, rather than by firms, regardless of their multinationality.

3. Database

To analyze female participation in patenting activities in Brazil, this study gathers data from the INPI. Typically, patent databases for the analysis of inventive activity consider filed applications, as they represent the initial step in the patent granting process and are closest to the date of the inventive activity. The patent application process can be lengthy and varies across different official offices. Additionally, not every application ultimately receives a patent title.

Between 2000 and 2019, the INPI-Brazil received a total of 469,795 invention patent applications (INPI, 2015 and 2021). At the start of processing, approximately 3.5% of applications were either assigned a new number due to alterations in the nature of the application or were canceled for reasons such as inconsistencies in the provided information or failure to meet formal requirements. These applications often contain incomplete data on inventors or technologies and are consequently excluded from the study.

Patent documents include the names of all inventors, but the database poses several challenges in processing and analyzing this data. First, the primary data collected in application forms do not include an attribute indicating the gender of inventors. Second, approximately 12% of inventors with Brazilian nationality have missing data in the field for their national identification number of individuals (known as "Cadastro de Pessoa Física" — CPF), which complicates merging with external databases that rely on this number to access gender information. Third, the field for the inventor's name lacks standardization, requiring cleaning and standardization efforts. Standardizing names proves particularly challenging for foreign inventors, due to differing cultural conventions.

The inference of gender from the names of inventors conducted in this study involved two primary tasks: standardization and matching with name dictionaries. Two dictionaries were used to assign gender to names: data from the 2010 IBGE Census and the global dictionary of names from the World Intellectual Property Organization (WIPO). This method was unable to determine the gender of 9% of the inventors, and the highest percentages of unidentified gender were found among non-resident inventors.

Regarding patent applicants, they were classified into four institutional profiles: firms, educational/research/government institutions, individual applicants, and cooperative efforts between two or more applicants, indicating collaboration among different institutions, firms, or individuals. Additionally, firms were further categorized into sub-groups: multinational companies (residing abroad), multinational subsidiaries (residing in Brazil), and national firms. Multinational companies and subsidiaries were

identified through multiple searches using free online databases such as the Multinational Enterprise Information Platform from OECD and UNSD, US Securities and Exchange Commission website, Fortune's global firms, and corporate websites.

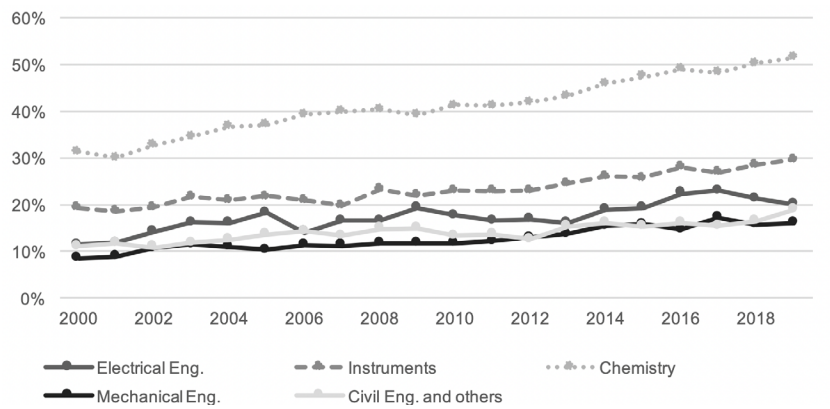
4. Evolution of female participation in Brazil

This section begins with an overview of patenting activity in Brazil from 2000 to 2019. Then, for the empirical analysis in Section 5, the probit model will use a sample that includes only patents with applicants residing in Brazil, with a subsample specifically focused on patents filed by resident firms.

The distribution of patents among foreign applicants in Brazil remained stable, with firms accounting for over 90% of applications, and the United States leading. However, among Brazilian residents, there was a significant shift in the composition of applicants. The participation of educational, research, and government institutions, as well as cooperative efforts, increased significantly, while individual applicants declined. This change can be attributed to the organization of Technology Transfer Offices in universities and research institutes (Mueller and Perucchi, 2014). Patents filed by resident firms showed a slight increase. The sectors with the highest activity at INPI-Brazil are as follows: chemistry (37%), mechanical engineering (27%); electrical and electronic engineering (14%), and instruments (13%).

Regarding female participation, there was a notable increase across all technological sectors (Figure 1). Female participation was consistently higher in chemistry, rising from 31% to 51%. In instruments, female

Figure 1. Evolution of patents with female participation by technological sectors: 2000-2019



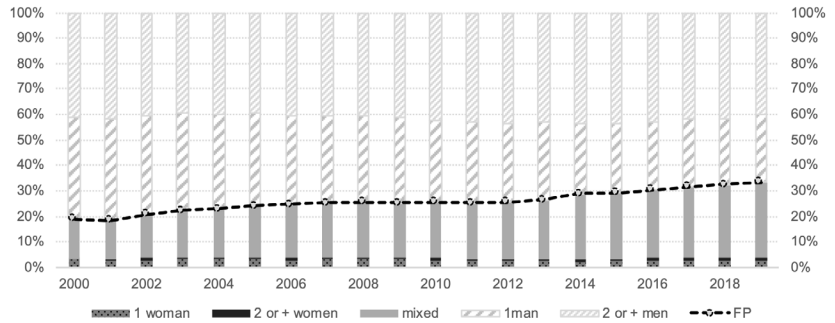
Source: Own elaboration based on data from BADEPI/INPI, extracted in March/2023.

participation grew from 19% to 30%, and in electrical and electronic engineering, from 12% to 20%. In the mechanical engineering sector, where female participation was the lowest, there was a significant increase from 8% to 16%.

Figure 2 shows that female participation (FP), as the percentage of patents with at least one female inventor, increased from 19% to 33%. This growth is primarily attributed to the rise in mixed-gender patents, which grew from 15.5% to 29%, as well as patents with two or more women, which increased from 0.5% to 1.4%. Meanwhile, patents attributed solely to all-male teams decreased from 81% to 67%, reflecting a shift towards greater gender diversity in patenting teams. These findings are consistent with previous literature (Azevedo and Abrantes, 2021). The data also show that women are less likely to be in single-gender patents compared to men, and they remain underrepresented as sole inventors. This may indicate that women play a secondary role in research more often than men (Mauleon, Daraio and Bordons, 2013). Regarding the increase in mixed-gender teams, this could be linked to the perception that gender diversity can enhance group processes and collective intelligence, which in turn may foster innovation and scientific discovery (Mauleon, Daraio and Bordons, 2013).

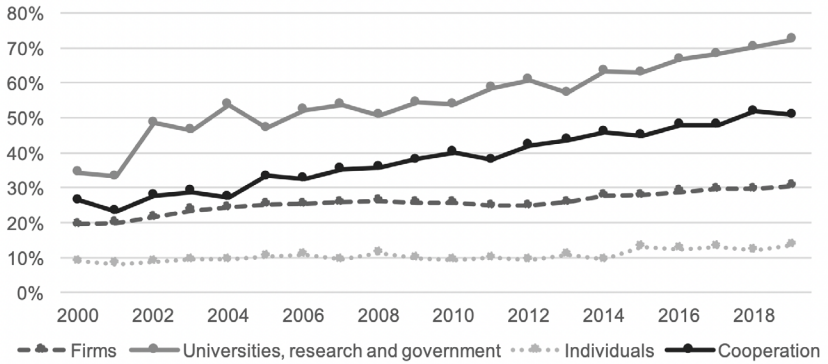
Figure 3 presents the trends in female participation across institutional sectors. Notably, universities, research, and government institutions show the highest percentage of female participation, followed by patents within cooperation between applicants, firms, and individual applicants. Specifically, female participation in universities, research, and government institutions increased from 34% in 2000 to 72% in 2019. Similarly, patents resulting from cooperation saw an increase from 26% to 51% in female participation. In patents filed by firms, the percentage of female participation rose from 20% to 30%, while among individual applicants, it grew from 9% to 14%.

Figure 2. Evolution of diversity and co-invention, 2000-2019



Source: Own elaboration based on BADEPI/INPI, extracted in March/2023.

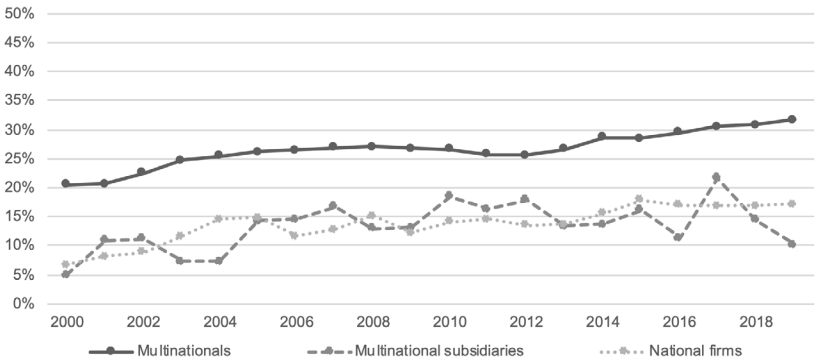
Figure 3. Evolution of female participation, by institutional profile of applicants, 2000-2019



Source: Own elaboration based on BADEPI/INPI, extracted in March/2023.

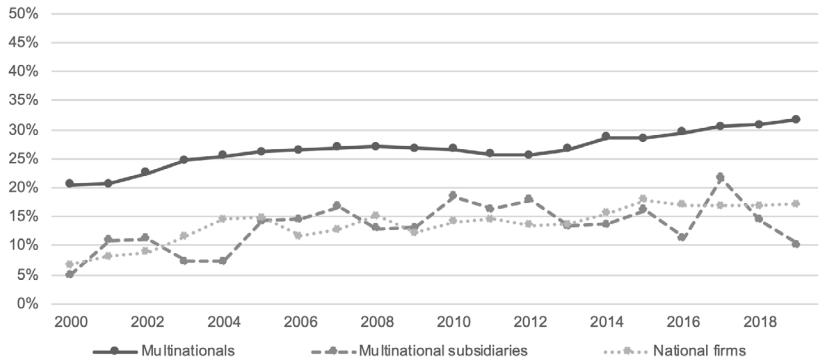
Figure 4 shows the female participation across different types of firms, classified by their origin and location. Notably, among patents filed by multinationals headquartered abroad, female participation rose from 21% to 32%. Similarly, among MN subsidiaries based in Brazil, female involvement increased from 5% to 10%. For national firms, female participation grew from 7% in 2000 to 17% in 2019. Additionally, Figure 5 illustrates how the distribution of patents varies across technological sectors among different firms. While MNs are primarily focused on chemistry, a sector dominated by women, MN subsidiaries and national firms are concentrated in mechanical engineering, a male-dominated field.

Figure 4. Evolution of female participation, by type of firms, 2000-2019



Source: Own elaboration based on BADEPI/INPI, extracted in March/2023.

Figure 5. Distribution of patens of firms, by technologies, 2000-2019



Source: Own elaboration based on BADEPI/INPI, extracted in March/2023.

5. Determinants of female participation in Brazil

5.1. The model, variables, and descriptive statistics

To assess the significance of the factors determining female participation in STI activities, the probit model in Sifontes and Morales (2020) will be applied to estimate the probability of female inclusion in patents in selected years. The empirical specification of the equation is as follows:

$$F_i = f(T_i, I_i, O_i, D_i)$$

Where F variable represents female participation in the patent, like in Naldi et al. (2004), Mauleón and Bordons (2010) and Sifontes and Morales (2020), and considers the value of one if there is at least one female among inventors. The exogenous variable groups are as follows: (T) represents a vector of dummy variables related to technological fields, with Electrical and Electronic Engineering assumed as the reference (omitted); (I) represents a vector of characteristics of inventor teams, including the existence of co-inventors and the number of inventors in the team; (O) represents a vector of institutional sector characteristics, distinguishing cases of cooperation[1], firms, universities, and individuals (assumed as the reference and therefore omitted); (D) represents a vector of dummy variables for each of the 27 Federation Units (Table 1).

The model is applied to two samples: one for all the resident applicants and another focusing only on resident firms. This distinction enables us to

1 This study includes joint patent applications between two or more individual applicants in the measure of cooperation.

investigate whether female participation in patented inventions is more likely when the patent is filed by a multinational subsidiary or by resident firms. The empirical specification of this particular equation includes a dummy variable that distinguishes between MN subsidiaries and resident firms.

A suitable model for analyzing the impacts on female participation in patents is the probit regression model, where the dependent variable is dichotomous: either at least one woman participates in the patent (Y = 1) or does not (Y = 0). Specifically, the functional form of the probit model is expressed as:

$$\text{Prob}\,(Y = 1) = \Phi(\beta T_i, \gamma I_i, \delta O_i)$$

Where Φ is the cumulative distribution function of the standard normal distribution, leading to the estimation:

$$Y'_i = \beta T_i + \gamma I_i + \delta O_i + u_i$$

Where u_i is a random term with a distribution of $N(0,\sigma^2)$ and Y'_i is a latent variable, such that:

$$Y_i = 1 \text{ se } Y'_i > 0 \text{ and } Y'_i > 0 \text{ otherwise}$$

Table 1. List of variables

Groups	Variables	Name	Description
F	F	Female participation	1: If at least a woman participates as an inventor in the patent
			0: No women are involved as inventors
T	T	Technological sectors	T_EE: Electrical and Electronic Engineering (assumed as reference)
			T_I: Instruments
			T: Chemistry
			T_ME: Mechanical Eng.
			T_O: Civil Engineering and Others
I	CI	Co-invention	1: If a team of inventors is listed in the patent document 0: otherwise
	NI	Number of inventors	Number of inventors in the team
O	CO	Cooperation	1: If there are two or more individuals or organizations holding the patent rights in the patent document; 0: otherwise
	URG	Universities, research, or governmental institutes	1: If the assignee is a university, research, or governmental institute; 0: otherwise
	RF	Resident firms	1: If the assignee is a firm; 0: otherwise
	MN_Sub	Multinational subsidiary	1: If the assignee is a multinational firm; 0: otherwise
D	D	Federation units	

Source: Own elaboration.

Table 2 presents descriptive statistics for a sample of total resident applicants across all groups of factors. Observing the average female participation, we find that in 2000, it was 0.1024, while in 2019, it increased to 0.3690. In terms of technological sectors, chemistry shows considerably higher female participation, whereas all engineering sectors have female participation below the overall average. In instruments, the average female participation is quite close to the overall average.

The data also shows that the average female participation in patents with co-invention (0.1994) is higher than the overall average (0.1024), whereas patents without co-invention exhibit female participation (0.0767) below the average.

Regarding the institutional sectors, universities have higher female participation compared to firms and individual patents.

Table 2. Descriptive statistics: Female participation for selected groups in full sample of resident applicants

Variables	2000	2005	2010	2015	2019
Number of patents	2,988	3,798	3,716	3,530	4,220
Average Female participation					
Total	0.1024	0.1643	0.2096	0.3113	0.3690
Technological sectors					
Electrical and Electronic Eng	0.0352	0.0984	0.1411	0.1810	0.1499
Instruments	0.1165	0.1902	0.2192	0.3106	0.3535
Chemistry	0.2473	0.3322	0.4311	0.6067	0.6486
Mechanical Eng	0.0500	0.0840	0.0826	0.1207	0.1622
Civil Engineering and Others	0.0889	0.1190	0.1141	0.1522	0.1770
Co-invention					
No	0.0767	0.0886	0.0775	0.0952	0.1151
Yes	0.1994	0.3695	0.4466	0.5327	0.5793
Cooperation					
No	0.0952	0.1473	0.1767	0.2823	0.3364
Yes	0.1584	0.2995	0.4181	0.4706	0.5254
Institutional sectors					
Universities	0.4479	0.5297	0.6025	0.6980	0.7550
Firms	0.0662	0.1506	0.1488	0.1726	0.1679
Individuals	0.0885	0.1010	0.0940	0.1350	0.1417

Source: Own elaboration.

Table 3 presents descriptive statistics for a subsample that includes only resident firms as applicants. Observing the average female participation, we can see that in 2000 it was 0.0556, rising to 0.1233 in 2019. Among the technological sectors, chemistry exhibits the highest female participation, while mechanical engineering shows the lowest.

Again, the data shows that patents with co-invention show higher female participation compared to the overall average, while patents without co-

invention show below-average female participation. In terms of firm types, the average female participation in multinational subsidiaries is similar to that in resident firms overall.

Table 3. Descriptive statistics: Female participation for selected groups in sub-sample of resident firms

Variables	2000	2005	2010	2015	2019
Number of patents	755	1,109	1,176	1,188	1,215
Average Female participation					
Total	0.0556	0.1401	0.1891	0.1504	0.1233
Technological sectors					
Electrical and Electronic Eng	0.0200	0.1215	0.1410	0.1759	0.1140
Instruments	0.0482	0.1783	0.1892	0.1800	0.1824
Chemistry	0.1854	0.3012	0.3323	0.4041	0.3894
Mechanical Eng	0.0337	0.0640	0.0640	0.0829	0.1045
Civil Engineering and Others	0.0556	0.1069	0.0914	0.1478	0.1429
Co-invention					
No	0.0367	0.0742	0.0615	0.0762	0.1025
Yes	0.1586	0.3064	0.3036	0.3256	0.2875
Type of firms					
National Firms	0.0766	0.1611	0.1585	0.2017	0.1976
MN Subsidiaries	0.0552	0.1310	0.1923	0.1617	0.1491

Source: Own elaboration.

5.2. Results

The empirical model tests the hypothesis regarding the role of the determinants addressed by the empirical literature on the persistence of gender gap in STI. These determinants include horizontal and vertical segregation, gender diversity in research networks, the organizational environment in private and public organization, and the cooperation between organizations.

The coefficient estimates presented in Table 4 provide support for our hypotheses. As expected, the technology sectors have different impacts on the probability of female participation in patents, with electrical and electronic engineering used as the reference sector. Technology related to the sectors of instruments, chemistry, and others have a positive impact on the likelihood of female participation. Technologies related to the mechanical engineering sector exhibit a similar behavior to electrical and electronic engineering in the annual samples. These results are consistent with previous literature on horizontal segregation (Azevedo and Abrantes, 2021; Schneegans et al. 2021).

The diversity of inventor teams, measured by co-invention and the number of inventors in a team, positively impacts the probability of female participation in patents. This finding supports previous literature (Sifontes and Morales, 2020; Azevedo and Abrantes, 2021), which shows that women are more likely to participate in patents when a group of inventors is involved.

Conversely, the pronounced coefficient for larger teams aligns with earlier arguments, namely, that women are more likely to participate in inventions where they have less individual responsibility (Murray and Graham, 2007) and lower visibility (De Negri, 2020). However, cooperation shows no significant effect. We attribute this lack of significance to the nature of cooperation in Brazil, where collaboration can involve companies, companies and universities, individuals and their respective organizations, and individuals on behalf of their organizations. Each type of cooperation might offer a distinct environment for women.

Regarding the institutional profile of the applicant, universities, research institutes, and government agencies show a positive coefficient, indicating an increased probability of female participation in patents. In contrast, female participation is less likely in patent filed by firms. These results are consistent with the findings from previous literature (Mauleón and Bordons, 2010; Sugimoto et al. 2015; Sifontes and Morales, 2020).

Table 4. Estimated coefficients (full sample)

Variables	Dependent Variable: Female participation				
	2000	2005	2010	2015	2019
T_I	0.534***	0.328***	0.320***	0.236**	0.370***
	(0.156)	(0.121)	(0.116)	(0.105)	(0.102)
T_C	0.986***	0.742***	0.780***	0.933***	1.072***
	(0.144)	(0.109)	(0.099)	(0.090)	(0.091)
T_ME	0.132	0.086	-0.013	-0.022	0.162*
	(0.147)	(0.111)	(0.107)	(0.098)	(0.097)
T_O	0.498***	0.363***	0.248**	0.305***	0.496***
	(0.149)	(0.117)	(0.114)	(0.107)	(0.111)
CI	0.128	0.321***	0.375***	0.392***	0.063
	(0.158)	(0.100)	(0.099)	(0.090)	(0.084)
NI	0.236***	0.250***	0.292***	0.264***	0.294***
	(0.049)	(0.031)	(0.027)	(0.022)	(0.019)
CO	-0.165	-0.051	0.077	-0.031	0.107
	(0.149)	(0.105)	(0.103)	(0.102)	(0.091)
URG	0.541***	0.389***	0.441***	0.448***	0.737***
	(0.185)	(0.119)	(0.107)	(0.100)	(0.091)
RF	-0.482***	-0.184**	-0.287***	-0.286***	-0.246***
	(0.106)	(0.075)	(0.081)	(0.082)	(0.075)
D	Included	Included	Included	Included	Included
Observations	2,918	3,798	3,716	3,530	4,220

Note: *p < 0.1; **p < 0.05; ***p < 0.01

The results for the subsample that considers only resident firms as applicants are reported in Table 5. These results indicate that the likelihood of female involvement in patents decreases when the patents are assigned to multinational subsidiary firms. This observation aligns with the expected sign

but show no significant effect in most of the annual subsamples. This finding is consistent with the work-family balance hypothesis, which suggests that gender segregation in science and technology disciplines in Latin America is influenced by time and mobility constraints related to family responsibilities (Yáñez, 2016). This dynamic can be extended to the case of women working in MN subsidiaries, who may face difficulties accepting positions that require long and regular travel. The lack of significance suggests that MN subsidiaries do not differ from local companies in this respect. This implies that while gender diversity has the potential to enhance innovation outcomes, its actual impact may be constrained by organizational roles, types of knowledge, and institutional disparities across countries.

Table 5. Estimated coefficients (only firms)

Variables	Dependent Variable: Female participation				
	2000	2005	2010	2015	2019
T_I	0.58	0.251	0.246	0.071	0.288
	(0.472)	(0.227)	(0.205)	(0.182)	(0.214)
T_C	1.229***	0.482**	0.740***	0.817***	1.080***
	(0.422)	(0.198)	(0.175)	(0.149)	(0.175)
T_ME	0.574	-0.427**	-0.292	-0.243	0.234
	(0.435)	(0.210)	(0.190)	(0.160)	(0.179)
T_O	0.742*	-0.047	0.01	0.198	0.501**
	(0.444)	(0.230)	(0.209)	(0.166)	(0.209)
NI	0.177***	0.369***	0.388***	0.300***	0.281***
	(0.048)	(0.037)	(0.038)	(0.031)	(0.028)
MN_Sub	-0.058	-0.067	0.09	-0.141	-0.430**
	(0.230)	(0.157)	(0.140)	(0.135)	(0.171)
D	Included	Included	Included	Included	Yes
Observations	751	1,109	1,176	1,188	1,215

Note: *p<0.1; **p<0.05; ***p<0.01

6. Conclusions

This study investigated factors that influence female participation in patenting activity across various institutions, particularly focusing on the role of multinationals, identified by the origin of capital and the location of firms. The determinants examined included technological specialization (which configures horizontal segregation), co-invention, cooperation, and organizational and cultural characteristics. To conduct the investigation, we analyzed the invention patents filed with the INPI-Brazil from 2000 to 2019.

The results reveal an upward trend in female participation in patents in Brazil. However, women remain underrepresented, a finding consistent with empirical studies in other countries, and with the persistence of asymmetries that vary depending on the field of knowledge and institutional sector. Our analysis reveals a pattern of gender discrimination: women are more

prominently involved in chemistry, mixed-gender and larger teams, and in universities, research, and government institutions.

Regarding technological sector variables, the probability of female participation in patents increases when the patent is linked to chemistry and instruments fields, which are closer to areas of knowledge related to biological and life sciences. Conversely, the likelihood of female involvement decreases in engineering-related patents. These results are consistent with the persistence of horizontal segregation in STEM knowledge subareas and reflect the significant participation of women in medical and health sciences, which have a large and productive community as a result of the entry of women in higher education in care-related careers in the 1970s.

Our findings also confirm that technological knowledge production is more commonly achieved through co-invention, as measured by collaboration networks involving two or more inventors, rather than by individual inventors working alone. Moreover, co-invention played a significant role in both female inclusion in STI and, in a sense, acted as a mitigating factor for the effects of time dedicated to "domestic work" and "care work".

Regarding cooperation, there has been a noticeable increase in female involvement across the full patent dataset, suggesting that cooperation acts as a mechanism for inclusion. This is consistent with prior literature, which shows the growing importance of international cooperation networks as a potential means of integrating women into inventive activities (Medina and Alvarez, 2021). However, when applying the probit model to the sample of residents only, cooperation, as defined in footnote number 1, showed no significant effect, warranting further research. This result could inform the design of public policies aimed at improving cooperation between national institutions to foster greater stability for female participation.

Among the institutions filing patents in Brazil, universities, research, and government institutions showed the highest rates of female participation. Brazilian universities, in particular, were predominant in this category, underscoring their critical role in investing in science, technology, and innovation activities, particularly as a mechanism for fostering female participation in inventive activities. In this case, public policies could focus on mitigating the persistent gender segregation within the STI system and encouraging female students to pursue areas of knowledge that are traditionally male-dominated.

While multinationals are filing patents in chemical technologies, which explains the higher rate of female participation in their patents, MN subsidiaries in Brazil and national firms exhibit a relatively higher propensity to patent in the mechanical engineering sector, which coincides with the lowest rates of female involvement. Moreover, although the electrical and electronic engineering sector has seen global growth in patents published in 2020, this trend has not yet been reflected in Brazil. Considering this, public policies could aim to integrate more women into digital entrepreneurship and high-tech firms as a future avenue of inclusion. Additionally, in light of the significant role of technology- and knowledge-intensive sectors, such as export-oriented

services, in increasing female participation, public policies should encourage a shift towards these activities (Valera et al., 2024).

When considering a sub-sample of only resident firms, our model found no significant differences in the probability of female participation in patents between national firms and MN subsidiaries. However, it is noteworthy that national firms exhibit a higher relative presence of patents developed by individual inventors attributed to a single female inventor. Given the general trend towards increased team-based knowledge production, this represents a significant opportunity for national firms to foster greater diversity.

In summary, this study provides an overview of women's participation as inventors in technological knowledge generation in Brazil. The findings shed light on the situation of women researchers in technological activities, the role of institutions in reducing gender inequality, and the persistent challenges across various fields. By leveraging patent indicators disaggregated by applicant profile, inventor composition, and technological sectors, this research offers valuable insights for informing public policies aimed at promoting female inclusion. However, there is still a need for improved data treatment, including the integration of external databases, to further explore the life cycle characteristics of female inventors, such as career stage and the impact of maternity.

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