

The Intersectional Impact of Gender and Institutional Social Capital in an Academic Co-Authorships Network

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Abstract

This study analyses a unique dataset of 344,865 connections and non-connections to examine the impact of gender on academic co-authorship within a UK institution between 2013 and 2023. Drawing on social capital theory and homophily theory, we conceptualise co-authorship as a network-based process shaped by access to resources (social capital) and a preference for similarity (homophily). In our analysis, social capital theory provides a framework to understand how positional advantages in academic networks (e.g., centrality) facilitate collaboration and resource exchange, whereas homophily theory helps explain why individuals are more likely to collaborate with others who share similar attributes, particularly gender. By focusing on institutional-level dynamics rather than macro-level trends, we explore how gender and relative positional power influence co-authorship patterns.

Preliminary findings from regression models show that pairs including at least one internal author publish more than external-only pairs. Gender dynamics reveal that female-only author pairs consistently co-author fewer papers than male-only pairs, while male-only pairs show a strong positive association with co-authorship rates.

Network analysis reveals that larger differences in eigenvector centrality—a proxy for internal social capital—are positively associated with co-authorship frequency, highlighting the role of social capital in fostering collaboration. Additionally, the maximum centrality within a pair increases collaboration, while lower minimum centrality reduces it.

These findings underscore the importance of institutional networks in shaping academic output and suggest that gender and social capital play critical roles in co-authorship patterns, highlighting the need to advance equity and inclusion in academic collaboration.

Introduction

Gender inequality in academia remains a deeply embedded and multifaceted issue, particularly in relation to publication productivity, collaboration patterns, and access to research networks. Although considerable progress has been made in narrowing gender gaps, studies consistently show that female scholars publish less than their male counterparts, with output typically ranging from 70–80% of men's across various fields like natural sciences (22% gender variance), engineering (15%), and medicine (8%) (Larivière et al., 2011; Rørstad & Aksnes, 2015; Prpic, 2002; Symonds et al., 2006). Younger female researchers often outperform male peers early on, suggesting that disparities widen due to career attrition rather than initial capacity (van Arensbergen et al., 2012). This trend is encapsulated by the “leaky pipeline” metaphor, where

¹ In alphabetic order

gender balance at junior levels gives way to male dominance in senior roles, largely due to systemic obstacles (National Science Foundation, 2018; Long, 1992; ETAN, 2000).

Collaboration and networking provide further insights into gender dynamics. Women exhibit lower participation in collaborative activities and fewer distinct co-authors over time, partly due to shorter careers and gendered task allocation (e.g., teaching over research) (Kretschmer & Aguillo, 2005; Zeng et al., 2016; Rørstad & Aksnes, 2015). Gender homophily—men collaborating with men, women with women—prevails, potentially limiting women's access to influential networks (Araujo et al., 2017; Jadidi et al., 2018; Lerchenmueller et al., 2019). Yet, women in central co-authorship roles may leverage interpersonal strengths to overcome barriers (Badar et al., 2013). Social psychology frameworks highlight interpersonal attraction as a collaboration driver, with women valuing relational processes more, though institutional support often lags (Melin, 2000; Carr et al., 2009; Pololi et al., 2013).

Thus, the problem lies not only in how much women publish but also in the collaborative structures and network dynamics that shape those outputs. Most existing research focuses on individual-level factors—such as teaching load, rank, or personal circumstances—without examining the role of institutional networks or positional power in collaborative decisions. This presents a gap in our understanding of how gender disparities are reproduced and reinforced through academic co-authorship networks.

To address this gap, present study adopts a network-based approach, combining social capital theory and homophily theory. Social capital theory explains how access to and use of resources within networks—such as co-authorship centrality—can affect academic productivity. Homophily theory helps explain why individuals tend to collaborate with others who share similar characteristics, especially gender. By integrating these perspectives, this study aims to examine not only the structure of academic collaboration but also the underlying inequalities.

This study examines a uniquely collected dataset of 344,865 connections and nonconnections, comparing journal paper authorship within a Business and Law faculty at an UK academic institution. Prior literature has examined gender disparity in academic authorship primarily through structural factors—such as research time, teaching and administrative loads, or affiliation with research centres—and personal factors, including academic rank, age, marital status, and caregiving responsibilities (Bentley, 2011). These studies highlight how such variables influence both research productivity (measured by the number of publications) and research impact (measured by citations).

Additionally, the ten-year timespan allows the study to capture long-term developments in network formation and account for vertical segregation (Bentley, 2011). The study focuses on two key aspects: the first investigates how gender affects the number of co-authored papers. The second explores the role of social capital by analysing network centrality as a proxy for positional power. Unlike broader macro-level analyses, this institutional-level approach enables a more granular investigation of how relative positioning within academic networks shapes collaborative output.

By utilizing network analysis over a decade, the study aims to explore the cumulative effects of academic social networks and evaluate whether internal social capital over time mitigates traditional gender disparities in authorship and collaboration.

Since this work utilizes a network analysis of authorships, specifically examining the edges, or links, between pairs of authors, it enables the formulation of three distinct hypotheses on the impact of gender:

Hypotheses on Gender and Homophily

H1: The gender composition of co-authorship dyads significantly affects publication counts.

H1_a: Collaborations involving female co-authors will yield fewer publications than all-male dyads.

H1_b: All-female collaborations will generate more publications than mixed-gender dyads.

Hypotheses on Network Capital

H2: The Network Capital of coauthors is associated with a higher number of published papers.

H2_a: The Power dimension of coauthors' network capital (captured by their average eigenvector centrality) is associated with a higher number of published papers.

H2_b: The Embeddedness dimension of coauthors' network capital (captured by their average between centrality) is associated with a higher number of published papers.

Hypotheses on Interaction effects

H3: The effect of Network Capital on publication count is affected by the gender composition of the co-author link.

H3_a: The negative effect on publication count, due to the presence of female coauthors in a coauthor link (H1_a) is not affected by the level of average centrality of the two co-authors.

H3_b: The mitigating effect on publication count due to Homophily (H1_b) decreases with the level of average centrality of the two co-authors.

Literature review

Research Collaboration and Institutional Networks

Research collaboration is a process where researchers come together with the common goal of generating new scientific knowledge (Katz and Martin, 1997). Focusing on research collaboration helps map relationships between institutions, identifying key influencers and their roles in different research fields. This is because collaboration studies can also be used to explore knowledge-based innovation systems (Kenekayoro, Buckley and Thelwall, 2014), which are 'systems where efficient interactions between actors enable greater innovation' (Stuart, 2008, cited in Kenekayoro, Buckley and Thelwall, 2014). Collaborative research ties play a crucial role in advancing academic productivity, as studies show that collaborative papers tend to have a greater impact than single-authored works (Katz and Martin, 1997), further emphasizing the importance of academic collaboration. Whilst research collaborations and co-authorships are not equivalent concepts, in line with previous research, present research uses research co-authorship as a proxy to measure collaborations (Mayer and Rathmann, 2018).

Katz and Hicks (1997) found that publications involving co-authorships with foreign institutions generate the highest research impact in terms of citation numbers. Their analysis of impact

distribution based on the number of authors and institutional affiliations revealed that collaboration among researchers from the same institution leads to exponential increases in impact, while collaboration between domestic and foreign institutions results in linear increases. However, international collaborations consistently yield the greatest impact, surpassing both intra-institutional and domestic inter-institutional collaborations. This highlights the significant role of cross-border research partnerships in enhancing the visibility and influence of academic work (Katz and Martin, 1997). Given these findings, interuniversity collaboration is essential for expanding research impact, facilitating knowledge exchange, and increasing publication productivity. It involves research partnerships across institutions, often leading to joint authorship on academic publications. This type of collaboration enhances knowledge production, fosters expertise sharing, and strengthens research networks (Katz and Martin, 1997).

However, gender plays a significant role in shaping interuniversity collaborations. Research indicates that men are more likely to engage in interuniversity collaborations, benefiting from larger and more diverse academic networks spanning multiple institutions and countries (Kwiek and Roszka, 2021). Vabø et al. (2014) state that female scientists report a lower amount of international research collaboration than males. Gender disparity within academic publications is clearly evidenced, for example via differences of citations (Burstin and Arora, 2021; Chatterjee and Wenrer, 2021). Furthermore, women are more inclusive researchers suggesting being more likely to include women and men (Williams, 2023). This impact is further reinforced by the tendency of researchers of the same gender to collaborate more frequently in publishing (Holman and Morandin, 2019). This advantage is reinforced by institutional social capital, as male researchers frequently have greater access to leadership roles, external funding, and international research partnerships (Huang et al., 2020). Conversely, women's academic networks tend to be more localised, emphasising institutional rather than interuniversity or international collaborations (Larivière et al., 2011).

Gender and Collaboration in Academia

Gender dynamics have long been a subject of concern within academic environments, where disparities in representation, recognition, and collaboration persist. The literature consistently documents that women in academia face systemic barriers, including lower rates of publication, reduced access to collaborative networks, and underrepresentation in senior positions (West et al., 2013; Larivière et al., 2013).

Co-authorship is a critical form of academic collaboration, and gender plays a notable role in shaping co-authorship patterns. Research shows that women are more likely to collaborate with other women, reflecting gender-based homophily, but this tendency is often constrained by the lower number of female academics, especially in male-dominated fields (Holman et al., 2018). Men, who tend to be overrepresented in senior and central academic positions, often form denser and more productive collaboration networks with other men, reinforcing gendered stratification (Mayer and Rathmann, 2018).

Furthermore, gendered socialization and perceptions of competence may influence collaboration choices. Male academics may be more likely to collaborate with other men due to perceived

similarity in productivity or disciplinary alignment, while women may prefer same-gender collaborations for perceived psychological safety and mutual support (Rhoten and Pfirman, 2007). Cross-gender collaborations, while common, may be influenced by implicit biases, communication challenges, or structural hierarchies, potentially inhibiting their frequency and productivity.

Latent network capital

Social capital refers to the ‘productive value of social connections’ (Scrivens and Smith, 2013). Theoretically, it has been conceptualized in different ways. Bourdieu (1986) defines social capital as an individual asset where personal collaborations and relationships offer direct benefits. In contrast, Putnam (2015), views social capital as a collective resource – a public good based on trust and civic participation. According to Putnam, all members of a network will benefit from the links and relationships within the network.

Our research aims to investigate whether, within the context of a specific institution, the strength of the internal and external networks has positive impacts on co-authorship, either at the group or individual level.

The Theory of Homophily

Homophily refers to the tendency of individuals to associate and bond with similar others (McPherson et al., 2001). This sociological principle posits that similarity, whether in terms of demographics, values, beliefs, or social status, facilitates interpersonal connections by enhancing mutual understanding and communication efficiency. In the context of social networks, homophily shapes the structure and flow of information, often resulting in the formation of clusters or cliques based on shared characteristics (Lazarsfeld and Merton, 1954).

Two principal forms of homophily are distinguished in the literature: status homophily and value homophily. Status homophily is grounded in socio-demographic factors such as gender, age, ethnicity, or profession, while value homophily arises from alignment in attitudes, beliefs, or aspirations (Ibarra, 1992). In professional and academic contexts, status homophily—especially gender-based homophily—plays a significant role in shaping collaborative behaviours. For example, Fishman et al. (2017) find that female first authors are less likely to publish with last (senior) male authors, supporting the homophily theory around gender concordance. Similarly, Boschini and Sjogren (2007) concluded that women were twice as likely to publish with a female co-author than men. Individuals may perceive same-gender collaborations as more accessible or less conflict-prone, reinforcing the patterns of gender homophily in professional networks.

Importantly, homophily does not merely reflect individual preferences but is also shaped by structural and institutional constraints that influence opportunities for interaction. In academia, gendered norms and historical inequalities may reinforce homophilic tendencies by limiting the diversity of one’s accessible network or the perceived inclusivity of cross-gender collaboration (Brass, 1985; Ridgeway and Smith-Lovin, 1999).

Hypothesis development

The theory of homophily provides a robust theoretical foundation for understanding gendered collaboration patterns in academia, particularly when examined through the lens of institutionalized "old boy networks." Status homophily—specifically gender homophily—suggests individuals disproportionately form relationships with those sharing their gender identity due to perceived trust, mutual understanding, and shared professional values (McPherson et al., 2001). Within academic environments where these factors critically enable productive collaboration, gender homophily significantly structures co-authorship dynamics. Crucially, these patterns operate within systemic "old boy networks" that systematically advantage male academics through privileged access to resources, visibility, and collaboration opportunities (Kwiek & Roszka, 2021).

Empirical evidence reveals divergent pathways for same-gender collaborations. Male-male dyads leverage homophily within dominant networks to amplify productivity, benefiting from men's overrepresentation in senior positions and high-yield co-authorship networks (Holman et al., 2018). This structural advantage creates self-reinforcing collaboration cycles characterized by increased repeat partnerships (Bunker et al., 2024), greater institutional support (Kwiek & Roszka, 2021), and enhanced visibility of research outputs. Conversely, female-female dyads often utilize homophily as a strategic response to systemic exclusion. In fields where women are underrepresented, they form tightly-knit collaborative clusters that mitigate barriers to male-dominated networks while fostering psychological safety, trust, and synergistic partnerships that enhance publication productivity (Ozel et al., 2014; Bunker et al., 2024).

Mixed-gender collaborations, however, face significant structural headwinds. Women experience systematic under-crediting in mixed-gender teams, reducing their perceived contributions (West et al., 2013), while cross-gender partnerships demonstrate lower persistence than same-gender collaborations, suggesting diminished network embeddedness (Jadidi et al., 2018). Furthermore, implicit gender biases hinder mutual recognition and long-term partnership development (Koch et al., 2015). These challenges are amplified by "old boy networks" that control access to high-impact collaborations, creating asymmetric environments where male homophily reinforces power structures while female homophily serves as an adaptive strategy against exclusion.

This theoretical and empirical foundation leads us to propose that gender composition fundamentally affects publication output through distinct collaborative mechanisms. We therefore hypothesize:

H1: The gender composition of co-authorship dyads significantly affects publication counts.

H1_a: Collaborations involving female co-authors will yield fewer publications than all-male dyads. This expectation arises from male collaborations' institutional advantages within homophilous networks, contrasted with systemic devaluation and collaboration barriers in female-involved dyads.

H1_b: All-female collaborations will generate more publications than mixed-gender dyads. This mitigating effect stems from gender homophily creating supportive collaborative environments that offset women's exclusion from dominant networks, enhancing productivity relative to mixed gender collaborations.

Gender, Network Centrality, and Academic Research Performance

A growing body of research has explored how gendered structures within professional networks influence scholarly productivity, yet systemic disparities in access to network capital persist. Foundational work by Ibarra (1992) demonstrated that gender homophily in networks systematically disadvantages women, limiting their access to high-status contacts and mentorship opportunities—critical components of network capital. This network segregation often reduces women's centrality in academic collaborations, which in turn constrains access to resources, information, and productive co-authorship ties. Mannheim (1993) further contextualized these dynamics by linking gender to institutional status and work values, arguing that network-based visibility and collaboration opportunities are shaped by broader organizational and cultural norms.

While structural barriers continue to shape access to central positions, network capital itself—defined as the positional advantage and embeddedness within collaborative structures—has consistently been linked to increased research productivity. Badar et al. (2013) empirically demonstrated that co-authorship network centrality is positively associated with publication output. However, they also revealed that the productivity benefits of centrality are unevenly distributed, with men deriving greater returns from similar network positions. These gendered disparities, moderated by institutional sector and career stage (Badar et al., 2014), underscore the role of context in shaping how centrality translates into scholarly performance.

Importantly, the literature distinguishes between different dimensions of centrality that contribute to network capital. The power dimension, often captured by eigenvector centrality, reflects the extent to which individuals are connected to others who themselves occupy influential network positions. This form of centrality amplifies access to knowledge flows and reputational spillovers, which can enhance publication outcomes (Park and Gough, 2024). The embeddedness dimension, represented by betweenness centrality, captures the extent to which individuals serve as bridges between otherwise disconnected actors. This brokerage role facilitates unique knowledge combinations and greater visibility in the network, both of which are positively linked to productivity (Villesèche and Sinani, 2023).

Despite the general productivity-enhancing effects of network capital, gendered asymmetries remain. Women often face structural constraints that limit their participation in high-yield network positions, including homophily-driven exclusion (Ibarra, 1992), reduced influence in cross-gender collaborations (Faris and Felmler, 2011), and lower returns on centrality metrics (Badar et al., 2013; Park and Gough, 2024). However, these structural inequities do not negate the broader theoretical and empirical linkage between network capital and scholarly output. Rather, they highlight the conditionality of these effects across gendered contexts.

Taken together, the literature supports the proposition that coauthors' network capital is a critical determinant of research productivity, both in terms of power (H2_a) and embeddedness (H2_b). These dimensions of centrality serve as structural enablers of collaboration, visibility, and knowledge exchange—key mechanisms through which academic work is produced and recognized. Thus, while acknowledging the persistent gendered barriers to accessing and

leveraging network capital, we argue that, overall, higher levels of coauthors' network capital will be positively associated with the number of published papers. Therefore, we hypothesise:

H2: The Network Capital of coauthors is associated with a higher number of published papers.

H2_a: The Power dimension of coauthors' network capital (captured by their average eigenvector centrality) is associated with a higher number of published papers.

H2_b: the Embeddedness dimension of coauthors' network capital (captured by their average between centrality) is associated with a higher number of published papers.

Building on established relationships between co-authorship gender composition and publication output (H1) and network capital and productivity (H2), we propose a critical contingency: the effect of co-authors' network centrality on publication count is moderated by the gender composition of the collaboration (H3). This proposition synthesizes homophily theory (McPherson et al., 2001), gendered network returns (Badar et al., 2013), and power asymmetry in academic collaboration (Faris and Felmler, 2011). While centrality typically enhances research output through resource access and collaboration efficiency (Katz and Martin, 1997), we argue that gender dynamics fundamentally reconfigure this relationship through two distinct pathways:

We hypothesize that the negative effect of female co-authorship on publication count (H1_a) remains robust across all centrality levels. Gendered evaluation biases and exclusionary practices in male-dominated "old boy networks" (Kwiek and Roszka, 2021) constrain productivity gains for female-involved dyads, even when structural centrality is achieved. As Ibarra (1992) theorized, women experience asymmetric returns on network investments due to legitimacy deficits in hierarchical fields. Empirical evidence confirms that women's influence and credit attribution lag behind their structural positions (Villesèche and Sinani, 2023; West et al., 2013), suggesting the penalty reflects systemic devaluation rather than capability gaps. Consequently, centrality fails to neutralize gender-based productivity disadvantages. Therefore, we hypothesise:

H3: The effect of Network Capital on publication count is affected by the gender composition of the co-author link.

H3_a): The negative effect on publication count, due to the presence of female coauthors in a coauthor link (H1_a) is not affected by the level of average centrality of the two co-authors.

Conversely, we posit that the productivity advantage of all-female collaborations (H1_b) weakens as average dyadic centrality increases. While homophily provides psychological safety and mutual support that enhances output for marginalized groups (Ozel et al., 2014), high-centrality positions shift the competitive advantage toward brokerage opportunities (Park and Gough, 2024). When co-authors occupy central network positions—enabling access to diverse, resource-rich connections (Badar et al., 2014)—homophilous closure may constrain brokerage potential. This effect is amplified when strategic partnerships are gatekept by male-dominated power structures (Faris and Felmler, 2011). As Badar et al. (2013) observed, women's homophilous networks boost early-career productivity but become limiting when cross-group brokerage determines high-impact output. Thus, the protective function of homophily diminishes precisely where structural opportunities for breakthrough collaborations emerge. Therefore, we hypothesise:

H3_b) The mitigating effect on publication counts due to homophily, whereby all female co-authorships links are associate with higher number of publications that mix gender co-authorships ones, (H1_b), decreases with the level of average centrality of the two co-authors.

Methodology

Data collection:

Data was collected from an organizational database of journal publications in the Faculty of Business and Law between 2013 and 2023. We focused on data from one faculty to address some of the limitations of previous research, specifically around the potential of a strong science effect (Katz & Martin, 1997). Business and Law is a field which can be seen as more gender balanced when compared to science related disciplines (traditionally seen as male dominated) or nursing and teacher training (seen as female dominated), thus addressing the ‘horizontal gender segregation’ (Bentley, 2011). The ten-year period aims to address the ‘vertical gender segregation’ of women occupying lower ranking positions as would allow for women to progress and develop their social network.

The first five authors of each publication, both internal and external to the organization, were mapped into a network based upon whether they had published together or not. Any author affiliated with the organization at any point within the examined timeframe was classified as internal. This process resulted in a unique dataset comprising of 344,865 instances of both collaboration and non-collaboration. Both the connections and non-connections are essential, as the work examines the drivers of co-authorship, via examination of both the authors which have published together and the authors that have not published together. Furthermore, information on gender, keywords, and whether they were part of the organization was also captured and included in the models described below.

Network design:

Each node in the network is an author, nodes are connected by edges to each other if they have coauthored together, these are weighted by the number of times they are connected. Thus, it is a form of co-occurrence network, more specifically a co-authorship network which have been utilised to examine various structures of scholarly co-ordination as demonstrated by Kumar (2015). For each node eigenvector and betweenness centrality is calculated, to demonstrate the importance of their positioning within the network. Betweenness centrality in academic networks may demonstrate high levels of interdisciplinarity of the author and how crucial the author is within the network as a measure of the author’s knowledge sharing (Leydesdorff, 2007; Su, 2024). With eigenvector centrality having the ability to demonstrate the importance of being connected to by other highly influential nodes and in some cases the social capital of the node (Bonacich, 2007 and Lakon et al, 2008). We are specifically examining the edges of the networks, not the nodes themselves, as it is the edges or lack of edges which demonstrate whether the authors have written a paper together or not. Thus, when examining the centrality measures, the edge does not directly have a centrality measure, it is either a combination of both nodes’ centrality, the minimum of the nodes’ centrality or the differences between the nodes’ centralities. With each of these measures

being interpretable in various ways. Additionally, this also applies to both gender and internal vs external authors, as demonstrated within the variable table 1 below.

Model design:

Our dependent variable is the number of publications coauthored by each pair of authors. Since most pairs of authors had not published together, for the vast majority—more than 99%—of our observations, our dependent variable is zero. Therefore, to ensure the robustness of the estimates, we employ a selection of estimators for count data, including both hurdle and zero inflated estimators to correctly handle the large proportion of zeros in our dependent variable.

Table 1 Variables table

Variable	Description
Weight	Dependent variable; Number of publications coauthored by each pair of authors.
Both Internal	Dummy variable, 1 if both actors are part of the examined organisation, 0 if both actors are not part of the examined organisation. Internal in this study refers to anyone who has ever worked within the organisation.
Both external	Dummy variable, 0 if either author in the pair is internal to the examined organisation, 1 if both external to the examined organisation.
Internal and External	Dummy variable, 1 if the pair of authors include one internal and one external author, 0 if they are both internal or both external to the organisation.
Dif_Gender	Dummy variable, 1 if the authors have a different gender, 0 if the authors are the same gender. Gender was identified via the usage of pronouns within their profile, university profile, LinkedIn profile and photos, in the case where gender was uncertain this was left blank. However, this was only the case in under 10 cases.
Both_female	Dummy variable, 1 if the authors are female, 0 if the authors are not both female.
Both_male	Dummy variable, 1 if the authors are male, 0 if the authors are not both male.
Sim1	Jaccard similarity measure based on the similarity of keywords used by the pair of authors, the values between 0 and 1, with more similar group of keywords being closer to 1 and less similar groups of keywords being closer to 0.
Eigen_mean	The mean of the weighted eigenvector centrality measures for each author in the pair.
Bet_mean	The mean betweenness centrality of the authors in each pair.

Summary statistics

Table 2 below provides a set of summary statistics of the examined variables.

Table 2: Summary statistics

	mean	sd	min	max
No. of papers coauthored	0.0095	0.1325	0	20
Both male	0.3676	0.4821	0	1
Both female	0.1508	0.3578	0	1
Different genders	0.4816	0.4997	0	1
Both Internal	0.0282	0.1656	0	1
Internal and External	0.2805	0.4493	0	1
Both external	0.6913	0.4620	0	1
Jaccard Similarity index	0.0076	0.0746	0	1
Avg. eigenvector centrality	0.0478	0.1340	0.0004	0.9895
Avg. betweenness centrality	0.0721	0.3291	0.0000	6.0924
Observations	344865			
Observations with papers				

In order to address these Research questions, we follow two similar modelling strategies. These address in an integrated way the necessity, first, to derive the drivers of the lack of a successfully co-authored publications amongst any two authors that otherwise appear on the ARU authors' database. Second, when focussing on the remaining subset of co-publishing authors, we derive the drivers of persistence in co-publishing, captured by Poisson-Style count regressions.

Model 1) Poisson

Model 2) Negative Binomial

An alternative two steps Modelling approach to address two key research questions:

- 1) *how gender and centrality in the coauthors' networks, might affect the lack of published co-authorship, and, once co-authorship succeeds,*
- 2) *how do these two factors affect persistence in co-publishing success, as expressed by the number of co-authored publications?*
- 3) Internal external

Model 3) Hurdle model²

Hurdle models³ address outcomes that are constrained within specific limits. The number of co-authored publications is naturally constrained at a lower limit of zero. Hurdle models utilise distinct equations for bounded and unbounded outcomes, in contrast to more traditional Tobit models, which apply a single equation for both types of outcomes. The main idea, captured through Hurdle models is that unbounded outcomes, in our case the number of co-authored publications, arise from surpassing a given threshold, while failure to clear the hurdle of achieving one co-authored publication leads to the lower bound, zero.

We adopt a two-equation hurdle specification that addresses lower bounding constraints. The initial equation establishes the criteria for clearing the hurdle of publishing a co-authored work, not an easy hurdle to pass, while the second equation assesses the number of co-authored publications contingent upon successfully clearing the initial hurdle. A limitation of this approach is in the fact that the residuals of the hurdle equation(s) and the outcome equation are uncorrelated. Typically, it is then assumed that there are different individuals between the two alternatives. In our cases, the unit of analysis is coauthors links, so those links, not the single authors need to be mainly coming from different segments of the initial population of potential co-authors.

Model 4) Zero Inflated Poisson

The second approach we used is based on Zero-inflated Poisson (ZIP) models. These are appropriate to address our dataset, as it contains a higher fraction of zeros than it is likely to be generated from a Poisson model used to estimate the drivers of the number of successfully published coauthored papers. This is helpful as, differently from simple Poisson models, ZIP models allow us to keep the information contained in the very large set of observations of zeros (coauthors links), capturing the set of all potential co-authors who never actually coauthored a

² See <https://www.stata.com/features/overview/hurdle-models/>

³ Cragg, J. G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica* 39: 829–844. <https://doi.org/10.2307/1909582>.

published paper, without restricting the range of outcomes. The logic is similar to hurdle models. With a ZIP model we assume that the number of papers published by a pair of coauthors is 0 with a probability p , or is a realization of a Poisson random variable, starting at 0, with the complementary probability $1-p$ ⁴. In our case, the dependent variable, coauthored publication, exhibits many more zero observations than would be predicted by a Poisson count model. Our hypothesis is that most of these zero links are due to the potential co-authors not having worked together, while only a few of them are due to failed attempts to publish co-authored research. Hence, the inflated number of zeros is due to non-collaboration, rather than non-co-publication. Since a simple Poisson model considers these two types of zero links as a homogeneous group, it is likely to produce biased estimates. On the contrary, by using a logit or probit model, we can estimate the probability p of two potential co-authors not collaborating, due to a set of specifically relevant covariates and through the Poisson model, we model the probability of how many publications an actual pair of co-authors publishes as the results of different factors, covariates, linked with the success of publishing.

Hence, if all potential co-authorships are assumed to be independent, the j^{th} link will follow the probability distribution, across number of co-authored publications Y_j :

$$Pr(Y_j = 0 / \mathbf{x}_j ; \mathbf{z}_j) = F_j + (1 - F_j) \exp(-\lambda_j)$$

$$Pr(Y_j = n / \mathbf{x}_j ; \mathbf{z}_j) = (1 - F_j) \exp(-\lambda_j) \frac{\lambda_j^n}{n!}$$

For $n=1,2,\dots$

Where $F(\mathbf{z}_j\boldsymbol{\gamma})$ is the inverse of the logit function, $\mathbf{z}_j$ is the vector of covariates affecting the probability that a potential couple of co-authors works together, $\boldsymbol{\gamma}$, the unknown parameters of these factors, to be estimated via MLE. Similarly, the Poisson parameter is $\lambda_j = \exp(\mathbf{x}_j\boldsymbol{\beta})$, where $\mathbf{x}_j$ is the vector of covariates affecting the probability of the publication count if co-authors are working together and, $\boldsymbol{\beta}$, the vector of unknown parameters of these factors, also to be estimated via MLE.

Model 5) Zero Inflated Negative Binomial Regression

Preliminary results Table 3 Poisson and Negative Binomial

No. of papers coauthored	(1) poisson1	(2) nbreg1	(3) poisson2	(4) nbreg2	(5) poisson6	(6) nbreg6
One female in pair	-0.352*** (0.0518)	-0.352*** (0.0518)	-0.410*** (0.0527)	-0.403*** (0.0507)	-0.316*** (0.0478)	-0.423*** (0.0603)
Both female	-0.179** (0.0695)	-0.179** (0.0695)	-0.304*** (0.0709)	-0.305*** (0.0692)	-0.248*** (0.0685)	-0.257** (0.0783)
One internal in pair			0.491*** (0.0555)	0.475*** (0.0533)	1.660*** (0.0800)	1.921*** (0.0940)
Both internal			1.252*** (0.101)	1.269*** (0.103)	1.951*** (0.118)	2.285*** (0.122)
Jaccard Similarity index					0.0642***	0.0691***

⁴ See Long (1997, 242–247) and Cameron and Trivedi (2005, 680–681) for a discussion of the ZIP model and other zero-modified count models.

Preliminary results Table 4 Hurdle and Zero Inflated Poisson

No. of papers coauthored	Hurdle models			Zero Inflated Poisson		Zero Inflated Negative Binomial	
	First stage Logit	Second Stage Poisson	Neg. binomial	Binary equation	Count equation	Binary equation	Count equation
One female in pair	-0.405*** (0.0676)	-0.494*** (0.129)	-0.664*** (0.148)	0.398* (0.196)	-0.166*** (0.0420)	0.398* (0.196)	-0.166*** (0.0420)
Both female	-0.101 (0.0908)	-0.601*** (0.177)	-0.728*** (0.206)	1.105** (0.391)	-0.0646 (0.0571)	1.105** (0.391)	-0.0646 (0.0571)
One internal in pair	1.977*** (0.0882)	1.537*** (0.212)	1.731*** (0.246)	-4.438*** (0.670)	1.079*** (0.0803)	-4.438*** (0.670)	1.079*** (0.0803)
Both internal	2.454*** (0.121)	1.665*** (0.232)	1.889*** (0.275)	-3.585*** (0.700)	1.360*** (0.0904)	-3.585*** (0.700)	1.360*** (0.0904)
Jaccard similarity (x100)	0.0864*** (0.00101)	0.0135*** (0.00206)	0.0154*** (0.00283)	-1.301*** (0.0603)	0.0142*** (0.000845)	-1.301*** (0.0603)	0.0142*** (0.000845)
Avg. eigenvector centrality (x100)	0.0349*** (0.00105)	-0.0148*** (0.00444)	-0.0201*** (0.00308)	-0.0362*** (0.00279)	0.00527*** (0.000350)	-0.0362*** (0.00279)	0.00527*** (0.000350)
Avg. betweenness centrality (x100)	0.00767*** (0.000271)	0.00227*** (0.000593)	0.00293** (0.000959)	-0.00979*** (0.000747)	0.00311*** (0.000378)	-0.00979*** (0.000747)	0.00311*** (0.000378)
lnalpha			17.12*** (0.415)			-15.63*** (1.556)	
Log likelihood (both stages)		-8518.2	-8366.8	-5472.0		-5472.0	
AIC (both stages)		17068.5	16767.7	10975.9		10977.9	
BIC (both stages)		17240.5	16950.4	11147.9		11160.7	
N	344865	2,610	2,610	344865		344865	

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Preliminary results and discussion

Table 3 shows the results of three different parameterizations of the internal and external dummies and the gender dummies. The columns show alternatively the Poisson and the negative binomial results, next to each other, for the different parameters configuration. Rows 4-5 of Table 3 show that, across specifications, author pairs including at least one internal author are associated with higher numbers of publications than the reference category, both external authors. The estimated coefficients on one internal author and both internal authors are positive, statistically significant and similar in magnitude

The first two rows of Table 3 show our results relating to author gender. These results support H1: The gender composition of co-authorship dyads significantly affects publication counts and H1_a: Collaborations involving female co-authors will yield fewer publications than all-male dyads.

Across all different versions of the models, the estimated coefficients on one author being female and both authors being female are consistently highly statistically significant and negative. Thus, having at least one female author in a pair is associated with a lower number of published papers for a pair of coauthors, relative to the reference category of two male authors. What is important to consider is that this is specifically comparing the number of papers from joint female authors to the number of papers with both male authors; as such, the negative coefficient reflects female authors publishing fewer papers together than the male peers. The number of papers is important, as this may explain the difference from existing research, which has shown female authors being more likely to author with other female authors. Our third hypothesis, H1_b: All-female collaborations will generate more publications than mixed-gender dyads, is also supported by the results in Table 3. Across all specifications, the estimated coefficients on both female authors, whilst negative and statistically significant is consistently of lower magnitude than the estimated coefficient on one female author. This suggests that, on average, pairs of coauthors with two female authors produce fewer published papers than all male pairs but publish more papers than coauthors of mixed genders.

Examining the centrality measures in Table 3 the average eigenvector centrality of the authors is positive and statistically significant when included. Thus, authors with greater eigenvector centrality in the network have a higher number of papers published together. As the eigenvector centrality can represent the social capital within the organisational network (Lakon 2008), this suggests that social capital within the network is an important determinant of the number of papers published by pairs of coauthors.

Preliminary results Table 5: Interaction between gender and centrality

	(1) Poisson	(2) Negative Binomial	(3) Zero Inflated Poisson	
			Binary equation	Count equation
One female in pair	-0.339*** (0.0567)	-0.413*** (0.0633)	0.401* (0.199)	-0.163** (0.0506)
One female in pair # Avg. eigenvector centrality (x100)	0.00119 (0.000943)	-0.000904 (0.00198)		-0.0000651 (0.000653)
Both female	-0.222** (0.0790)	-0.176* (0.0837)	1.151** (0.396)	-0.0187 (0.0655)
Both female # Avg. eigenvector centrality (x100)	-0.00212 (0.00120)	-0.00803** (0.00253)		-0.00297*** (0.000764)
One internal in pair	1.656*** (0.0800)	1.919*** (0.0942)	-4.443*** (0.672)	1.077*** (0.0804)
Both internal	1.946*** (0.119)	2.277*** (0.122)	-3.597*** (0.702)	1.347*** (0.0906)
Jaccard similarity (x100)	0.0642*** (0.000587)	0.0692*** (0.000964)	-1.302*** (0.0603)	0.0142*** (0.000845)
Avg. eigenvector centrality (x100)	0.00673*** (0.000810)	0.0104*** (0.00190)	-0.0361*** (0.00279)	0.00563*** (0.000585)
Avg. betweenness centrality (x100)	0.00839*** (0.000277)	0.00804*** (0.000268)	-0.00975*** (0.000748)	0.00315*** (0.000379)
lnalpha		-0.0468 (0.166)		
Log likelihood	-10231.0	-10022.7	-5470.2	
AIC	20482.1	20067.4	10976.4	
BIC	20589.6	20185.6	11169.9	
N	344865	344865	344865	

The empirical evidence from the full model that includes interaction confirm our hypotheses. In Table 5, the results show that, with regards to H1, the gender composition of co-author pairs affects their publications count. In fact, there are two clear effects: the presence of one female co-author consistently leads to significantly negative effects on publication counts in the Poisson Model reported in column 1, (-0.339***), as well in the Negative binomial Model reported in column 2, (-0.413***) and in the Zero Inflated Poisson, reported in column 3 count equation (-0.163**), supporting H1_a. Similarly, the mitigating effects of Homophily is displayed by coefficients that are less negative and less significant than for pairs with a single female author: in the Poisson Model, reported in column 1 (-0.222**), in the Negative binomial Model reported in column 2 (-0.176*), and in the Zero Inflated Poisson, reported in column 3 count equation (-0.0187). The difference between the coefficients for one female author and both authors being female is consistently showing the mitigating effects of homophily compared to having one female author only, supporting H1_b.

Moving to the association of coauthors' network capital with the number of published papers, the empirical evidence from the full model that including interactions between our gender variables and network centrality confirm our hypotheses. The results in Table 5 show that the power dimension of coauthors' network capital (captured by their average eigenvector centrality) is associated with a higher number of published papers in the Poisson Model, reported in column 1, (0.00673***), in the Negative binomial Model reported in column 2, (-0.0361***) and also in the Zero Inflated Poisson, reported in column 3 count equation (0.00563***). This supports H2_a. Furthermore, the embeddedness dimension of coauthors' network capital (captured by their average between centrality) is associated with a higher number of published papers in the Poisson Model, reported in column 1, (0.00839***), in the Negative binomial Model reported in column 2, (0.00804***) and also in the Zero Inflated Poisson, reported in column 3 count equation (0.00315***) providing evidence to support H2_b.

Finally, when focussing on the hypotheses regarding the interaction effects between gender and network centrality, Table 5 shows that the effect of Network Capital on publications' count is affected by the homophily of the co-authors' link (captured by the interaction between gender composition and their average eigenvector centrality). In particular, the mitigating effect on publications' count due to Homophily, whereby all female co-authorships links were associated with higher number of publications than mix gender co-authorships ones, (H1_b), decreases with the level of average centrality of the two co-authors. This is shown by the sets of coefficients, for the interaction variable (Both female # Avg. eigenvector centrality (x100)) in the Poisson Model, reported in column 1, (-0.00212), in the Negative binomial Model reported in column 2, (-0.00803**) and also in the Zero Inflated Poisson, reported in column 3 count equation (-0.00297***). We can conclude that the empirical evidence does not allow us to reject lending supporting evidence to H3_b. Similarly, as all the coefficients of the variable "One female in pair # Avg. eigenvector centrality (x100)" are not statistically significant: as shown in the Poisson Model, reported in column 1, (0.00119), in the Negative binomial Model reported in column 2, (-0.000904) and also in the Zero Inflated Poisson, reported in column 3 count equation (-0.0000651) we cannot reject H3_a stating that the negative effect on publications' count, due to the presence of female coauthors in a coauthors' link, (H1_a), is not affected by the level of average centrality of the two co-authors.

Our preliminary findings are consistent with the lenses of social capital theory and homophily theory. According to social capital theory, individuals' positions within networks—particularly structural advantages such as centrality—enhance access to information, resources, and collaboration opportunities, thereby boosting productivity (Bourdieu, 1986). The observed positive effect average eigenvector centrality supports this perspective, suggesting that collaboration with more centrally positioned (and thus socially capitalized) authors yields higher publication outputs. Homophily theory, on the other hand, posits that individuals tend to form ties with those who share similar attributes, such as gender (McPherson, Smith-Lovin, and Cook, 2001). Our preliminary findings—in which male–male author pairs publish, on average, higher numbers of papers than female–female pairs who, in turn, publish more than mix gender coauthor pairs are consistent with gender-based homophily.

In further development of the work, we will more fully explore two-step modelling approaches using the hurdle and zero inflated models to more carefully account for the high fraction of zeros in our dependant variable. We also intend to more fully explore and analyse interaction effects between gender and centrality power to further understand the gender publication gap.

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