Women in Corporate Boards: Network Centrality and Gender Quotas*

(*Preliminary Draft - DO NOT CITE OR CIRCULATE*)

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Abstract: This paper examines how professional network centrality and gender quotas interact in shaping board appointments. Using the Cope-Zimmerman law introduced in France in 2010 and BoardEx data on publicly listed French firms (2001–2019), I study the role of networks in first-time board appointments and how the quota reform influenced this dynamic. I find that network centrality, measured via degree and betweenness, is a key driver of board access. To address endogeneity in network formation, I use the centrality of second-degree connections as an instrument. The quota significantly increased female representation and led to more qualified first-time appointees. However, its benefits were unevenly distributed; women with stronger networks were better positioned to benefit. My findings suggest that while quotas reduce gender disparities, network-driven barriers to board access persist.

Keywords: Gender Diversity; Gender Quotas; Women-on-Boards; Network Centrality

JEL Codes: J16, J78, C26

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1 Introduction

In response to a longstanding movement towards achieving gender equality and diversity on corporate boards, several European countries have implemented corporate gender quotas[1]. The European Parliament passed a corporate quota law in November 2022, requiring companies to ensure a minimum of 40% representation of underrepresented genders on their boards. In France, the Cope-Zimmerman law was introduced in 2010, initially setting a target of 20% women on boards by 2014, which later increased to 40% by 2017 (Bender et al., 2015). The objective of these quotas is to improve women representation at all levels in the firm hierarchy and reduce gender gap especially in wages.

Women representation on boards is not only important from a social justice viewpoint but also to provide role models and conducive environment for women within firms. Given that firms often rely on referrals from current directors and executives for board appointments, low representation of women in professional networks can limit their access to referrals (Beaman and Magruder, 2018), potentially hindering board diversity (von Essen and Smith, 2023).

This paper aims to assess whether higher network centrality of executives in French listed firms increases their probability of becoming a board member in general, and whether this probability is different for men and women. I use the French Cope-Zimmerman law of 2010 to assess whether it forced firms to hire board members with lower network centrality i.e. if there is any difference in the network's effect on becoming a board member after the law.

This study builds on previous research by utilizing the Boardex database, also employed by Ferreira et al. (2021), Maghin (2021), and Dalvit et al. (2022), to analyze directors, firms, and boards. My contributions are threefold. Firstly, unlike the broader arrival rate at the board level analyzed by Ferreira et al. (2021), my outcome variable, as defined by von Essen and Smith (2023), specifically focuses on individuals becoming board members for the first time in a given year. Secondly, I expand on the professional network analysis as explored by von Essen and Smith (2023), by considering referrals within the co-worker network that are defined in two ways. Lastly, I advance beyond the network measure in von Essen and Smith (2023) by incorporating betweenness

[1]Norway led the way by mandating a 40% representation of women on corporate boards in 2003. This was followed by Iceland (40% in 2010), Italy (33% in 2011), Belgium (33% in 2012), Denmark (40% in 2012), and Germany (30% in 2015).

centrality to gauge a node's centrality based on its intermediary roles in network paths.

The analysis is based on a comprehensive sample of 23,872 individuals working at managerial roles in 1,065 publicly listed French firms from 2001 to 2019. It helps to investigate the dynamics of board composition, focusing on gender and the impact of the Cope-Zimmerman law 2010. The outcome variable for board membership is defined as a binary variable indicating first-time board membership. The study employs both degree and betweenness centrality measures to capture different dimensions of network influence, local connectivity and global bridging properties, respectively. The trends highlight significant post-law shift in women on boards with average women first time board members jump from 15% in 2009 to 26% in 2010.

Network centrality measures are derived from the employment history of individuals in managerial roles. This poses a challenge to identifying a causal relationship between networks and entry into new boards, as there is a possibility of the strategic formation of connections. An individual aspiring to enter the boardroom may intentionally form connections that can help them climb the ladder of corporate leadership. This would render the networks endogenous. The peer-effects literature suggests that if *peers of the peers are not direct peers*, then the characteristics of peers of the peers can potentially help identify network effects (De Giorgi et al., 2010; Nicoletti et al., 2018; Bramoullé et al., 2020). Following this intuition, we employ an instrumental variable (IV) approach, using the centrality of second-degree connections as an instrument for the individual's own network centrality.

Our first-stage results suggest that this second-degree network significantly predicts the position of an individual in the network. The f-stats also indicates that the instrument is valid. The IV estimates suggest that network centrality, whether measured through degree (number of direct connections) or betweenness (the extent to which an individual lies on crucial paths between others) significantly predicts the probability of becoming a new board member. The interaction terms introduced in the models show a substantial jump in the likelihood of women joining boards post-quota reform of 2010 in France. The results also indicate that network position remains pivotal, even in the presence of quotas. Well-connected women may have benefited more than their less-connected counterparts, hinting at potential inequalities in how policy benefits are distributed.

The remainder of this paper is structured as follows. Section 2 presents the literature review. Section 3 outlays the conceptual framework. Section 4 describes the institutional context and quota

law. Section 5 describes the dataset, study sample, and the construction of outcome variable and key network measures. Section 6 lays out the empirical strategy and construction of the instrument. Section 7 discusses the main results. Section 8 concludes this paper.

2 Literature Review

Gender inequalities remain a central issue in labor economics, with women persistently facing disparities in representation and compensation (Goldin, 2006; Bertrand, 2011; Blau and Kahn, 2017). Explanations for gender gaps include discrimination (Goldin and Rouse, 2000; Biasi and Sarsons, 2022), and the disproportionate burden of caregiving, often termed the *child penalty*, which shapes women's labor market outcomes (Bertrand et al., 2010; Kleven et al., 2019; Goldin, 2021). Industrial transformation and the rise of the service sector also contribute to the evolution of gender gaps over time and across countries (Olivetti and Petrongolo, 2014, 2016). Goldin (2014) notes that gender gaps persist in high-paying occupations because these roles "*impose heavy penalties on employees who seek fewer hours and more flexible employment*"—typically women.

From a social justice perspective, more women in leadership can promote broader diversity via mentorship and role modeling (Athey et al., 2000; Matsa and Miller, 2013; Beaman et al., 2009). Women leaders can shape inclusive policies and elevate the representation of women (Boustan and Langan, 2019). Research in political science shows that critical mass—having a sufficient number of women—gives them greater authority to address issues like caregiving (Mendelberg et al., 2014), although a few committed and well-placed representatives can also be effective (Childs and Krook, 2009).

In corporate governance, board diversity is often linked with better shareholder value (Fernandez-Temprano and Tejerina-Gaite, 2020). Gender-diverse boards are associated with improved firm performance across different contexts: the U.S. (Carter et al., 2003; Erhardt et al., 2003), Europe (Green and Homroy, 2018), Spain (Campbell and Mínguez-Vera, 2008), Australia (Bonn, 2004), and China (Liu et al., 2014). While Joecks et al. (2013) finds initial negative effects of board diversity, performance improves once a critical mass of women is reached. Terjesen et al. (2016) shows that more diverse boards correlate with higher market and accounting performance. Diversity may enhance monitoring, improving firm outcomes (Iacoviello et al., 2015), although some studies find

no effect or even negative associations (Reddy and Jadhav, 2019).

A broad literature advocates for affirmative action to address structural barriers in male-dominated, high-income sectors (Goldin, 2006; Bertrand, 2011; Olivetti and Petrongolo, 2016). Views on gender quotas are mixed. Supporters emphasize justice and inclusiveness (Bertrand, 2011), and argue that in discriminatory environments, quotas help access untapped talent (Beaman et al., 2009). Political quota studies suggest they can improve candidate quality by pushing parties to select highly qualified women (Baltrunaite et al., 2014; Besley et al., 2017).

Assessing the success of quotas depends on how success is defined. In corporate contexts, success can be evaluated by firm performance and women's advancement across hierarchies (Kirsch, 2018). For example, Chattopadhyay and Duflo (2004) show that quotas increased women's influence on policy preferences, and Beaman et al. (2009) finds that quotas raised aspirations among young girls through role modeling.

Several European countries have adopted corporate gender quotas, yielding mixed results. Norway's 2003 law mandating 40% female representation improved the qualifications of female directors and narrowed board-level pay gaps without broader labor market effects (Bertrand et al., 2019). However, it also led to short-term declines in stock prices and long-term performance deterioration (Ahern and Dittmar, 2012). In Italy, quotas boosted women's board presence, but had limited trickle-down effects on executive roles (Maida and Weber, 2022). Similar patterns are found in France (Dalvit et al., 2022). While Comi et al. (2020) finds positive effects on firm performance in Italy, results for Spain and France are less favorable. Ferrari et al. (2018) finds that more women on boards in Italy reduces stock price volatility and improves returns.

In labor markets with informational frictions, referral hiring benefits both firms and job seekers (Schmutte, 2016). For high-skilled roles, unobservable traits are often inferred through referrals, especially in sectors valuing soft skills (Montgomery, 1991). For instance, hiring patterns in U.S. law firms highlight the role of alumni networks (Oyer and Schaefer, 2012). Referrals ease hiring and lead to better initial offers due to credible recommendations (Hensvik and Skans, 2016). Calvó-Armengol and Jackson (2007) show that improved employment outcomes within one's network directly enhance individual job prospects.

However, the effect of networks on equity is complex (Holzer, 1987; Loury, 2006; Jackson,

2008). On one hand, they reduce statistical discrimination by providing individualized signals (Calvo-Armengol and Jackson, 2004); on the other, gendered networks can entrench inequality. Professional networks strongly influence promotion to top roles (Zhu and Westphal, 2014), and gender gaps in these networks limit women's advancement (Doldor and Vinnicombe, 2015). Casella and Hanaki (2006) argue that network signaling is only effective when signaling costs are low; in gender-segregated networks, varying costs may restrict underrepresented groups. This is reflected in qualitative accounts like that of a CEO interviewed by Zhu and Westphal (2014), who noted:

> *I often look at whether [the director] has worked with a CEO who has a comparable ... background, but I'll weight that more heavily if [the director's] background isn't totally compatible with my own.*

2.1 Literature Gap

In this study, we utilize the same database - Boardex as used by Ferreira et al. (2021), Maghin (2021), and Dalvit et al. (2022), to gather information on directors, firms, and boards. However, this paper contributes on three levels not captured by previous papers. First, the outcome variable is defined as becoming a board member for the first time in year t (following von Essen and Smith (2023)), which is at the individual level, unlike the arrival rate at the board level used by Ferreira et al. (2021). Second, the professional network of directors (following von Essen and Smith (2023)) is captured in two ways to accommodate the different possibilities of getting referrals from the co-worker network. Lastly, this study goes beyond von Essen and Smith (2023)'s network measure, using betweenness centrality to capture the centrality of a node based on the paths it lies on. It is pertinent to note that von Essen and Smith (2023) studied the effect of the network size of males and females on the potential of becoming a board member in Denmark. It shows that more connections lead to a higher probability of being on the board in general; however, in comparison, it is higher for men than women. We are addressing a different question: if the french Cope-Zimmerman law of 2010 forced firms to hire board members with weaker network and whether there is any gender effect.

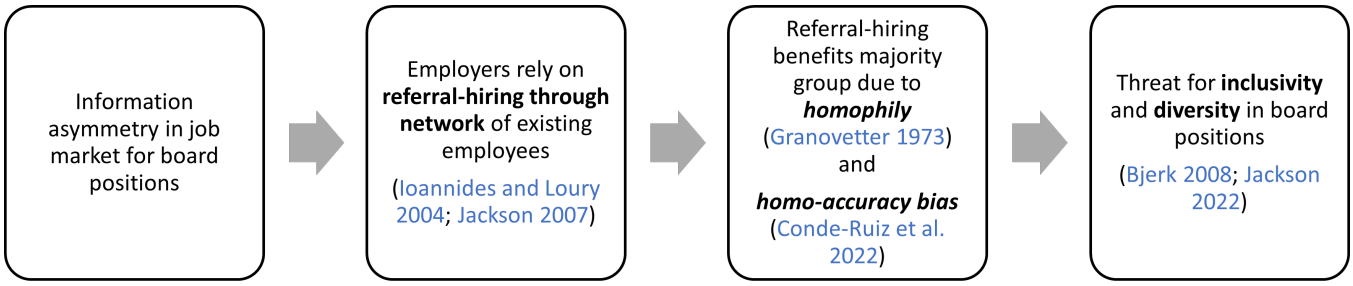
3 Conceptual Framework

3.1 Referral-hiring and Diversity

Referral-hiring relies heavily on the network of existing employees which seems like a potentially efficient matching process that helps both employer and employee. However, the question arises: *is it entirely fair*? If homophily drives the social capital of individuals then referral hiring would lead to exclusion of the group which has lower representation like Beaman and Magruder (2018) shows that women are disadvantaged in the labor market due to network hiring. This gives rise to many potential threats to inclusion and equal opportunities for all depending on the structure of networks in a certain setting (Hoffman, 2017; Schmutte, 2016).

The phenomenon of *glass-ceiling* effect is discussed as a demand side issue in labor market for women. Conde-Ruiz et al. (2022) suggests that this demand side issue is rooted in the institutional failure where the hiring committees are prone to *homo-accuracy bias*. A signal by the potential candidate is informative if the hiring committee members share the *same background* resulting in *discrimination-trap*. This *discrimination trap* can be dealt effectively using *temporary quotas* to promote inclusion.

Figure 1: **Referral-hiring and Diversity**



3.2 Gender Diversity and Corporate Quotas

A large body of literature that focuses on legislative quotas for underrepresented groups is aimed at making their voices heard and include them in the decision making process. Similar line of reasoning

is followed when corporate quotas are discussed. Corporate gender quotas are considered to act as a *stimulus* that can increase the pace towards the shared goal of inclusivity and diversity. On the other hand, the critics of quota laws often argue from an efficiency perspective, suggesting that altering market outcomes through enforced quotas could impair market efficiency. They believe that quotas interfere with the natural selection process of the market, which, in theory, rewards merit and optimizes organizational performance.

The supporters of quotas counter this viewpoint not only by emphasizing the moral imperatives of social justice and inclusiveness (Bertrand, 2011) but also by adopting a more sophisticated stance on efficiency itself. They argue that in environments characterized by rampant discrimination and lack of conducive policies for women, the absence of quotas actually restricts access to a broad pool of talent (Beaman et al., 2009). This limitation can, in turn, have detrimental effects on efficiency and quotas can improve total welfare (Conde-Ruiz et al., 2022). By mandating quotas, firms are compelled to cast a wider net in their recruitment efforts, potentially tapping into a pool of talent that can improve decision-making processes. Thus, while both critics and supporters argue for efficiency, supporters of quotas point to the negative side effects of an unregulated market that fails to harness the full spectrum of available talent. The ongoing debate reflects the complex nature of corporate quotas, which continue to evolve in various forms worldwide.

Figure 2: **Gender Diversity and Corporate Quotas**

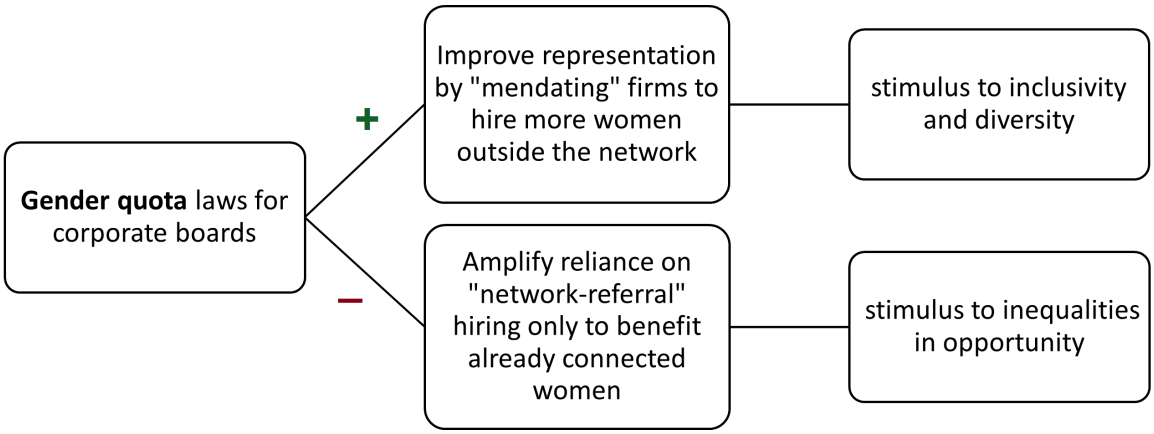


Figure 2 provides a summarized view of the impacts of gender quota laws for corporate boards. On the positive side, such laws compel firms to broaden their search for board members beyond

their traditional networks Bertrand et al. (2019), potentially leading to greater gender diversity. This could be seen as a step towards greater inclusivity within the corporate leadership circles. Conversely, the reliance on network-referral hiring practices that may persist despite these laws. This could inadvertently limit opportunities to a small group of women who are already within these networks, thereby perpetuating inequalities in opportunity rather than broadening access as intended (Chevrot-Bianco, 2021).

3.3 Measuring Professional Network

A network is characterized by a set of nodes, denoted as $N = \{1, ..., n\}$, which can be referred to as vertices (individuals). The *vertices* are joined by links referred to as *edges* (firms). Networks can be classified as either directed or undirected. In directed networks, relationships are non-reciprocal. On the other hand, undirected networks require mutual consent and joint agreement to establish and maintain relationships, such as trading partnerships, friendships, business relationships, or alliances (Jackson, 2008). In this study, we will assume that the networks are reciprocal or undirected.

Formally, network graph (N, g) consists of nodes $N = \{1, ..., n\}$ and a real-valued n x n matrix g, where g_{ij} is *adjacency matrix* that represents the relationship between node i and j. For an undirected network $g_{ij} = g_{ji}$. The *neighborhood of a node* i is a set of nodes that i is linked to,

$$N_i(g) = \{j : g_{ij} = 1\}$$

3.3.1 Network Centrality

It is imperative to measure the position of node i relative to other nodes in a network. Network centrality measures help to capture a node's position in a network. Different measures of centrality have been developed to capture different aspects. As Villesèche and Sinani (2023) shows that in the context of influence in corporate boards, importance of network matters more than just counting the connections, therefore, betweeness *(how important a node is in terms of connecting other nodes)* along with degree *(how connected a node is)* centrality is used in this paper.

A node with a high degree centrality is well-connected and may be considered a hub within the network. Node i's degree in a network g, denoted by $d_i(g)$, is

$$d_i(g) = \#N_i(g) = \#\{j : g_{ij} = 1\}$$

Degree centrality captures the *number of direct connections a node has within the network*. It is simply

$$\frac{d_i(g)}{(n-1)} \in (0,1); \text{ where, } 1 = \text{max connections and } 0 = \text{no connection.}$$

Rather than solely counting the number of connections, Freeman (1977) first introduced the idea of measuring node centrality based on the paths it passes through. A node with a high betweenness centrality is important for the flow of information or resources between different parts of the network. Let $P_i(jk)$ is the number of geodesics (shortest paths) between node j and k that i lies on while $P(jk)$ is the total number of shortest paths between node j and k. The ratio of $P_i(jk)$ to $P(jk)$ estimates the importance of node i in connecting the nodes j and k. It is worth noting that the betweenness centrality value may exceed 1, especially in large or dense graphs with many paths passing through the node. More formally, betweenness centrality of a node i is

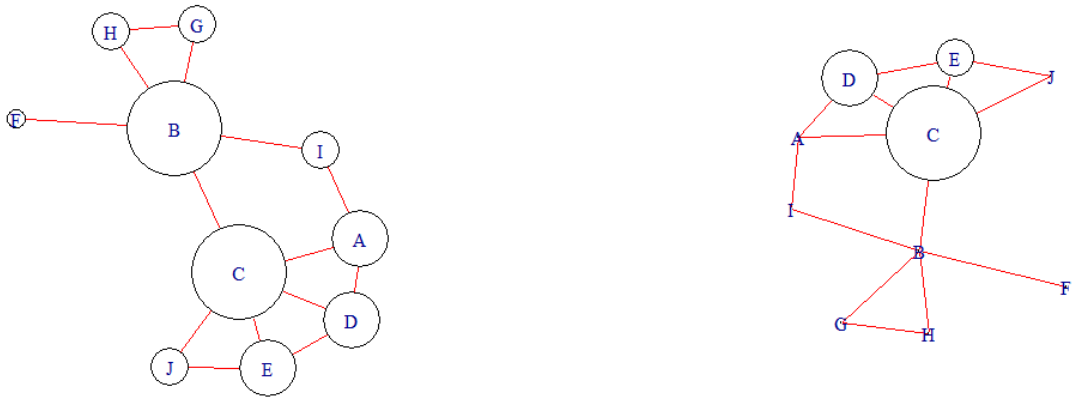
$$Ce_i^B(g) = \sum_{j \neq k : i \notin \{j,k\}} \frac{P_i(jk)/P(jk)}{(n-1)(n-2)/2}$$

The difference between the two measures of centrality is illustrated in figure 3. Consider an undirected network with set of nodes $N = \{A, B, ..., J\}$ and with *adjacency matrix* g such that some nodes are connected to others while some are not. The size of circle represents the centrality measure's magnitude for each node. It can be seen that both nodes B and C have same degree (5 connections each).

However, if we look closer, C lies on most of the shortest paths between nodes. The distinction between degree and betweenness lies in their focus on local connectivity versus global bridging properties, respectively. This is why both centrality measures are obtained for individual's professional

networks in order to study the importance of nodes in terms of flow of information which is more relevant in our context.

Figure 3: Illustration of Network Centrality



(a) Degree

(b) Betweenness

4 Institutional Background

Europe boasts the highest gender parity (76.3%) of all regions, while France is ranked 40th on the Global Gender Gap Index in 2023[2]. According to the Global Gender Gap Report (2023), less than one-fifth of firms in France have female top managers, pointing to a gender disparity at the highest levels of corporate leadership. On the indicator for advancement of women to leadership roles in France, the report suggests moderate success. While not at the bottom, there is room for improvement to reach the top of the scale, which would indicate optimal conditions for gender parity in leadership roles.

[2] *Global Gender Gap Report (2023), World Economic Forum.*

4.1 Gender Representation in French Labor Market

The data on the French labor market reveals several important trends in employment, wage disparity, and gender representation in management over time. There has been a significant increase in employment rates among women between 2013 to 2023, especially in the age groups of 45-54 and 55-64, where the employment rates increased from 77.9% to 81.6%, and from 46.3% to 57.2%, respectively. The employment rate for women over 65 also more than doubled from 1.8% in 2013 to 3.4% in 2023. Changes in male employment rates were more modest, with a slight increase overall from 55.4% in 2013 to 55.7% in 2023. Notably, employment rates for men aged 55-64 rose from 51.7% to 59.7%, and for those over 65 from 3.4% to 5.2% between 2013 to 2023[3].

The gender wage gap varies significantly by skill level, with notable disparities that have persisted and, in some cases, worsened over the decade. In 2020, the wage gap for low skill level was recorded at 4.1%, medium skill level at 6%, and high skill level at 11.6%. In comparison, the 2013 figures were 4.3% for low skill, 10.1% for medium skill, and 10.3% for high skill levels[3].

The proportion of women in managerial positions has shown a positive but fluctuating trend. Starting at 36% in 2013, the proportion dipped to 32.7% in 2014 but has generally increased each year, reaching 38.9% in 2023. The representation in senior and middle management roles also improved from 35.6% in 2013 to 39.4% in 2022 [3]. The increasing participation of older women in the workforce and improved overall representation of women in managerial roles are positive trends. However, the persistent wage gaps, particularly for medium and high skill levels, underscore the need for continued efforts to achieve gender parity.

4.2 Corporate Governance in France

The business structures in France can be classified according to the legal forms that broadly revolve around governance flexibility, capital requirements, transfer of shares, and the number of shareholders. Société par Actions Simplifiée (SAS) offers a flexible governance framework, allowing for a single person or a board of directors, with no minimum capital requirement and a more lenient transfer of shares. Société Anonyme (SA), on the other hand, typically features a more formalized

[3]All the statistics are sourced from ILO (2023).

governance structure with a board of directors, may have a minimum capital requirement, and is subject to stricter regulations regarding share transfer. Société en Commandite par Actions (SCA) adopts a unique two-tier board system comprising a distinct management board (Directoire) and a supervisory board (Conseil de surveillance), with specific considerations for capital arrangements and a structure involving limited and general partners. Lastly, Société à Responsabilité Limitée (SARL), operating as a limited liability company, is characterized by a more flexible governance structure, typically overseen by one or more managers responsible for day-to-day operations. Unlike some legal forms, SARL does not impose stringent minimum capital requirements, contributing to its appeal for small and medium-sized enterprises (SMEs).

Listed companies in France are typically required to adopt specific legal forms i.e. either SA or SCA that provide a structured governance framework with defined boards. Non-listed companies in France have more flexibility in choosing their legal form like SAS (boards are optional) or SARL (no boards). Bender et al. (2015) observes that there is a trend of companies changing their legal structure to a simplified joint-stock company (SAS) from a public limited company (SA). This shift is happening because SAS provides more flexibility and since the law does not apply to SAS [4]. Therefore, this trend might limit the law's impact, particularly on non-listed companies, and may not effectively address gender inequality in career advancement for women in France. Nevertheless, we only have listed companies in our sample.

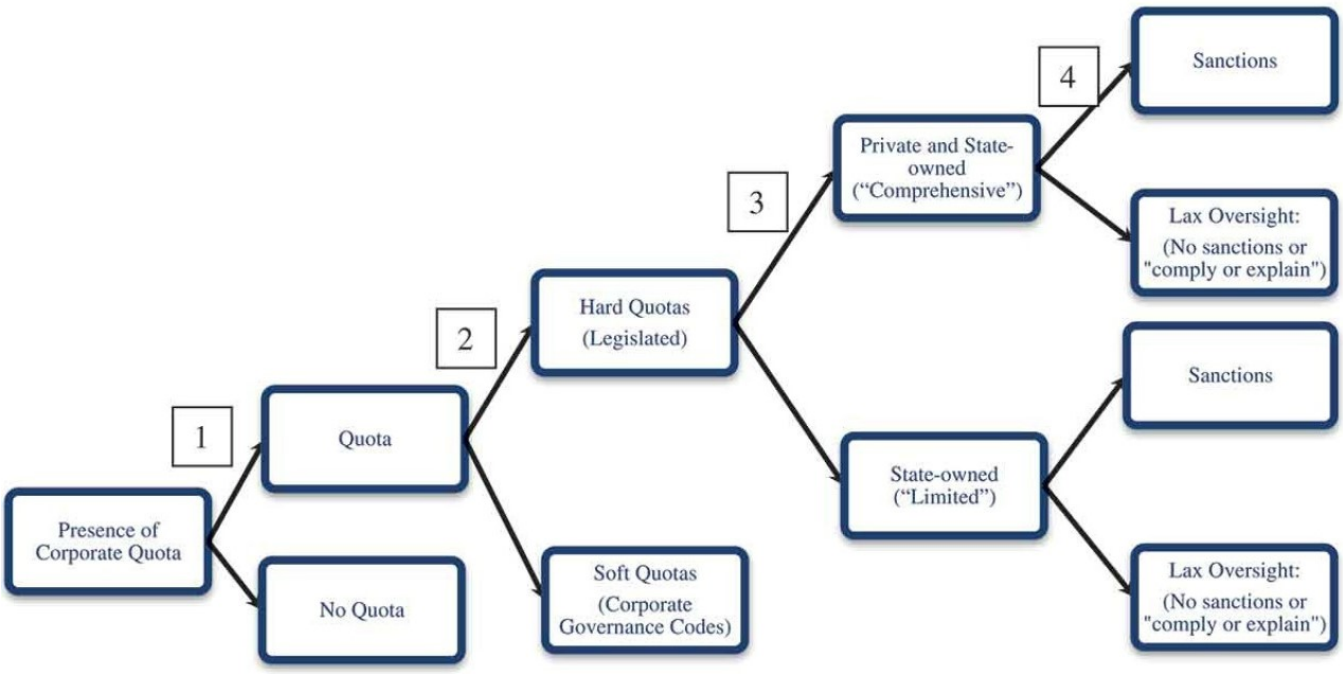
4.3 French gender quota reform: the Cope-Zimmermann Law

Piscopo and Muntean (2018) presents a topology of corporate quotas that countries have tried to implement over time. If a corporate quota law exists in a country, it is either involuntary (hard quota) or voluntary (soft quota). Hard quotas are through legislation while soft quotas are through corporate governance codes that guides the corporate governance in a country. If a country is not willing to regulate the private-owned enterprises and only have quota policies for state-owned firms, the quota is labeled as limited. Either quotas are comprehensive (for both state and private owned) or limited, there may be penalties and sanctions for non-compliance or simple comply or explain

[4] According to Bender et al. (2015), in January 1999, there were 168,900 SA companies, which reduced to 133,158 by January 2007 and further to 113,492 by September 2009. Conversely, the SAS companies, increased from 110,276 in January 207 to 138,953 by September 2009

rule where evasion from the law is possible by submitting explanation. Piscopo and Muntean (2018) has summed this up as shown in figure 4.

Figure 4: Topology of Corporate Quotas
source: Piscopo and Muntean (2018)



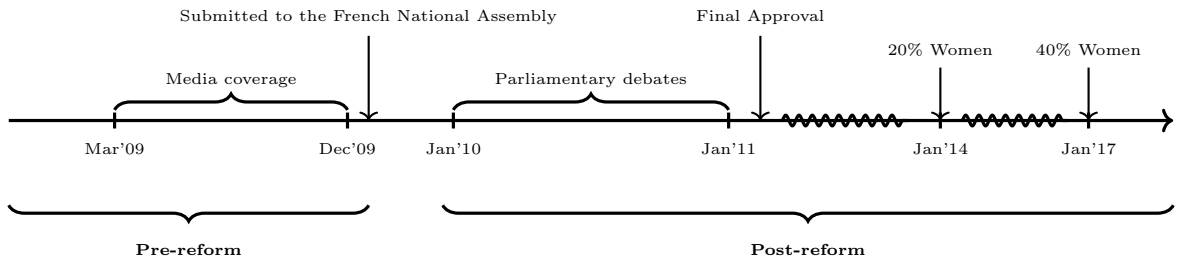
In France, the Cope-Zimmerman law was adopted formally in January 2011. French corporate quota law evolved from soft-quotas in early 2000s to comprehensive hard-quota in 2010. The law set specific goals for gender diversity on corporate boards, mandating a minimum of 20% women by January 2014 and increasing to at least 40% by January 2017. These quotas are accompanied by the sanctions such that the non-compliant boards have to forfeit compensation (Piscopo and Muntean (2018)). Companies obligated to comply with gender quotas include (a) all those whose shares are listed on a regulated market and (b) all non-listed employing at least 500 permanent employees[5] and more than EUR 50 million in revenues for three consecutive years. Due to limited

[5]This threshold was revised to 250 employees in August, 2014

availability of data, our analysis is focused on listed companies only that are all targeted by the quota law.

The government's motivation for implementing gender quotas for corporate boards was to increase the representation of women in decision-making roles. The law was proposed based on assembly debates highlighting gender disparity specially at the top-executive levels in the firms. Zimmerman used the metaphor of *electric shock* that is inevitable to reboot the stalled system (Chandler, 2016). The government explicitly communicated that this measure aimed to serve as a catalyst for broader transformations beyond the boardroom, specifically addressing gender imbalances within companies, including the gender wage gap. Essentially, the government viewed increased representation of women at the decision-making level as a strategic step toward fostering gender equality throughout the organizational structure.

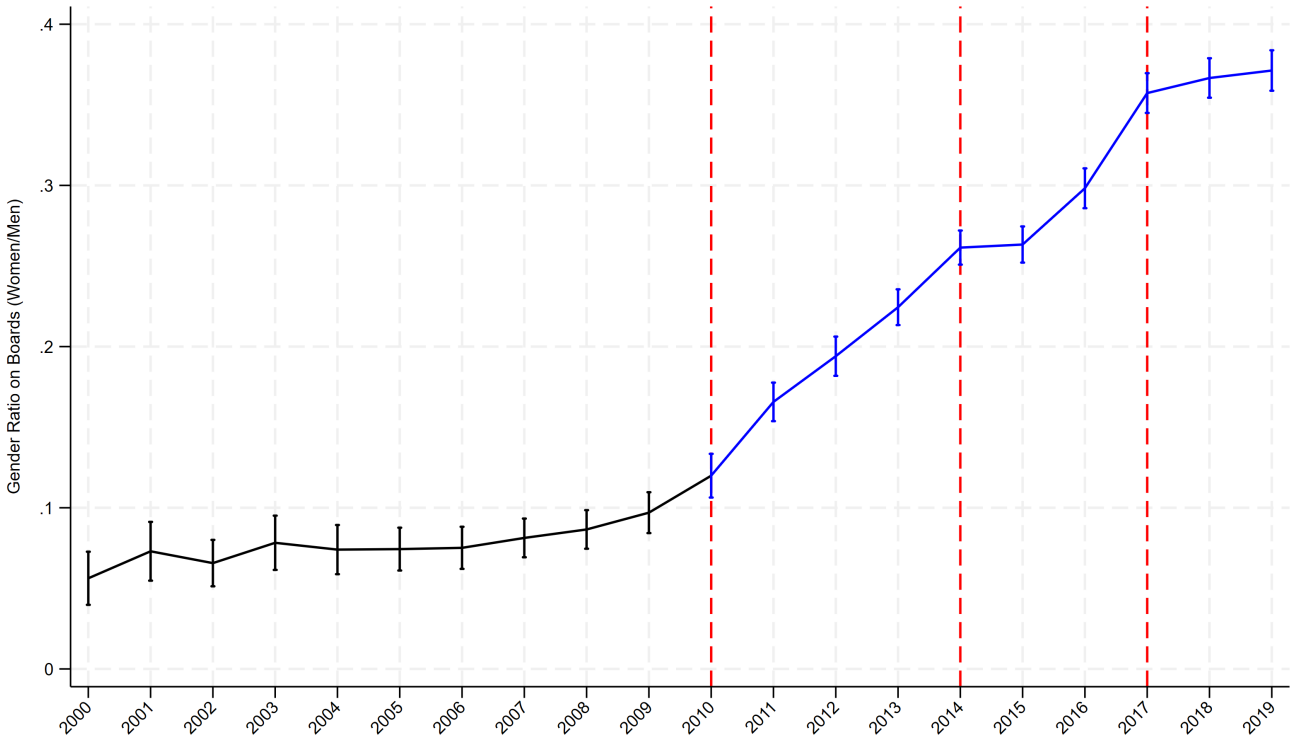
Figure 5: Timeline for French Corporate Quota Reform of 2010



The proposal was initially introduced and discussed in the media in March 2009, subsequently submitted to the French National Assembly in December 2009. The first version gained approval from the National Assembly in January 2010, initiating parliamentary debates throughout 2010 up to January 2011. The final version of the law received presidential approval in January 2011. The information (illustrated in figure 5) is derived from sources including Ladant and Paul-Delvaux (2024); Ferreira et al. (2021); Bender et al. (2015). As shown in Figure 6, there is a significant change in the gender ratio on French corporate boards of listed firms after 2010. The increasing trend suggests that more women are entering the boards. There is a staggering implementation with a goal of achieving *20% women on corporate boards* by 2014 and *40% women on corporate boards* by 2017. It can be seen that average gender ratio (defined as women-to-men) is below 10%

in listed firms. The ratio crosses the 20% threshold on average, somewhere in 2012 and kept on increasing till 2019.

Figure 6: Average Gender Ratio (Women/Men) on the Boards of Listed Firms (95% confidence-intervals)



5 Data Description

5.1 Data Source and Sample Size

Data is extracted from the BoardEx database for all publicly listed firms in France between 2001 and 2019. The data set includes information on the highest-ranking executives and board members within these firms and organizations, including roles such as CEOs, CFOs, board directors, and other senior leadership positions. The BoardEx database undergoes daily updates, with the frequency and types of variables varying as new information becomes available. The temporal range of BoardEx data can span several decades, contingent on data source availability and update frequency.

Table 1: Sample Size

Year	**Firms**	**Individuals**		**Gender ratio**
		Men	Women	(*Women/Men*)
2001	838	6025	1242	0.206
2002	872	6840	1434	0.210
2003	888	7544	1592	0.211
2004	908	8360	1783	0.213
2005	926	8915	1916	0.215
2006	948	9582	2081	0.217
2007	956	10217	2281	0.223
2008	972	10500	2389	0.228
2009	974	10693	2499	0.234
2010	984	10894	2658	0.244
2011	994	11060	2883	0.261
2012	995	11079	2989	0.270
2013	994	11292	3157	0.280
2014	999	11566	3405	0.294
2015	1000	11784	3603	0.306
2016	998	11901	3800	0.319
2017	1003	12015	4096	0.341
2018	1002	12109	4319	0.357
2019	999	12023	4454	0.370

The sample comprises 1,065 unique French firms listed on regulated markets between 2001 and 2019 and includes 23,872 unique individuals (18,305 men and 5,567 women) holding executive positions in listed firms during this period in France. Table 1 provides a year-wise breakdown of unique individuals and firms. It can be seen that the panel is unbalanced because there are new people entering the managerial roles as well as existing ones leaving their roles in each year. Overall, women are consistently lower in comparison to men for all years. However, the gender ratio is gradually rising over the sample time period on managerial positions in these firms (last column in table 1).

Table 2: Number of firms by sector

Grouped Sectors	No. of firms
Construction and Real Estate	99
Consumer Goods and Services	231
Energy and Utilities	51
Financial and Business Services	163
Healthcare and Pharmaceuticals	96
Manufacturing	159
Technology and Telecommunications	171
Transportation	21
Other	74

Additionally, the database allows for further categorization of firms into sectors. Table 2 displays the number of unique firms in the sample categorized by sector. The analysis for each sector is not possible due to very low number of observations (see table A1 for breakdown of each category), therefore, the sectors have been grouped together into seven categories (for number of firms, see table 2) namely, manufacturing industries, financial services, consumer goods and services, technology and telecommunications, healthcare and pharmaceuticals, energy and utilities, transportation, and construction and real estate.

Figure 7: Average Gender Ratio (Women/Men) on the Boards of Listed Firms by Sector (95% confidence-intervals)

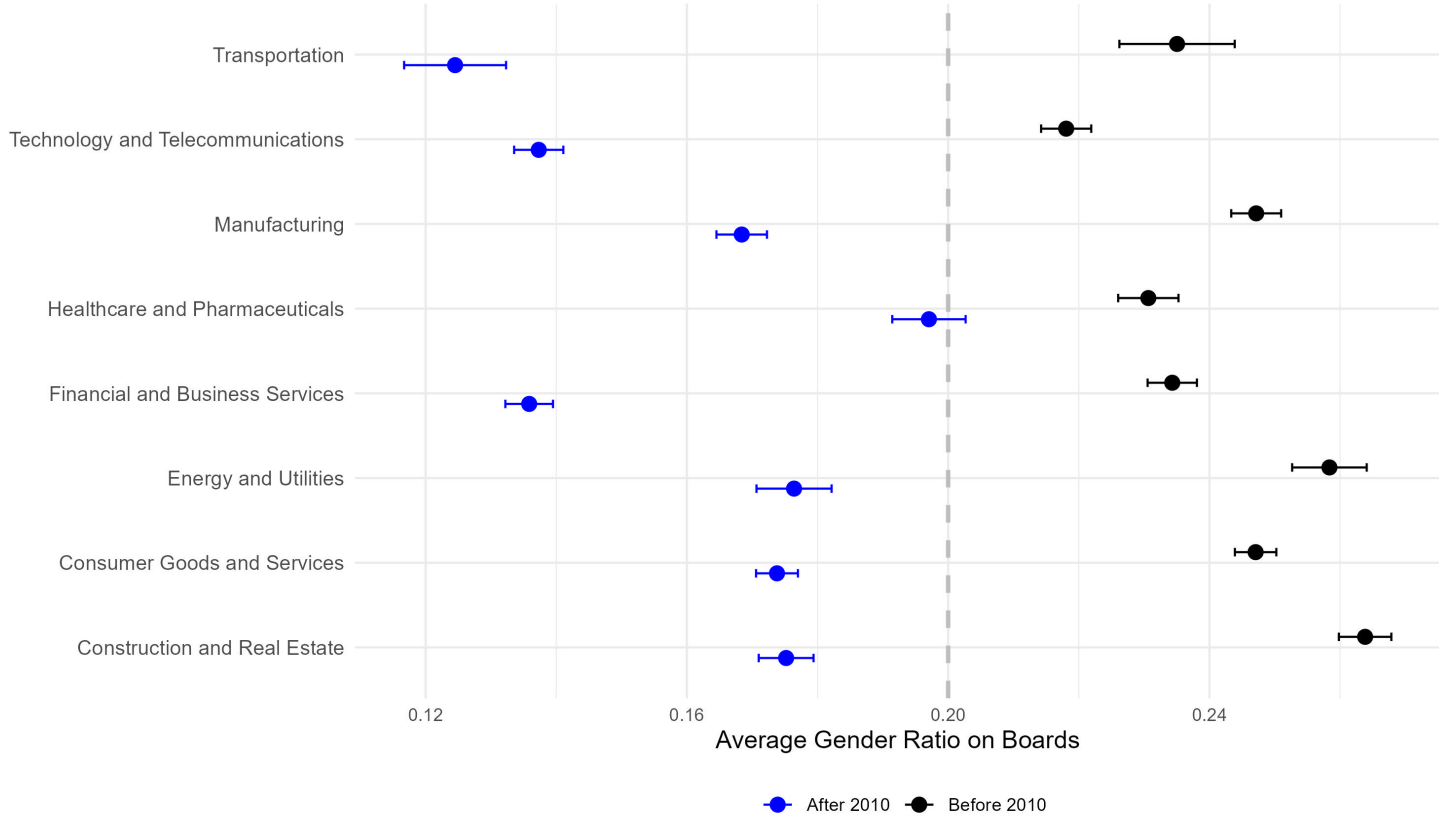


Figure 7 shows the gender ratio in 2009 and 2019 for each sector. All sectors show a similar trend with a significant increase in gender ratio (women/men) as a result of the gender quota for corporate boards. Therefore, it can be assumed that all sectors contribute to the overall rise in gender ratio on boards after 2010.

5.2 Outcome: Becoming a board member

The outcome variable *becoming a corporate board member* (BMF_{ijt}) is constructed by following the measure used by von Essen and Smith (2023). It measures *being appointed to a board* for the *first time*. BMF_{ijt} is defined as a binary variable which takes value 1 if an individual i is not a board-member at firm j in *t-1* and becomes a board member in t. For every *t+1*, an individual i is dropped from the sample if $BMF_{ijt} = 1$.

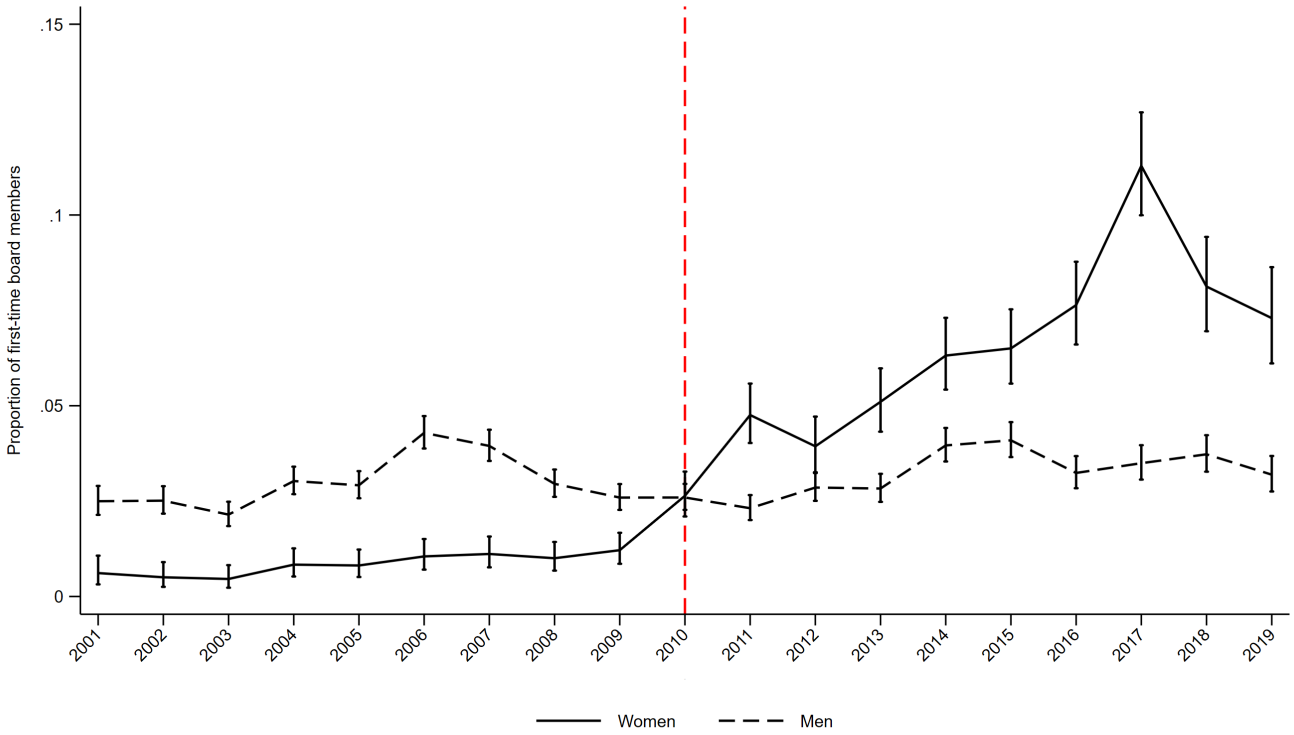
In France, after the introduction of the gender quota law in 2010, it is expected that more women are entering boards for the first time. Figure 8 shows that before 2010, there is no significant gap between men and women sitting on new boards for the first time. However, as expected, the gap becomes significant after 2010, and the representation of new women on boards (where they never sat before) increases. This supports the objective of the 2010 quota law that aimed to bring more women to leadership positions.

5.3 Defining Professional Network - *Weak Ties*

Professional connection is defined as a connection formed with a co-worker. Professional network is defined in two ways to capture different possibilities of receiving referrals from co-worker networks. The network analysis introduced by von Essen and Smith (2023) is extended in this paper by incorporating both degree and betweenness centrality measures to assess the centrality of nodes within the professional network. In this way, we will be able to allow for different referral possibilities from the *weak-ties*.

The first is a conservative measure of executive network, $EN1_{it}$, captures the network of an individual i at time t with all the executives with whom they are currently working. This measure assesses the likelihood of individuals being referred to the board by other executives. The second measure, $EN2_{it}$, measures the executive connections of an individual i with whom they are currently working in t or have worked anytime in the last three years i.e. between t and $t-3$. For instance, $EN2_{i,2010}$ encompasses all the executives with whom individual i has worked between 2007 and 2010. The objective is to include recent past co-workers in *weak ties* who could potentially refer the individual for a board position and three year period is selected because this is the average tenure

Figure 8: Fraction of Individuals Becoming Board Members of Listed Firms (95% confidence-intervals)



of a board member.

5.3.1 Network characteristics

The board members are appointed from the executives pool and the professional networks play an important role in getting referrals for board positions. In terms of referrals, size of network increases the likelihood of being considered for board positions. Moreover, betweennness capturing the importance of bridging the network to help pass on the information more effectively. Higher the betweenness is, more is the chance to have access to opportunities through referrals.

The distribution plots of degree (figure 9) and betweeness (figure 10) show that some nodes (individuals within the network) have much higher centrality, meaning they are more central or

influential in the network compared to the majority. These nodes are critical because they significantly influence network dynamics, such as the flow of information or decision-making processes (like referral hiring). The concentration of values around zero and a long tail towards higher values in the degree distribution plot (figure 9) suggest a scale-free network. In scale-free networks, most nodes have a low number of connections (low degree), and a few nodes have a large number of connections. This type of distribution often follows a power-law [6]. It implies that small occurrences are extremely common, whereas large instances are rare. In the context of these network plots, it indicates that there are many executives with few connections and a few executives with many connections.

The changes in the mode of degree distribution for women after the implementation of the quota law suggest that the law might have altered the network structure for women, potentially increasing their centrality in the network [7]. Betweenness centrality measures how often a node appears on the shortest paths between other nodes in the network. Figure 10, which also shows a power-law distribution, implies that most nodes are not often on these paths, but a few are very central.

The distribution of centrality measures is skewed, which is a common characteristic of social and professional networks (Jackson, 2008). Therefore, we will compare median values in each year to assess differences in network centrality of men and women. Tables 3, 4, 5 and 6 display the median of individual centrality measures for executive networks, both conservative $EN1_{it}$ and other $EN2_{it}$, by gender. Across all centrality measures, men mostly exhibit significantly higher medians compared to women. The difference in medians is tested using Wilcoxon rank-sum test which is used when the samples are dependent and when data is not normally distributed.

Degree Centrality by Gender and Year

The table 3 for EN_1, which measures the total co-worker connections an individual has built up over the executive career observed in our sample, the median centrality for men consistently exceeds that of women, with statistically significant differences emerging particularly after 2008. This suggests a widening gap in cumulative professional connections, potentially reflecting structural barriers that limit women's access to diverse networks in executive roles.

[6] A power-law is a functional relationship between two quantities, where a relative change in one quantity results in a proportional relative change in the other quantity, independent of the initial size of those quantities. This is typically represented in a distribution as a straight line on a log-log plot.

[7] It is pertinent to note that network of an individual includes both men and women.

In contrast, the results for EN_2 in table 4, which considers connections formed within the past three years, indicate more variation. While men continue to exhibit higher median centrality than women in most years, the magnitude of the difference is generally smaller compared to EN_1. However, significant gaps emerge over time, especially post-2010, with women consistently trailing behind men.

Betweenness Centrality by Gender and Year

The betweenness centrality tables 5 and 6, for EN_1 and EN_2, further underscore the gender disparities in network influence. For EN_1, women's median betweenness centrality begins to surpass men's starting in 2008, with statistically significant differences emerging after 2012. This suggests that women who remain in executive roles increasingly occupy strategic positions in their networks, which may enhance their ability to access referrals.

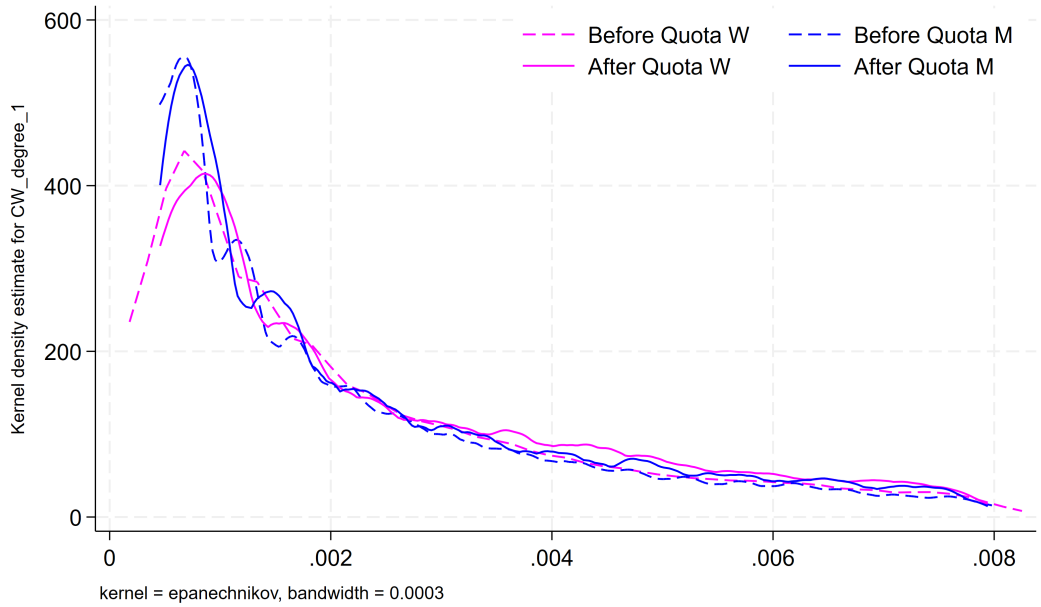
However, for EN_2 (Table 6), the pattern diverges. Men exhibit significantly higher betweenness centrality in earlier years, particularly between 2003 and 2008, reflecting their greater influence in recent professional networks. After 2010, women begin to narrow the gap, with statistically significant positive differences for women in later years (e.g., 2015 onward). This trend indicates a potential shift in women's ability to leverage recent connections for strategic network positioning, likely influenced by institutional changes such as quotas or efforts to promote gender parity in leadership.

Table 3: Degree Centrality EN_1 - by Gender and Year

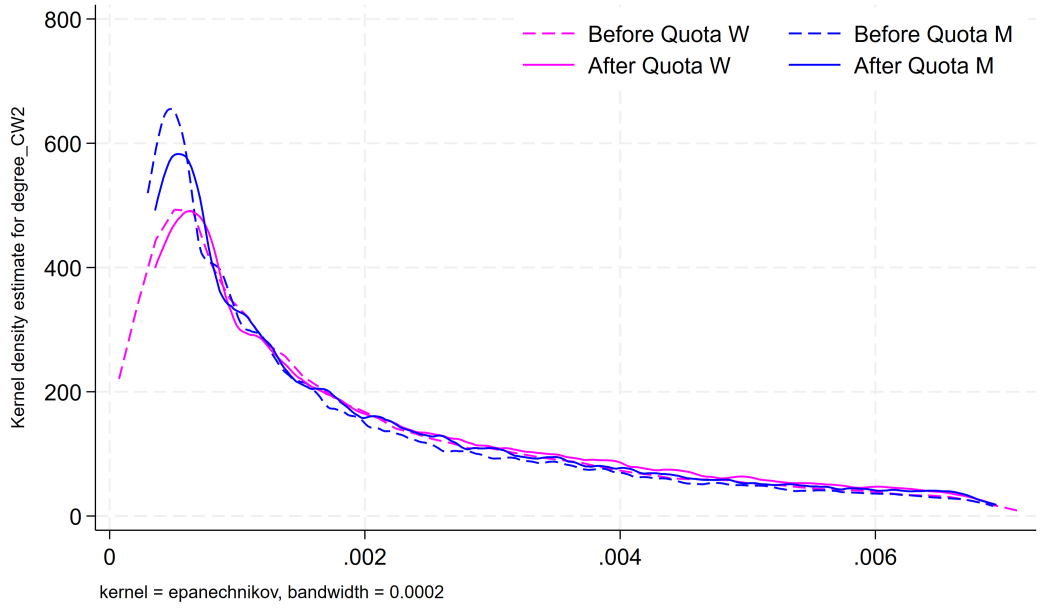
	Women			Men			
Year	Min	Max	Median	Min	Max	Median	Diff
2001	1	1320	15	1	1666	16	1*
2002	1	1207	15	1	1841	15	0
2003	1	1182	14	1	1588	15	1
2004	1	1409	14	1	1603	14	0
2005	1	2219	14	1	1710	14	0
2006	1	2090	13	1	2429	14	1
2007	1	2313	13	1	2240	14	1
2008	1	2239	12	1	1546	13	1**
2009	1	2040	12	1	2242	13	1**
2010	1	2009	12	1	2063	13	1**
2011	1	1828	12	1	1404	13	1**
2012	1	1445	12	1	1318	13	1***
2013	1	1182	12	1	1389	14	2***
2014	1	1006	12	1	1293	14	2***
2015	1	651	12	1	1169	14	2***
2016	1	685	12	1	1007	14	2***
2017	1	854	12	1	909	15	3***
2018	1	1058	12	1	858	15	3***
2019	1	928	12	1	817	15	3***

Notes: Wilcoxon rank-sum test is used to test the difference between median centrality of men and women. The difference is calculated as the median for women minus the median for men. EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 9: Degree Distribution of Executive Network

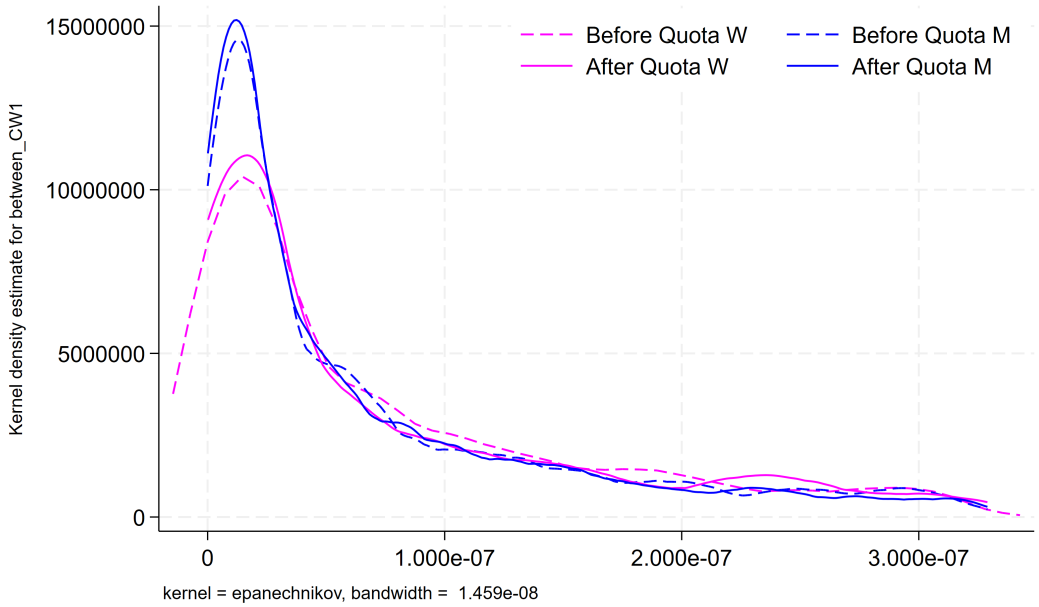


(a) $EN1_{it}$

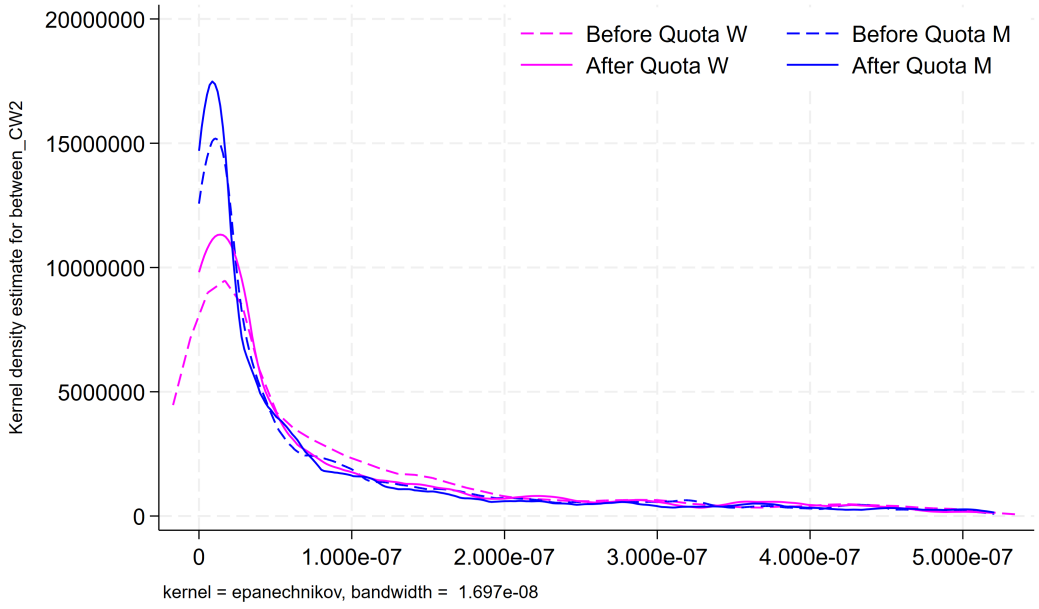


(b) $EN2_{it}$

Figure 10: Betweenness Distribution of Executive Network



(a) $EN1_{it}$



(b) $EN2_{it}$

Table 4: Degree Centrality EN_2 - by Gender and Year

	Women			Men			
Year	Min	Max	Median	Min	Max	Median	Diff
2001	1	1320	16	1	1666	15	1*
2002	1	1353	17	1	2785	17	0
2003	1	1486	20	1	2981	19	1
2004	1	1711	21	1	3263	21	0
2005	1	2219	21	1	2729	21	0
2006	1	2219	21	1	3053	20	1
2007	1	2465	20	1	3123	20	0
2008	1	2704	20	1	3079	19	1
2009	1	2842	20	1	4067	19	1
2010	1	2825	20	1	2926	19	1*
2011	1	2554	20	1	2909	18	2**
2012	1	2621	20	1	2787	18	2***
2013	1	2318	19	1	2494	18	1***
2014	1	1895	19	1	1845	18	1***
2015	1	1496	19	1	1882	17	2***
2016	1	1415	20	1	1867	17	3***
2017	1	1222	20	1	1748	18	2***
2018	1	1298	20	1	1582	17	3***
2019	1	1307	20	1	1383	17	3***

Notes: Wilcoxon rank-sum test is used to test the difference between median centrality of men and women. The difference is calculated as the median for women minus the median for men. EN_2 represents the executive network consisting only of co-workers the individual has worked with over the past three years. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Betweenness Centrality EN_1 - by Gender and Year

	Women			Men			
Year	Min	Max	Median	Min	Max	Median	Diff
2001	0	68023070	235.028	0	99136673	205.591	29.437
2002	0	75935819	335.069	0	134097061	355.438	-20.369*
2003	0	65439883	442.604	0	124119606	486.993	-44.389
2004	0	62214091	706.074	0	113012738	974.517	-268.443*
2005	0	90277596	745.601	0	149118314	988.836	-243.235*
2006	0	66578827	864.479	0	113956153	992.580	-128.101
2007	0	70539255	1151.852	0	135414066	996.168	155.684
2008	0	66384121	1340.870	0	101223390	882.316	458.554
2009	0	61420769	967.014	0	86881396	724.799	242.215
2010	0	66610344	987.278	0	95381128	713.234	274.044
2011	0	62048124	1265.875	0	93229847	1125.570	140.305
2012	0	44696333	1376.942	0	113192321	878.104	498.838**
2013	0	62041249	1446.374	0	105856162	808.941	637.433***
2014	0	74816135	1606.402	0	76766892	809.108	797.294***
2015	0	48978655	1723.664	0	76618850	778.836	944.828***
2016	0	45420836	1715.165	0	59468948	652.414	1062.751***
2017	0	45278789	1245.552	0	49444834	490.055	755.497***
2018	0	54799834	1034.653	0	51408646	388.226	646.427***
2019	0	34243602	796.207	0	35239261	232.303	563.904***

Notes: Wilcoxon rank-sum test is used to test the difference between median centrality of men and women. The difference is calculated as the median for women minus the median for men. EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Betweenness Centrality EN_2 - by Gender and Year

	Women			Men			
Year	Min	Max	Median	Min	Max	Median	Diff
2001	0	68023070	235.028	0	99136673	205.591	29.437
2002	0	96744758	456.128	0	141919191	564.904	-108.776*
2003	0	122643613	921.702	0	167562052	1245.741	-324.039**
2004	0	153727257	1562.256	0	214990630	2274.716	-712.46***
2005	0	128111234	1577.377	0	304356327	2363.804	-786.427***
2006	0	112240576	1734.135	0	318325931	2342.768	-608.633***
2007	0	134596588	2528.409	0	285639867	2826.977	-298.568***
2008	0	166574802	2918.521	0	249873256	3244.812	-326.291*
2009	0	130136261	3960.058	0	191566983	3687.489	272.569
2010	0	130196314	3547.336	0	166042650	3361.179	186.157
2011	0	79322600	3321.970	0	165798413	3242.032	79.938
2012	0	76806885	3758.671	0	124937486	3211.663	547.008
2013	0	143319288	3512.249	0	150976641	2872.040	640.209***
2014	0	160079981	4132.746	0	164061602	3237.012	895.734***
2015	0	146790786	4453.333	0	167699762	3267.164	1186.169***
2016	0	125064530	4548.179	0	158803371	3232.616	1315.563***
2017	0	94337948	3917.881	0	116033417	2699.185	1218.696***
2018	0	109087664	3545.795	0	104222924	2195.529	1350.266***
2019	0	100506860	3218.201	0	74133088	1752.747	1465.454***

Notes: Wilcoxon rank-sum test is used to test the difference between median centrality of men and women. The difference is calculated as the median for women minus the median for men. EN_2 represents the executive network consisting only of co-workers the individual has worked with over the past three years. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.4 Individual Characteristics by Gender

The table:7 provides a comparison of individual characteristics by gender before (2001-2009) and after (2010-2019) the gender quota. First, the average board membership increased for women, rising from 36.0% in the pre-quota period to 39.1% post-quota. In contrast, men's likelihood of holding a board membership decreased from 41.1% to 36.7% over the same period. This indicates a narrowing gender gap in board representation following the introduction of corporate gender quota in France. Similarly, the average of *becoming* a board member saw a significant rise for both genders, with women experiencing a larger increase from 5.9% to 22.3%, compared to men, whose probability rose from 11.9% to 20.2%.

In terms of educational background, attendance at Grande Ecole, often revered as the French equivalent of Ivy League institutions and esteemed for its perceived signal of human capital. Women attendance at these elite schools has been historically low, with Ecole Polytechnique, a premier engineering school, only starting to admit women in 1972 and had fewer than 20% female students in 2015 (Ferreira et al., 2021). Furthermore, from 1989 to 2009, only 25 30% of graduates of the École Nationale d'Administration were women. In our sample, the proportion of women attending a *Grande École* remained relatively stable, while for men it decreased slightly from 31. 6% to 29. 5% (table:7).

Highest education level is categorized into 1 =Diploma, 2 =Bachelor, 3 =Master and 4 =PhD. On average, both men and women have atleast a bachelor degree. The number of qualifications refers to the number of degrees and qualifications[8] acquired by a board member at and after the undergraduate level. The average number of qualifications held by women increased from 1.08 to 1.52 from pre to post quota reform. For men, there is only an increase from 1.38 to 1.42 on average (table:7).

Age is measured in years, and as expected, the average age is quite close to retirement age. The average age of both men and women declined over time, suggesting a shift toward younger people assuming managerial roles in the post-quota period. Number of current listed boards refers to the number of boards of listed firms on which an individual serves simultaneously. Table:7 shows that women in the sample on average sat on less boards compared to men. Women saw an increase in

[8]This includes professional exams and certifications, along with university degrees.

Table 7: Individual Characteristics by Gender - Full Sample

	(2001-2009)		*(2010-2019)*			
Variable	Mean	N	Mean	N	Diff	SE
Women						
Board Member (1 = Yes)	0.360	17,227	0.391	35,403	0.031***	0.004
Becoming Board Member	0.059	17,227	0.223	35,403	0.163***	0.003
Grande École (1 = Attended)	0.204	12,526	0.211	24,268	0.007	0.004
Age (Years)	58.649	10,346	56.868	20,183	-1.781***	0.117
Highest Education Level	2.555	12,526	2.554	24,268	-0.001	0.008
No. of Qualifications	1.078	1,404	1.526	8,243	0.447***	0.039
No. of Current Listed Boards	1.337	1,379	1.407	8,243	0.070***	0.025
Compensation (000 USD)	66.391	517	77.932	1,691	11.541*	6.515
Men						
Board Member (1 = Yes)	0.411	78,715	0.367	115,748	-0.044***	0.002
Becoming Board Member	0.119	78,715	0.202	115,748	0.083***	0.002
Grande École (1 = Attended)	0.316	58,675	0.295	84,027	-0.021***	0.002
Age (Years)	64.393	56,476	61.402	77,089	-2.990***	0.061
Highest Education Level	2.521	58,675	2.535	84,027	0.014***	0.004
No. of Qualifications	1.382	13,662	1.426	21,400	0.044***	0.013
No. of Current Listed Boards	1.661	13,469	1.408	21,394	-0.253***	0.013
Compensation (000 USD)	326.027	4,706	390.304	3,469	64.277***	17.870

Notes: 2001-2009 is the pre-quota period while 2010-2019 is the post-quota period. Highest degree is defined as a categorical variable (1 =Diploma, 2 =Bachelor, 3 =Master, 4 =PhD). Number of qualifications include all the professional qualifications including certifications. Compensation is inflation adjusted with 2010 as base year. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

number of board seats while men saw a significant decrease after the quota law.

Total compensation is measured in thousands of US dollars adjusted for inflation (using CPI with 2010 as base year) and comprises of salary and bonus. While it might not be a comprehensive measure, especially at higher managerial levels where remuneration includes many perks not captured by salary or bonus alone, it is used here due to the non-availability of data on other monetary and non-monetary perks for board members. Due to missing values, the data on compensation is very noisy. While there are missing values for both men and women, their proportions in the avail-

able data mirror those of the non-missing values of total compensation in the dataset[9]. It can be seen in table 7 that the women's compensation increased significantly from approximately $66,000 to $78,000, while the men's compensation saw a much greater jump from $326,000 to $390,000, reflecting persistent gender disparities in remuneration which could be attributed to differences in human capital and other characteristics.

5.5 Gender Gap in Characteristics of First-time Board Members

The table:8 highlights the gender differences in characteristics of first-time board members both before and after the introduction of gender quota in France. Men first-time board members were significantly more likely to have attended a *Grande École*, with 32% of men compared to 26% of women in the pre-quota period. This gap of 6 percentage point persisted in the post-quota period, where 27% of men first-timers and 21% of women first-timers had attended a *Grande École*. The average age of first-time board members also differed considerably both before and after the quota. First-time women board members are younger (64.65 years) than their male counterparts (69.28 years) with a difference of 4.63 years. This pattern continues after the quota as women first-timers continued to be younger than men first-timers, with their average age dropping to 59.47 years compared to 64.84 years for men, widening the age gap to 5.37 years.

In terms of professional qualifications, first-time men board members had a significantly higher number (1.39) compared to women members (1.12), with a gap of 0.28 before the introduction of gender quota. The number of qualifications shifted after the quota, with women now holding more qualifications on average (1.49) than men (1.35), a reversal of the earlier trend. Moreover, men board members served on more current listed boards (1.66) compared to women (1.35) before the quota. There is a reversal of trend in number of boards as well with women first-timers sit on average on 1.4 boards while men members now sit on 1.33 after the quota. The gender gap in compensation persists across the time period with men board members earning more than women before as well as after the quota. The gap also widened slightly from $153,930 to $154,537.

[9]Table A2 shows that approximately 78.3% of missing values of total compensation is for men while 21.7% is for women and approximately 78.7% of missing values of total compensation is for men while 21.3% is for women.

Table 8: Gender Gap in Characteristics of First-time Board Members

	Before the Gender Quota (2001-2009)			
Variable	Mean (Women)	Mean (Men)	Difference	Std. Error
Grande École (1 = Attended)	0.26	0.32	-0.06***	(0.02)
Age (Years)	64.65	69.28	-4.63***	(0.41)
Highest Education Level	2.51	2.57	-0.06	(0.04)
No. of Qualifications	1.12	1.39	-0.28***	(0.07)
No. of Current Listed Boards	1.35	1.66	-0.30***	(0.05)
Compensation (000 USD)	28.188	182.118	-153.93***	(13.858)
	After the Gender Quota (2010-2019)			
Variable	Mean (Women)	Mean (Men)	Difference	Std. Error
Grande École (1 = Attended)	0.21	0.27	-0.06***	(0.007)
Age (Years)	59.47	64.84	-5.37***	(0.15)
Highest Education Level	2.56	2.60	-0.04***	(0.013)
No. of Qualifications	1.49	1.35	0.15***	(0.022)
No. of Current Listed Boards	1.40	1.33	0.07***	(0.014)
Compensation (000 USD)	69.345	223.882	-154.537***	(19.78)

Notes: The difference is calculated as the mean for women minus the mean for men. Highest degree is defined as a categorical variable (1 =Diploma, 2 =Bachelor, 3 =Master, 4 =PhD). Number of qualifications include all the professional qualifications including certifications. Compensation is inflation adjusted with 2010 as base year. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.6 Characteristics of First-time Women Board Members

The table:9 highlights the differences in key characteristics of first-time women board members across two periods: pre-quota (2001-2009) and post-quota (2010-2019). The proportion of first-time women board members who attended a *Grande École* decreased significantly from 26.1% to 21.3%, indicating a shift in the educational background of women entering boards after the quota. However, in terms of the average highest degree obtained by first-time women board members, there are no significant change between the two periods, both averaging close to a master's level of education.

Women are appointed to boards at comparatively younger ages than earlier, following the implementation of quota policies. The average age of first-time women board members dropped

significantly from 64.65 years in the pre-quota period to 59.47 years post-quota. Another significant shift is seen in the number of professional qualifications. Women in the post-quota period held more professional qualifications on average (1.49) compared to those in the pre-quota period (1.12), reflecting an increase of 0.38 qualifications. This suggests that women entering new boards are on average "*better quality*" in terms of qualification compared to pre-quota period.

Table 9: Characteristics of First-time Women Board Members

	2001-2009		*2010-2019*			
Variable	Mean	N	Mean	N	Difference	SE
Grande Ecole (1 =Attended)	0.261	422	0.213	5145	-0.047**	(0.022)
Age (years)	64.651	734	59.468	6862	-5.183***	(0.419)
Highest degree	2.512	422	2.562	5145	0.050	(0.040)
No. of Qualifications	1.115	477	1.494	5444	0.379***	(0.069)
No. of Listed Boards	1.354	475	1.398	5444	0.044	(0.045)
Total compensation ($K)	28.188	131	69.345	987	41.157***	(6.124)

Notes: The difference is calculated as the mean value before quota minus the mean after quota. 2001-2009 is the pre-quota period while 2010-2019 is the post-quota period. Highest degree is defined as a categorical variable (1 =Diploma, 2 =Bachelor, 3 =Master, 4 =PhD). Number of qualifications include all the professional qualifications including certifications. Compensation is inflation adjusted with 2010 as base year. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

First-time women board members in the post-quota period got total compensation of $69,345 on average, significantly higher than the pre-quota average of $28,188. However, this substantial increase may be attributed to the entry of more qualified women on boards. The number of listed boards on which first-time women board members served remained relatively stable, with an insignificant increase from 1.35 to 1.40. This suggests that while more women are being appointed to boards, their distribution across multiple boards has not significantly changed (on average).

6 Empirical Strategy

The outcome variable for board membership is defined as a binary variable indicating first-time board membership. Professional networks are captured through measures of network centrality,

highlighting the importance of network position in achieving board positions. The study employs both degree and betweenness centrality measures to capture different dimensions of network influence —local connectivity and global bridging properties, respectively as detailed in section 3.3. This dual approach allows a nuanced understanding of how professional ties influence career advancements to board positions, underscored by detailed network analysis to account for the flow of information and referrals within these networks. In this backdrop, equation 1 is the specified reduced form model.

$$\begin{aligned} BM_{ijt} = \beta_1 \text{Cent}_{it-1} + \beta_2 \text{W}_i + \beta_3 \text{W}_i \times \text{Cent}_{it-1} + \beta_4 \text{Quota}_t \times \text{Cent}_{it-1} \\ + \beta_5 \text{Quota}_t \times \text{W}_i \times \text{Cent}_{it-1} + \beta_6 X_i + \beta_7 Y_j + \delta_j + \delta_t + \mu_{jt} \end{aligned} \tag{1}$$

The coefficient β_1 captures the direct effect of an individual's network in the previous year (Cent_{it-1})on their probability of becoming a board member in a given year $\text{BM}_{ij,t}$. The coefficient of the interaction term ($\text{W}_i \times \text{Cent}_{it-1}$) indicates that the effect of an individual's network on board membership may differ by gender. Additionally, the interaction term $\text{Quota}_t \times \text{Cent}_{it-1}$ suggests that the network's influence on board appointments may be affected by the introduction of the quota law in 2010. A triple interaction term, $\text{Quota}_t \times \text{W}_i \times \text{Cent}_{it-1}$, is also included to measure the heterogeneous effect of the quota on women's likelihood of becoming board members, depending on their network centrality. It is expected that women with higher centrality have more chances of entering new board after the announcement of gender quotas in 2010.

The vector X_i represents individual control variables, including age, education, board experience, and the type of educational institution attended (Ecole Grande). The vector Y_j includes firm-level control variables such as firm size (measured through market capitalization and the number of employees) and the gender ratio in managerial roles. The error term is denoted by μ_{jt}. The model also includes firm fixed effects (δ_j) and time fixed effects (δ_t) to control for unobserved heterogeneity across firms and over time, respectively.

Standard errors are clustered at both the firm and year levels to account for two sources of potential correlation. Firm-level clustering addresses the possibility that individuals associated with the same firm may share unobserved characteristics influencing their likelihood of joining a board. These characteristics could include firm-specific policies on compensation, working hours, workplace environment, or other unobserved dynamics. Year-level clustering accounts for shared

shocks (e.g., macroeconomic conditions or changes in industry practices) that may affect board appointments in a given year. Together, these clustering strategies provide robust standard errors by addressing intra-group correlation and temporal shocks.

6.1 Potential Threats to Identification - Endogeniety of Networks

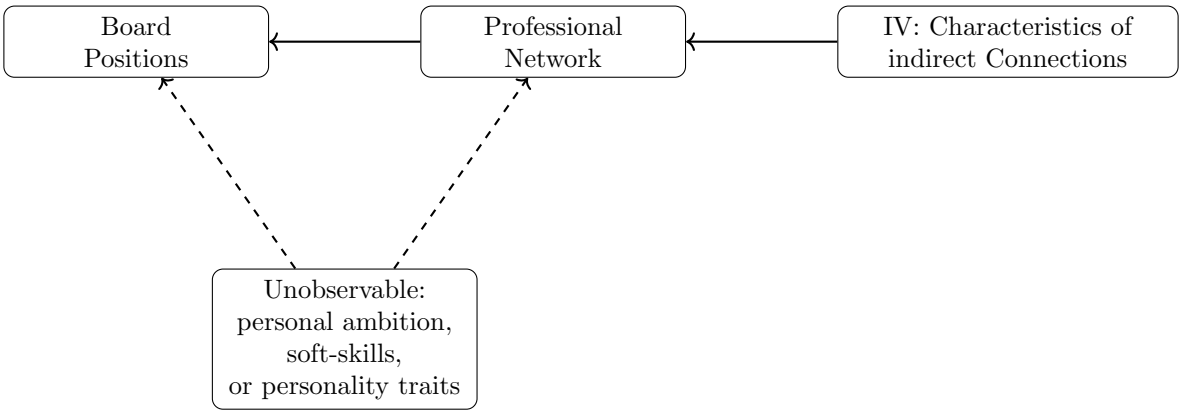
Centrality within a professional network may both affect and be affected by board membership. Individuals possessing high centrality are likely to be selected for board positions due to their extensive connections and visibility; conversely, once appointed to a board, these individuals may gain further centrality as their network expands. To mitigate potential endogeneity concerns arising from this bi-directional causality, the study's primary outcome variable is defined as the event of becoming a board member at a new firm as detailed in section 5.2. Upon achieving this status, individuals are excluded from the sample in subsequent years. This method helps to isolate the effect of pre-existing network centrality on the likelihood of attaining board membership on a new board without the confounding effects of post-appointment network changes.

Unobserved variables such as personal ambition, skills, or networking ability could also influence both an individual's centrality within a network and their likelihood of becoming a board member. Although these characteristics are challenging to measure directly and may not be fully captured by the available control variables, the selection of our sample mitigates some of these concerns. The sample comprises individuals who have already attained managerial roles, suggesting a baseline level of competence and ambition among the participants. Nonetheless, it is important to acknowledge that the BoardEx database, while extensive, does not include data on personal attributes such as marital status or number of children, which could influence career trajectories. This absence represents a limitation of our analysis, as such factors might contribute to variations in career progression and network formation that are not accounted for in the current study framework.

In assessing the network centrality measures derived from employment history, one might consider the potential for measurement errors. These centrality measures are constructed based on the assumption that individuals are connected (*weak-ties*) if they have been employed at the same firm within the same year. A caveat of this method is that mere co-employment does not necessarily transalte into meaningful connections that could influence board recommendations in future. Such

interactions may require deeper, more substantive relationships than those captured by simple co-employment. Although this approach might lead to an overestimation of an individual's network size, it remains a useful approximation tool in the literature e.g., (von Essen and Smith, 2023) in absence of more detailed interaction data. Therefore, it is important to interpret the results with an understanding of these potential limitations.

Figure 11: Endogeneity of Networks and Causal Identification



6.2 Identification strategy - Instrumental Variable Approach

Estimating the causal effect of professional network centrality on an individual's likelihood of obtaining board memberships for the first time (as specified by equation 1) presents a significant empirical challenge due to potential endogeneity. Unobserved factors, such as innate ability, personality traits, or unmeasured aspects of human capital, may influence both an individual's network centrality and their probability of board appointment. To address this endogeneity concern, we employ an instrumental variable (IV) approach using the centrality of second-degree connections as an instrument for the individual's own network centrality (Figure 11). This instrument is detailed below.

6.2.1 Instrument: Centrality of Second-Degree Connections

The proposed instrument is the centrality of an individual's second-degree connections. Specifically, the connections of their immediate contacts within the professional network of connections at a distance of two. The peer-effects literature suggests that if *peers of the peers are not direct peers*, then characteristics of peers of the peers can potentially help to identify the network effects (De Giorgi et al., 2010; Nicoletti et al., 2018; Bramoullé et al., 2020).

Before discussing the relevance and exclusion restriction of our IV, the illustration of second-degree connections or indirect neighbours in a network is provided in Figure 12. For an individual A, who is directly connected to individuals B and C, the second-degree connections are those connected to B but not directly to A (e.g., individuals X, Y, and Z). The centrality of these second-degree connections captures the extent to which A's immediate contacts are connected to influential or well-positioned individuals within the broader network. As, our outcome is inherently driven by the referrals coming from the networks, the only way to obtain referrals from nodes at distance 2 is through nodes at distance 1 (direct connections).

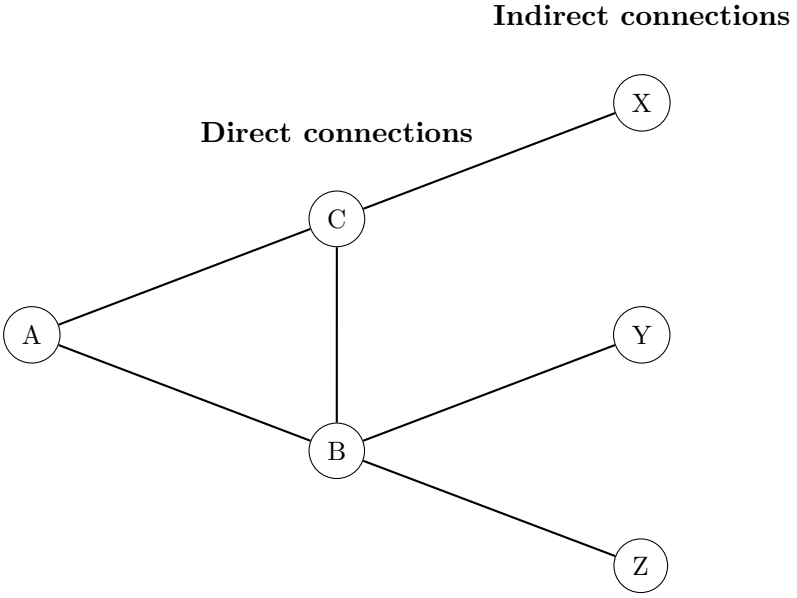


Figure 12: Illustration of Direct and Indirect Connections

The caveat here (Figure 12) to note is that node C is at a distance of 1 from A, but it is also

a direct connection of B. If we use the characteristics of the indirect connections of A without accounting for this overlap of connections, our instrument would be rendered invalid (Bramoullé et al., 2020). Therefore, we define indirect connections as a set of nodes that are at a minimum distance of 2 from A.

Formally, if network graph (N, g) consists of nodes $N = \{1, ..., n\}$ and a real-valued n x n matrix g, where g_{ij} is *adjacency matrix* that represents the relationship between node i and j. The *direct* neighborhood of a node i is a set of nodes that i is linked to,

$$\textit{Direct-}N_i(g) = \{j \mid g_{ij} = 1\}$$

While, the *indirect* neighborhood of a node i is a set of nodes that i is linked to only through j,

$$\textit{Indirect-}N_i(g) = \{k \mid \exists j \text{ such that } g_{ij} = 1, g_{ik} = 0, \text{ and } g_{jk} = 1\}$$

Therefore, we estimate the first-stage as specified below in equation 2. The coefficient γ_1 determines the effect of average centrality of indirect networks (*peers-of-peers*) on an individual's own network position.

$$\text{Cent}_{it} = \gamma_0 + \gamma_1 \overline{\text{Cent}_{kt}} + \gamma_2 X_i + \delta_t + \delta_i + \eta_{it} \tag{2}$$

Relevance of the Instrument

The relevance condition requires that the instrument be correlated with the endogenous explanatory variable, in this case, the individual's professional network centrality. The centrality of second-degree connections fulfills this condition for two main reasons.

First, if an individual's immediate contacts are linked to highly central nodes, this can enhance the individual's network value through indirect channels. As illustrated in (Figure 12), B's connections to well-positioned nodes like X, Y, or Z can provide A with access to valuable information and opportunities, such as insights into board positions. This indirect access improves A's standing within the professional network, elevating their centrality.

Second, the centrality of B's connections reinforces B's own network position, increasing their influence and resources. A more central B is likely to be better positioned to act as a connector or provide endorsements for A, further strengthening A's network centrality through facilitated introductions or referrals.

Empirically, these dynamics suggest a strong positive correlation between the centrality of second-degree connections and an individual's own network centrality, thereby satisfying the relevance requirement for a valid instrument.

Validity and Exclusion Restriction

The validity of the instrument hinges on the exclusion restriction, which suggests that the instrument affects the dependent variable (board membership) only through its impact on the endogenous explanatory variable (professional network centrality), not through any other channels. In peer-effects literature, Bramoullé et al. (2020) suggests that the characteristics of peers of peers who are not directly connected to an individual (nodes at distance 2) only affect that individual's outcome indirectly, through their impact on the outcomes of their direct connections.

In our context, the exclusion restriction implies that the centrality of an individual's second-degree connections influences their probability of obtaining a board membership solely via its effect on their own network centrality. Several arguments support this assumption:

1. The second-degree connections (X, Y, Z) are not directly connected to A and, therefore, are unlikely to influence A's board appointments through direct referrals. Any effect they have on A's likelihood of becoming a board member is through B, the immediate connection of A.

2. By including comprehensive human capital controls (e.g., education, experience) and fixed effects (e.g., industry, year), we account for observable factors that could correlate with both the instrument and the dependent variable, reducing the risk of omitted variable bias.

6.3 Characteristics of Direct and Indirect Connections

The table:10 provides a detailed comparison of the characteristics of direct connections for first-time board members, by gender and periods before and after the implementation of the gender quota. Prior to the implementation of gender quotas, men board members had significantly more direct connections (43.45 vs. 31.43, difference = -12.02, $p < 0.01$) and higher mean degree centrality of these direct connections. These differences suggest that direct connections of male board members are better positioned into professional networks, giving them a potential advantage in securing board positions.

Similarly, direct connections of men board members hold a higher average number of listed board positions and exhibited substantially higher betweenness centrality, indicating that they occupied more strategic positions in the network.

The post-quota period reveals a striking reversal in network patterns. Women first-time board members now surpass men in direct connections (42.72 vs. 30.44, difference = 12.28, $p < 0.01$) and the proportion of women in their networks increases significantly (7.93 vs. 4.70, difference = 3.23, $p < 0.01$). Additionally, average degree centrality of direct connections of women board members improves relative to men, with statistically significant positive differences in both EN_1 and EN_2.

This shift suggests that the gender quota policy may have facilitated greater integration of women into professional networks, both quantitatively (in terms of connections) and qualitatively (in terms of centrality of direct connections). However, direct connections of men and women remain similar in other characteristics such as the number of qualifications and listed boards.

The table:11 compares the network characteristics of indirect connections (second-order) for first-time board members by gender, before and after the implementation of gender quotas. Prior to the gender quota, indirect connections of men board members exhibits consistently higher levels of both degree and betweenness centrality. Similarly, while the differences in *betweenness centrality* were not statistically significant, indirect connections of men still displayed higher values for both EN_1 and EN_2. This indicates that, although not conclusive, male indirect networks likely facilitated more strategic bridging roles compared to their female counterparts.

Post-quota, the gender gap in centrality of indirect connections largely disappears. The difference

Table 10: Gender Gap in Characteristics of Direct Connections of First-time Board Members

	Before the Gender Quota (2001-2009)			
Variable	Mean (Women)	Mean (Men)	Difference	Std. Error
Direct Connections	31.43	43.45	-12.02***	(2.50)
Women as direct connection	3.63	4.29	-0.65***	(0.24)
Avg. Age	66.16	65.94	0.22	(0.25)
Avg. No. of Qualifications	1.53	1.56	-0.03	(0.04)
Avg. No. of Listed Boards	1.95	2.05	-0.104*	(0.06)
Prop. Grande Ecole (1 =Attended)	0.33	0.32	0.008	(0.01)
Prop. First-time Board Members	0.63	0.64	-0.005	(0.009)
Avg. Degree Centrality (EN_1)	28.95	33.61	-4.66***	(0.76)
Avg. Degree Centrality (EN_2)	42.65	49.94	-7.29***	(1.15)
Avg. Betweenness Centrality (EN_1)	533434.1	692502.3	-159068.2***	(26728.2)
Avg. Betweenness Centrality (EN_2)	855469.9	1085819.3	-230349.2***	(40297.8)
	After the Gender Quota (2010-2019)			
Variable	Mean (Women)	Mean (Men)	Difference	Std. Error
Direct Connections	42.72	30.44	12.28***	(0.87)
Women as direct connection	7.93	4.70	3.23***	(0.13)
Avg. Age	60.92	61.13	-0.21**	(0.08)
Avg. No. of Qualifications	1.53	1.53	-0.006	(0.015)
Avg. No. of Listed Boards	1.49	1.51	-0.014	(0.014)
Prop. Grande Ecole (1 =Attended)	0.28	0.27	0.013***	(0.003)
Prop. First-time Board Members	0.49	0.51	-0.01***	(0.003)
Avg. Degree Centrality (EN_1)	28.54	26.75	1.79***	(0.26)
Avg. Degree Centrality (EN_2)	42.21	39.18	3.03***	(0.40)
Avg. Betweenness Centrality (EN_1)	503161.6	506258.0	-3096.4	(8451.7)
Avg. Betweenness Centrality (EN_2)	917914.2	878683.2	39231.0***	(14295.2)

Notes: The difference is calculated as the mean for women minus the mean for men. Highest degree is defined as a categorical variable (1 =Diploma, 2 =Bachelor, 3 =Master, 4 =PhD). Number of qualifications include all the professional qualifications including certifications. EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year, while EN_2 refers to the executive network consisting only of co-workers the individual has worked with over the past three years. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in *degree centrality* and *betweenness centrality* is statistically insignificant. For EN_2, women slightly surpass men (63.74 vs. 63.33, difference = 0.41), though this difference is also not significant. These findings suggest that the quota has helped level the playing field, enabling women to access similar types of indirect professional networks.

Table 11: Gender Gap in Characteristics of Indirect Connections of First-time Board Members

	Before the Gender Quota (2001-2009)			
Variable	Mean (Women)	Mean (Men)	Difference	Std. Error
Avg. Degree Centrality (EN_1)	39.77	46.12	-6.35***	(1.33)
Avg. Degree Centrality (EN_2)	61.91	71.79	-9.88***	(2.27)
Avg. Betweenness Centrality (EN_1)	1,043,049	1,133,008	-89,959.14	(78,202.13)
Avg. Betweenness Centrality (EN_2)	1,773,383	1,911,152	-137,769.04	(127,809.72)
Avg. Age	64.70	64.51	0.18	(0.21)
Avg. Ecole Attendance	152.28	193.90	-41.61***	(9.82)
Avg. Gender Ratio	187.26	237.97	-50.70***	(11.88)
	After the Gender Quota (2010-2019)			
Variable	Mean (Women)	Mean (Men)	Difference	Std. Error
Degree Centrality (EN_1)	39.17	38.07	1.10***	(0.35)
Degree Centrality (EN_2)	62.59	60.90	1.69***	(0.59)
Betweenness Centrality (EN_1)	804,751	846,617	-41,865.85***	(11,767.05)
Betweenness Centrality (EN_2)	1,570,406	1,640,967	-70,561.16***	(26,505.88)
Avg. Age	60.17	60.86	-0.69***	(0.07)
Avg. Ecole Attendance	193.47	133.44	60.03***	(3.84)
Gender Ratio	240.48	165.91	74.57***	(4.72)

Notes: EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year, while EN_2 refers to the executive network consisting only of co-workers the individual has worked with over the past three years. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

7 Results

7.1 Individual level Outcome

Table 12 presents both OLS and 2SLS estimates of how network centrality affects an individual's likelihood of joining at least one new board in that year conditional on the individual has not sat on that board before. The centrality measures are instrumented using the average centrality of indirect connections as discussed in Section 6.2.1. First-stage results reported in the lower section of Table 12 show that the instrument is valid, as indicated by the F-statistic. The average centrality of indirect connections significantly and positively affects individuals' centrality for each measure and network definition.

The 2SLS coefficients are generally larger in magnitude than the OLS estimates for betweenness centrality. This indicates that OLS may underestimate the true influence of networks on board appointments. Looking at the centrality coefficients across the 2SLS columns, we see consistent evidence that higher centrality significantly increases the probability of becoming a board member. Similarly, individuals with one additional connection in their executive network EN_2 are 0.08 percentage points more likely to become a board member at a listed firm where they have never previously served as a board member. Betweenness centrality is used in log form to account for the large values. If an executive has a 1% increase in betweenness centrality, the likelihood of becoming a board member for the first time increases significantly by 0.8 percentage points for network EN_1 and by 1.32 percentage points for network EN_2.

In order to examine how this differs for women, and whether the quota amplifies the importance of networks, we include interaction terms in our models. The main effect of *women* is negative in all columns of Table 12, implying that (holding centrality and other controls constant) women executives face a lower baseline probability (around 5.3% to 6.4% less, depending on the centrality measure and network definition used) of becoming a board member. However, the interaction *Women* $\times$ *Quota2010* is positive and highly significant, suggesting that the quota policy increased the net probability by approximately 7% while controlling for degree centrality and by 15% while controlling for betweenness centrality in the likelihood of women joining boards they had not sat on before.

The coefficient on *Centrality* × *Quota2010* is negative, indicating the quota somewhat diminishes the marginal effect of centrality alone for both men and women executives. We also include a triple interaction, *Centrality* × *Women* × *Quota2010*, to examine how centrality affects the likelihood of becoming a board member for women after the French reform of 2010. In some specifications, these interactions become positive, suggesting the quota may strengthen the effect of network centrality for women specifically—although the significance varies across different centrality definitions. For an additional connection in EN_1, being a woman after the quota increases the probability of sitting on new boards by 0.03 percentage points (column 2 of Table 12). Meanwhile, the same net effect for having one more connection in EN_2 is 0.01 percentage points (column 4 of Table 12). These effects are, however, not very significant.

Betweenness measures the influence one holds in the network. The net effect of a one percent increase in betweenness in executive network EN_1 is a 0.33 percentage point reduction in the probability of becoming a board member for a woman after the quota. The net effect for betweenness in executive network EN_2 is around 0.3 percentage points; however, this effect is not statistically significant.

All models in Table 12 employ year fixed effects, and standard errors are clustered at the year level. Moreover, time-invariant individual controls include age, number of qualifications, and attendance at an Ecole institute. The total number of boards an individual sits on in that year is included as a time-varying control variable.

Table 12: OLS vs. 2SLS for Becoming a board member (Individual level)

	Time period: *2001 - 2019* Dependent variable: *Becoming a Board Member*							
	(OLS)	(2SLS)	(OLS)	(2SLS)	(OLS)	(2SLS)	(OLS)	(2SLS)
Centrality	0.0001**	0.0011***	-0.00004	0.0008***	0.0045**	0.0084**	-0.0042	0.0132***
	(0.00005)	(0.0003)	(0.00003)	(0.0001)	(0.0016)	(0.0011)	(0.0031)	(0.0031)
Women	-0.0606***	-0.0639***	-0.0581***	-0.0574***	-0.0630***	-0.0643***	-0.0619***	-0.0530***
	(0.0089)	(0.0107)	(0.0089)	(0.0096)	(0.0085)	(0.0101)	(0.0093)	(0.0106)
Centrality × Quota2010	-0.0005***	-0.0011***	-0.0003***	-0.0009***	-0.0087***	-0.0059***	-0.0070**	-0.0107***
	(0.0001)	(0.0003)	(0.00004)	(0.0001)	(0.0020)	(0.0015)	(0.0032)	(0.0032)
Women × Quota2010	0.1431***	0.1348***	0.1550***	0.1238***	0.1657***	0.2179***	0.1754***	0.2061***
	(0.0139)	(0.0146)	(0.0143)	(0.0187)	(0.0214)	(0.0304)	(0.0264)	(0.0446)
Centrality × Women	0.0001	0.0003*	-0.00001	0.0002	-0.0008	-0.0058**	-0.0016	-0.0054
× Quota2010	(0.0001)	(0.0001)	(0.00006)	(0.0001)	(0.0019)	(0.0029)	(0.0019)	(0.0039)
Centrality Measures	Degree EN_1		Degree EN_2		Betweenness EN_1		Betweenness EN_2	
Year Fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	30,708	29,425	30,710	29,425	30,493	29,095	30,349	28,848
First-stage								
Avg. Centrality of Indirect		0.6770***		0.4799***		0.6113***		0.5130***
Connections		(0.1123)		(0.1509)		(0.0120)		(0.0299)
F-statistic		364		321.9		4,001.4		2,011.1

Notes: Becoming a board member BMF_{it} is a binary variable with pooled sample mean of 0.162. EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year. EN_2 represents the executive network comprising all the co-workers an individual has worked with as an executive over the last three years. Individual controls include age, number of qualifications, Ecole institution attendance, number of boards an individual is sitting in that year. Standard errors are clustered at year level. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

7.2 Dyad level Outcome

Tables 13, 14, 15 and 16 present the results of OLS and 2SLS regressions analyzing the impact of network centrality on an individual's likelihood of becoming a board member in firms where they have not previously served as a board member. The analysis is conducted at the dyad level where the dyad consists of individual i and firm j pair. An individual can be a board member at more than one firms while a firm also have more than one employees which means the dyads are not independent of each other[10]. Four dimensions of network centrality are considered: degree centrality of executive networks (EN_1 and EN_2) and betweenness centrality of executive networks (EN_1 and EN_2) as detailed in section 3.3. The centrality measures are used in lagged form in order to avoid the connections formed in the period one joins the new board. The models also account for gender interactions and the effect of the 2010 quota policy in France.

The results consistently show that the OLS estimates of the effect of network centrality are smaller in magnitude compared to the 2SLS estimates. This difference confirms the potential endogeneity in the centrality measures discussed in the section 6.1. The centrality of an individual in a network may be correlated with unobserved factors (e.g., ambition, prior experience, or unobservable qualities) that also affect board appointments. By using the average centrality of indirect connections as an instrument for centrality, the 2SLS approach addresses this endogeneity.

Degree Centrality: For executive network EN_1, the 2SLS coefficient on centrality is positive and significant, indicating that a higher degree in an individual's executive network in previous period increases the likelihood of becoming a board member next period (table 13). If there is an increase of one connection in a certain year, probability of entering a new board increases by 0.5 percentage points in the next year. For executive network EN_2, the results are similar, with a 2SLS estimate of approximately 0.37 percentage points for every addition in the connections in the previous period, compared to a negligible OLS coefficient (table 14). This suggests that recent connections in the executive network (last three years) are also a significant determinant of board appointments.

Betweenness Centrality: For executive network EN_1, the 2SLS coefficients are larger and

[10]A firm is paired with multiple individuals and one individual can also be paired with multiple firms (although less likely in a given year).

more significant than the OLS estimates (table 15). This implies that individuals who occupy strategic positions in their network (as indicated by betweenness centrality) are more likely to leverage their influence to secure board positions. As log-transformation od betweenness is used, we can say that for a percent increase in betweenness there is 2.46 percentage points increase in likelihood of individual to become a board member at a new firm in the next year. For executive network EN_2, the results also indicate a strong positive effect of betweenness centrality on board appointments, with a 2SLS coefficient of 0.0300 compared to smaller and less significant OLS coefficients. It suggests that if an individual's influence increases by one percent in a certain year, their chances of sitting on new board next year increases by 3 percentage points (column 2 of table 16).

Heterogeniety of network effects by Gender and Quota: The interaction terms are introduced to capture the role of gender and the impact of the 2010 quota on gender disparities in board appointments. The coefficient on *Women* is negative where significant in models reported in tables 13, 14, 15 and 16, suggesting that women face lower baseline probabilities of being appointed to boards compared to men, even after controlling for network centrality and other co-variates. The interaction term *Women* × *Quota2010* is positive and significant in most specifications, indicating that the quota policy mitigated the gender gap by increasing women's likelihood of joining boards. The effect size indicates that quota raises the likelihood of entering boards for the first time for women by around 20 to 30 percent.

The triple interaction term *Centrality* × *Women* × *Quota2010* suggests that the quota amplified the importance of centrality for women in certain models. From table 13, importance of having more connections for women entering new boards is higher by approximately 0.1 percentage point after the quota (compared to women before quota). Similarly, if we compare the centrality effect of men and women after quota, women's connection still have approximately 0.43 percentage points more contribution to the likelihood of becoming a board member compared to men's connection. Similar results can be observed in case of other centrality measures with difference in effect size. These results show that women with higher centrality in the executive network significantly benefited more from the quota policy, highlighting the complementarity between network position and institutional reforms.

Instrument Validity: The first-stage results provide evidence for the validity of the instru-

mental variable (average centrality of indirect connections). The F-statistics for the first stage are well above the conventional threshold of 10, ensuring that the instruments are not weak. The positive and significant coefficients on the instrument in the first stage further confirm its relevance in all the specifications for all four measures of centarlity.

Table 13: Becoming a board member (dyad level) & Degree Centrality of Executive Network EN_1

	Time period: *2001 - 2019* Dependent Variable: *Becoming a Board Member* BMF_{ijt}					
Variables	(OLS)	(2SLS)	(OLS)	(2SLS)	(OLS)	(2SLS)
Centrality - Degree EN_1	-0.00004	0.0050*	-0.0002	0.0036*	-0.0002	0.0037*
	(0.0001)	(0.0024)	(0.0001)	(0.0019)	(0.0001)	(0.0019)
Women	0.0055	0.0672	-0.0608	-0.2852**	-0.0076	-0.1207
	(0.0393)	(0.0756)	(0.0426)	(0.1115)	(0.0481)	(0.1242)
Women × Quota2010	0.3070***	0.220**	0.3230***	0.3119***	0.2492***	0.0848
	(0.0468)	(0.079)	(0.0460)	(0.0827)	(0.0561)	(0.1526)
Centrality × Women			0.0007	0.0035***	0.0001	0.0017*
			(0.0004)	(0.0010)	(0.0004)	(0.0010)
Centrality × Quota2010			0.0003**	0.0026***	0.0002*	0.0023**
			(0.0001)	(0.0007)	(0.0001)	(0.0008)
Centrality × Women					0.0009**	0.0026*
× Quota2010					(0.0003)	(0.0013)
Year Fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,782	8,886	9,782	8,886	9,782	8,886
First-stage						
Avg. Centrality of Indirect		0.459 **		0.606**		0.607**
Connections		(0.1876)		(0.2337)		(0.2368)
F-statistic		137.1		54.773		41.078

Notes: Becoming a board member BMF_{ijt} is a binary variable with pooled sample mean of 0.0315 and standard deviation of 0.1747. EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year. Individual controls include age, number of qualifications, Ecole institution attendance, number of boards an individual is sitting in that year. Firm controls include market capitalization, number of employees for size of firm and the gender ratio in the firm. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 14: Becoming a board member (dyad level) & Degree Centrality of Executive Network EN_2

	Dependent Variable: Becoming a Board Member BMF_{ijt}					
Variables	(OLS)	(2SLS)	(OLS)	(2SLS)	(OLS)	(2SLS)
Centrality - Degree EN_2	-0.00001	0.0037**	-0.0001	0.0029*	-0.0001	0.0030*
	(0.00007)	(0.0016)	(0.00007)	(0.0014)	(0.00007)	(0.0015)
Women	0.0066	0.0815	-0.0517	-0.2841**	-0.0161	-0.0566
	(0.0397)	(0.0929)	(0.0384)	(0.1199)	(0.0422)	(0.1350)
Women × Quota2010	0.3074***	0.2278**	0.3173***	0.3068***	0.2690***	-0.0010
	(0.0452)	(0.0859)	(0.0436)	(0.1003)	(0.0499)	(0.1648)
Centrality × Women			0.0004*	0.0023***	0.0001	0.0008
			(0.0002)	(0.0007)	(0.0002)	(0.0007)
Centrality × Quota2010			0.0001**	0.0008	0.0001**	0.0006
			(0.00006)	(0.0005)	(0.00005)	(0.0006)
Centrality × Women					0.0004*	0.0022**
× Quota2010					(0.0002)	(0.0008)
Year Fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,940	8,886	9,940	8,886	9,940	8,886
First-stage						
Avg. Centrality of Indirect		0.4366**		0.5466*		0.5426*
Connections		(0.0979)		(0.1129)		(0.1245)
F-statistic		96.765		34.898		26.209

Notes: Becoming a board member BMF_{ijt} is a binary variable with sample mean of 0.0315 and standard deviation of 0.1747. EN_2 represents the executive network comprising all the co-workers an individual has worked with as an executive over the last three years. Individual controls include age, number of qualifications, Ecole institution attendance, number of boards an individual is sitting in that year. Firm controls include market capitalization, number of employees for size of firm and the gender ratio in the firm. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 15: Becoming a board member (dyad level) & Betweenness Centrality of Executive Network EN_1

	Dependent Variable: Becoming a Board Member BMF_{ijt}					
Variables	(OLS)	(2SLS)	(OLS)	(2SLS)	(OLS)	(2SLS)
Centrality - Betweenness EN_1	0.0109***	0.0246***	0.0027	0.0202***	0.0040	0.0221***
	(0.0026)	(0.0029)	(0.0029)	(0.0036)	(0.0028)	(0.0036)
Women	0.0154	0.0348	-0.1896***	-0.2088***	-0.0112	0.0150
	(0.0387)	(0.0447)	(0.0484)	(0.0636)	(0.0534)	(0.0614)
Women × Quota2010	0.2975***	0.2746***	0.3067***	0.2800***	0.0683	-0.0226
	(0.0476)	(0.0532)	(0.0484)	(0.0562)	(0.0556)	(0.0740)
Centrality × Women			0.0193***	0.0232***	0.0020	0.0018
			(0.0050)	(0.0057)	(0.0057)	(0.0065)
Centrality × Quota2010			0.0085**	0.0022	0.0060*	-0.0008
			(0.0030)	(0.0029)	(0.0029)	(0.0029)
Centrality × Women					0.0232***	0.0291***
× Quota2010					(0.0050)	(0.0078)
Year Fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,685	8,742	9,685	8,742	9,685	8,742
First-stage						
Avg. Centrality of Indirect		0.5924***		0.5870***		0.5927***
Connections		(0.0216)		(0.0335)		(0.0339)
F-statistic		4,289.4		1,430.1		1,073.3

Notes: Becoming a board member BMF_{ijt} is a binary variable with sample mean of 0.0315 and standard deviation of 0.1747. EN_1 represents the executive network comprising all the co-workers an individual has worked with as an executive up to that year. Individual controls include age, number of qualifications, Ecole institution attendance, number of boards an individual is sitting in that year. Firm controls include market capitalization, number of employees for size of firm and the gender ratio in the firm. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 16: Becoming a board member (dyad level) & Betweenness Centrality of Executive Network EN_2

	Dependent Variable: Becoming a Board Member BMF_{ijt}					
Variables	(OLS)	(2SLS)	(OLS)	(2SLS)	(OLS)	(2SLS)
Centrality - Betweenness EN_2	0.0109***	0.0300***	0.0013	0.0221***	0.0025	0.0260***
	(0.0028)	(0.0030)	(0.0026)	(0.0050)	(0.0026)	(0.0034)
Women	0.0184	0.0498	-0.2049***	-0.2373**	-0.0672	0.0948*
	(0.0391)	(0.0375)	(0.0511)	(0.1006)	(0.0573)	(0.0523)
Women × Quota2010	0.2936***	0.2612***	0.2952***	0.2614***	0.1002	-0.2444***
	(0.0454)	(0.0456)	(0.0448)	(0.0577)	(0.0583)	(0.0815)
Centrality × Women			0.0195***	0.0251**	0.0070	-0.0045
			(0.0043)	(0.0090)	(0.0054)	(0.0050)
Centrality × Quota2010			0.0104***	0.0066	0.0082**	0.0001
			(0.0030)	(0.0047)	(0.0029)	(0.0032)
Centrality × Women					0.0175***	0.0447***
× Quota2010					(0.0054)	(0.0085)
Year Fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,879	8,803	9,879	8,803	9,879	8,803
First-stage						
Avg. Centrality of Indirect		0.5258***		0.5300***		0.5265***
Connections		(0.0109)		(0.0556)		(0.0193)
F-statistic		2,371.8		793.04		594.88

Notes: Becoming a board member BMF_{ijt} is a binary variable with sample mean of 0.0315 and standard deviation of 0.1747. EN_2 represents the executive network comprising all the co-workers an individual has worked with as an executive over the last three years. Individual controls include age, number of qualifications, Ecole institution attendance, number of boards an individual is sitting in that year. Firm controls include market capitalization, number of employees for size of firm and the gender ratio in the firm. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

7.3 Discussion

A recurring pattern in both the individual-level and dyad-level regressions is that network centrality, whether measured through degree (number of direct connections) or betweenness (the extent to which an individual lies on crucial paths between others), significantly predicts the probability of becoming a new board member. From the results reported in previous section (tables 12, 13, 14, 15, 16), the 2SLS coefficients are larger in magnitude compared to OLS. This suggests that OLS regressions may underestimate the true impact of an individual's network. Once we account for possible endogeneity of professional networks, the relationship becomes stronger. The first-stage F-statistics exceed standard thresholds, indicating that the instrument, average centrality of one's indirect (second-degree) connections, is both relevant and unlikely to be weak.

Does network position matters for entering boards?
An additional connection in an individual's executive network in a certain year can translate into a 0.08 percentage-point boost in the likelihood of board membership in the next year at the individual level (Table 12), or up to 0.5 percentage points in the dyad setting (Table 13). These findings underscore that number of direct ties matters for identifying opportunities and securing referrals to boards. For betweenness in a log-transformed manner, a 1% increase in betweenness can raise the probability of board appointment by around 0.8 to 1.32 percentage points at the individual level. At the dyad level, this effect is even more pronounced (up to 2–3 percentage points). By positioning oneself in the network such that it lies on more paths between nodes, an individual gains influence that can be leveraged to obtain referrals and endorsements for board seats.

Does gender quotas in France helped women enter new corporate boards?
The negative main effect for *Women* suggests that, holding centrality and other controls constant, women historically faced lower probabilities (around 5–6% less at the individual level, and similarly negative or insignificant coefficients at the dyad level) of entering new boards boards. This suggests that women have lower chances of getting referrals for boards they have never sat on earlier. The introduction of the 2010 gender quota in France emerges as a driver of more women entering boards. The interaction term *Women* $\times$ *Quota2010* is positive and significant in nearly all specifications, indicating a substantial jump in the likelihood of women joining boards post-quota. Clearly, the quota helped mitigate the gender gap by compelling firms to broaden recruitment to include more qualified women.

Does network matter more for women under the quota?
The triple interaction *Centrality* × *Women* × *Quota2010* is sometimes positive (though not always significant) in the individual level analysis. At the dyad level, certain models show that the quota amplifies the benefits of centrality for women, resulting in an additional 0.1 to 0.4 percentage-point gain in some specifications. This suggests that women who were already well-connected may have been especially well-positioned to capitalize on the gender quota of 2010, where firms needed qualified female candidates and were likely to rely on networks to identify them.

8 Conclusion

This paper examines the impact of network centrality on board appointments and the role of gender quotas in altering these dynamics. The study aims to assess whether the quota reform introduced in France in 2010 succeeded in increasing female representation on corporate boards and whether it influenced the network-driven appointment process. The central objective of this paper was to analyze how professional networks influence the likelihood of first-time board appointments and to evaluate whether gender quotas reduced barriers to entry for women.

The analysis utilizes a comprehensive dataset from the BoardEx database, covering 23,872 individuals in managerial roles at 1,065 publicly listed French firms between 2001 and 2019. Network centrality is measured using degree and betweenness, capturing both local connectivity and global bridging properties within professional networks. To address potential endogeneity in network formation, the paper employs an instrumental variable approach, using the centrality of second-degree connections as an instrument for individual network centrality.

The empirical findings demonstrate that network centrality significantly predicts the likelihood of becoming a first-time board member, both before and after the implementation of the gender quota. The quota reform had a substantial impact on female representation, with the proportion of women on boards increasing sharply following the law's introduction. Notably, the law also influenced the characteristics of first-time appointees, with women entering boards becoming younger (relatively) and better qualified.

The 2SLS results indicate that network structures continue to play a dominant role in determin-

ing board appointments. Women with higher network centrality were better able to leverage the opportunities created by the quota, highlighting potential inequalities within the underrepresented group. This suggests that while the reform improved overall representation, it did not fully address the barriers posed by network-driven hiring practices.

The findings underline the effectiveness of gender quotas in addressing immediate disparities in board representation but also reveal their limitations. Quotas alone may not dismantle the structural barriers embedded in professional networks, which favor well-connected individuals. To enhance inclusivity, policymakers should consider complementary measures, such as initiatives to diversify professional networks, mentorship programs, and transparency in board appointment processes.

Comparative analyses across countries with varying institutional frameworks could provide additional insights into the interplay between networks and diversity-focused policies. Additionally, investigating the spillover effects of boardroom diversity on lower levels of corporate hierarchies would be a valuable avenue for further research.

Declaration of Generative AI and AI-Assisted Technologies

During the preparation of this draft, the author used AI-assisted writing tools to organize prior empirical results and produce an initial LaTeX draft. The author reviewed and edited the content and takes full responsibility for the final manuscript.

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Table A1: Number of firms by sector

Original Sector		Grouped Sectors	
Real Estate	74	Construction and Real Estate	99
Construction & Building Materials	25		
Media & Entertainment	59	Consumer Goods and Services	231
Clothing Personal Products	32		
Leisure Hotels	32		
General Retailers	31		
Food Producers & Processors	24		
Leisure Goods	13		
Beverages	12		
Household Products	11		
Food & Drug Retailers	9		
Consumer Services	7		
Tobacco	1		
Oil & Gas	19	Energy and Utilities	51
Renewable Energy	18		
Electricity	8		
Utilities - Other	6		
Business Services	70	Financial and Business Services	163
Speciality & Other Finance	45		
Banks	34		
Insurance	8		
Private Equity	5		
Life Assurance	1		
Pharmaceuticals and Biotechnology	58	Healthcare and Pharmaceuticals	96
Health	38		
Engineering & Machinery	41	Manufacturing	159
Electronic & Electrical Equipment	38		
Automobiles & Parts	23		
Chemicals	18		
Aerospace & Defence	16		
Steel & Other Metals	9		
Containers & Packaging	6		
Forestry & Paper	6		
Diversified Industrials	2		
Others	58	Other	74
Investment Companies	5		
Wholesale Trade	4		
Education	2		
Mining	2		
Blank Check / Shell Companies	1		
Legal	1		
Publishing	1		
Software & Computer Services	123	Technology and Telecommunications	171
Information Technology Hardware	31		
Telecommunication Services	17		
Transport	21	Transportation	21

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Table A2: Gender-wise Percentage of missing values for Total Compensation

Gender	Non-Missing	Missing
Men	78.27%	78.71%
Women	21.73%	21.29%

Table A3: Gender-wise Percentage of missing values for Current Listed Boards

Gender	Non-Missing	Missing
Men	78.32%	88.79%
Women	21.68%	11.21%